Dec. 6, 1949 E. P. HARRISON ET AL 2,490,266

HEAT EXCHANGE SYSTEM

Original Filed March 13, 1944 4 Sheets-Sheet 1

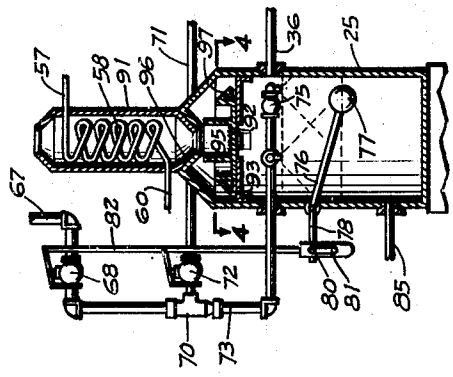


Fig. 3

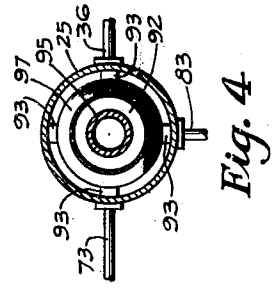


Fig. 4

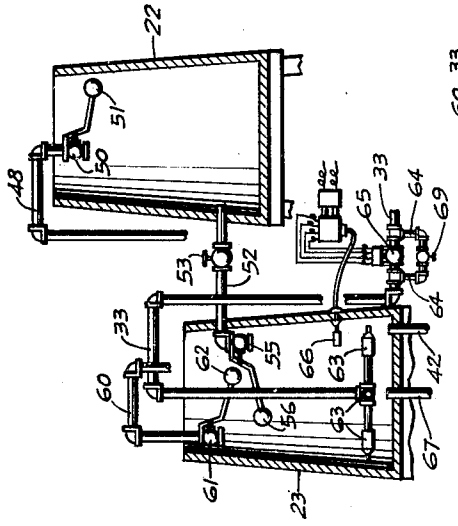


Fig. 2

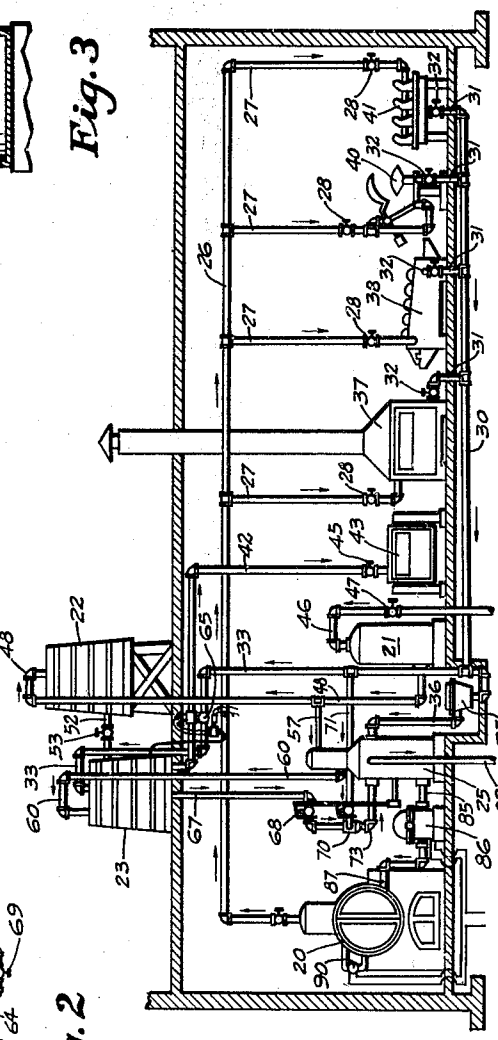


Fig. 1

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HEAT EXCHANGE SYSTEM

Original Filed March 13, 1944 4 Sheets-Sheet 2

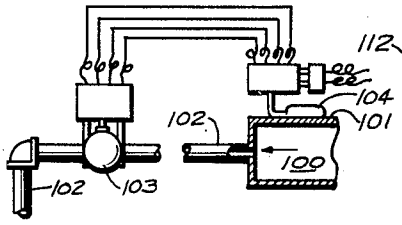


Fig. 5

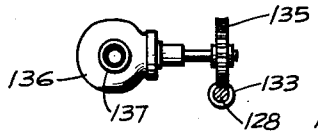


Fig. 7

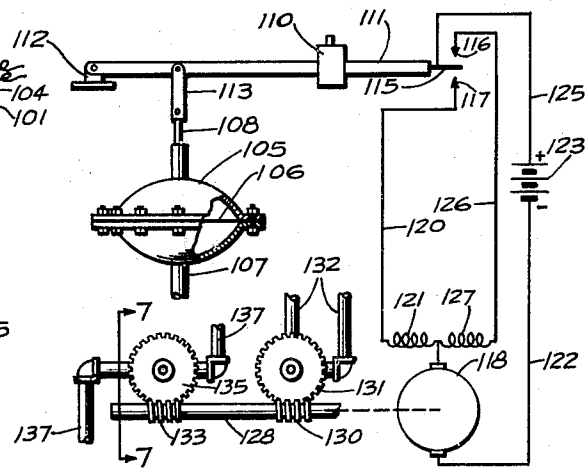


Fig. 6

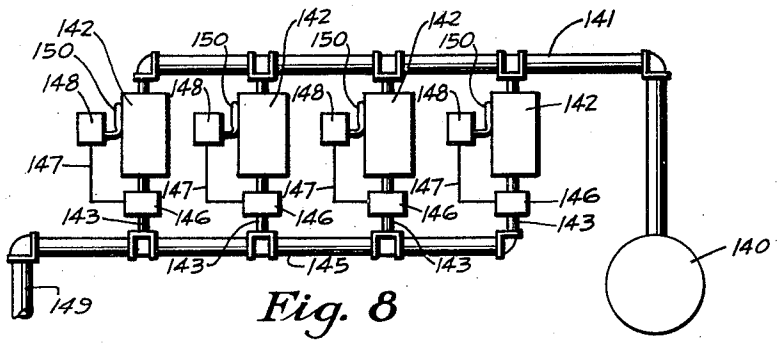


Fig. 8

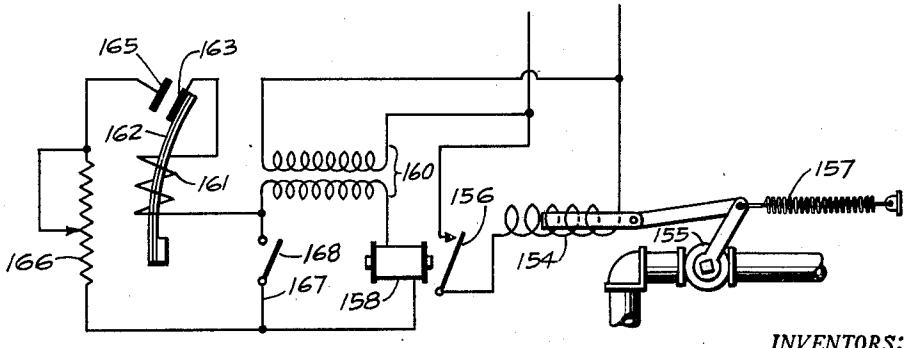


Fig. 9

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HEAT EXCHANGE SYSTEM

Original Filed March 13, 1944 4 Sheets-Sheet 3

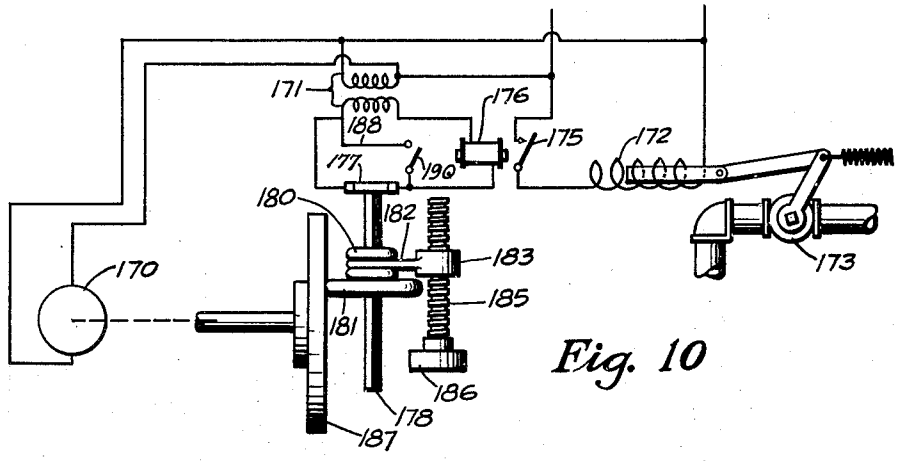


Fig. 10

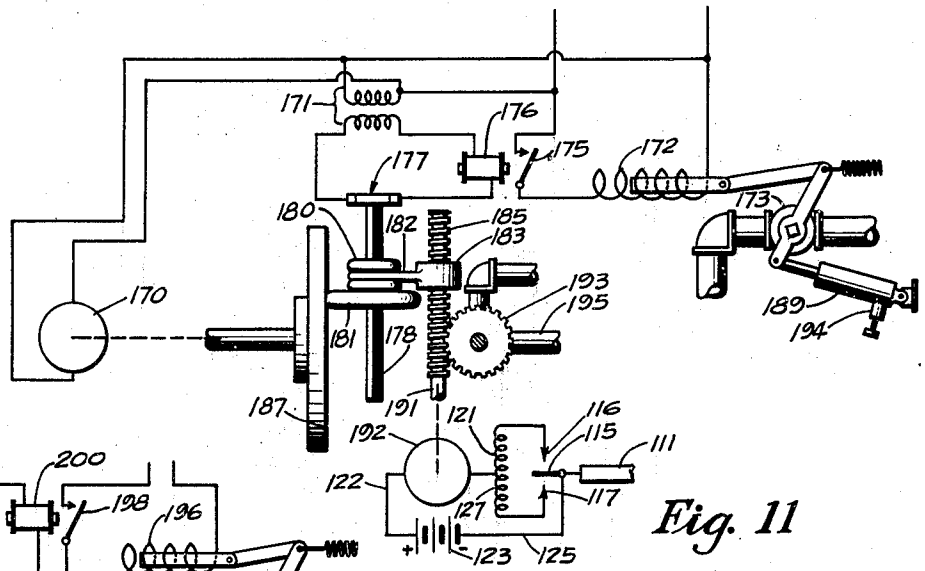


Fig. 11

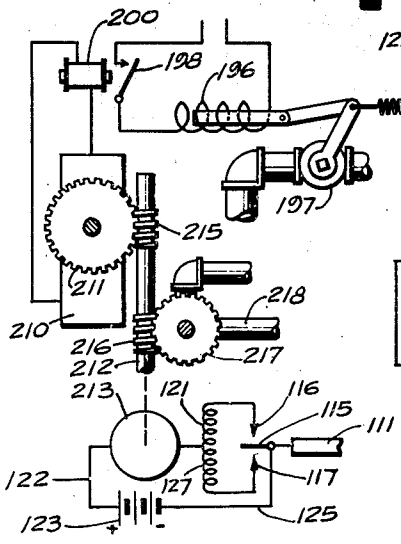


Fig. 13

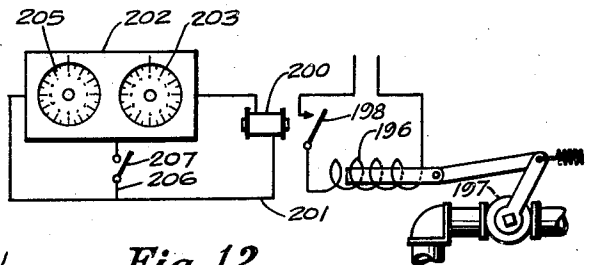


Fig. 12

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HEAT EXCHANGE SYSTEM

Original Filed March 13, 1944 4 Sheets-Sheet 4

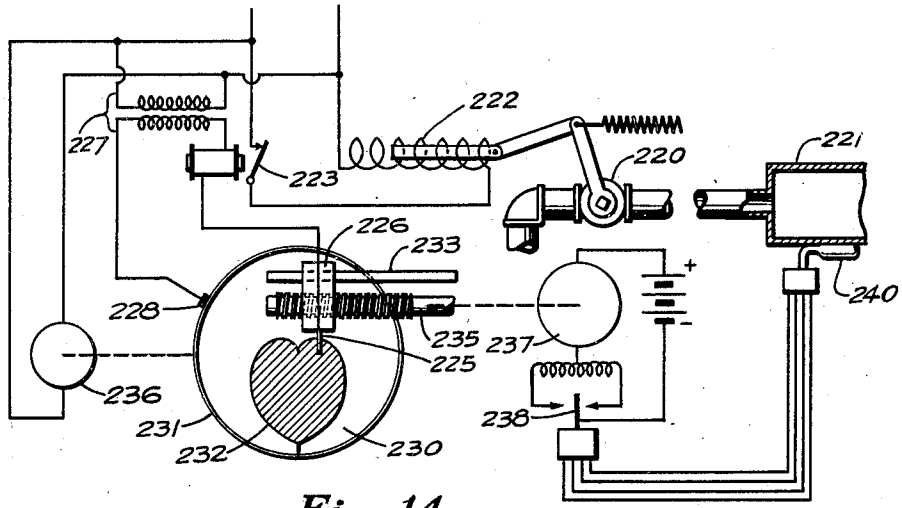


Fig. 14

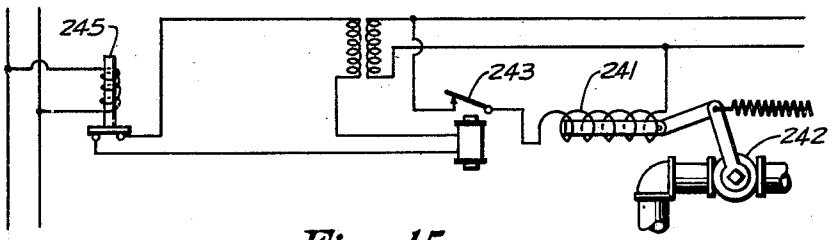


Fig. 15

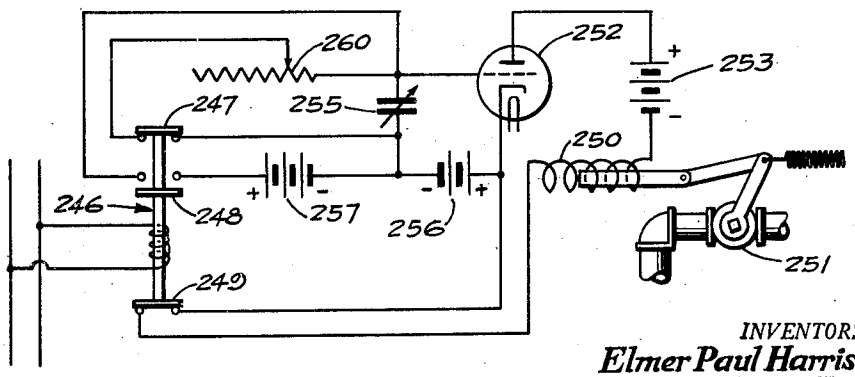


Fig. 16

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UNITED STATES PATENT OFFICE

2,490,266

HEAT EXCHANGE SYSTEM

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Original application March 13, 1944, Serial No. 526,152. Divided and this application March 8, 1945, Serial No. 581,586

14 Claims. (Cl. 237—9)

1

The present application is a division of our co-pending application, entitled Heat exchange system, Serial No. 526,152, filed March 13, 1944, now abandoned.

This invention relates to a steam system employing steam substantially above atmospheric pressure as distinguished from a vacuum system for heat processing material, and using steam of a quality such that the major portion of the heat to be used for heat processing must be derived from the latent heat of steam rather than its sensible heat. More particularly, the invention relates to a heat exchange system in which the heat from live steam is transferred through the walls of steam chests, and the heated wall surfaces are used for drying wet clothing, wet paper rolls, and the like, in laundries, factories, mills and like places, as well as to a particular method of handling and utilizing the steam in such systems. For purposes of clarity the invention has been illustrated for use in connection with a laundry plant, although it may be used in paper plants and the like.

A primary object is to provide means for raising the production level or actual heat output of steam plants with special reference to plants for processing traveling sheet material as in the laundry and paper manufacturing fields. Heretofore such plants have been operated year after year at what the present invention reveals as unnecessarily low rates of heat output. In other words, the present invention enters levels of heat output substantially above the heretofore commonly accepted limit for given systems and for conventional apparatus.

In the drying of a given sheet material with a given initial moisture content, the heat output varies directly as the product of the feet per minute travel and the temperature rise of the material. Thus, for example, the commonly accepted heat output limit of a four-roll ironer is represented by the commonly accepted speed of the ironer in feet per minute for given flat work. To run a four-roll ironer in a conventional steam system at substantially higher than the usual limit, say, at 60 feet per minute instead of the limit 45 feet, would be to present a demand for heat output above the maximum heat load the system is inherently capable of assuming. Our invention raises the actual heat output 25% or more above the commonly accepted ceiling and permits a four-roll ironer to operate at speeds heretofore requiring six or eight-roll ironers. Correspondingly increased efficiency is afforded in paper making and other arts.

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Our invention is based on two discoveries, the first discovery being that raising the velocity of steam flow through the system will move condensate and air out of the system so effectively as to make traps unnecessary, and, second, the discovery of how such increased velocities of flow may be achieved economically by releasing steam from the system. Heretofore, the desirability of the higher rates of steam flow within the heat-transferring apparatus has not been fully appreciated, traps that preclude such rates of flow have been commonly regarded as necessary for condensate disposal and the problem of economically achieving such flow of velocities by releasing steam from the system has not been solved.

The heretofore usual rates of steam flow in conventional steam systems have permitted relatively heavy films of condensate to blanket the heat transfer walls to such extent as to limit the rate of heat transfer from the flowing steam to the exterior surfaces of the heat transfer walls.

Our purpose is achieved by releasing steam from the return side of the system substantially continuously or by releasing steam in a suitably intermittent manner and preferably by making the heat demand presented to the system a factor for automatic regulation of either continuous or intermittent steam release. Many practices of our invention are characterized by a pulsating flow of steam through the system. The mode of operation may be termed "pulsating continuous flow of steam" in those instances in which the variation in each impulse is between two different positive rates of flow or may be termed "pulsating intermittent flow of steam" in those instances in which the variation in each impulse reach zero velocity. In any mode of operation, however, the average steam velocity over a period of time or the number of occurrences of flow at effective velocity over the period of time is so effective in removing condensate and non-condensable gases from the system as to bring the heat output into the new higher levels.

If the steam is released substantially continuously, the minimum rate for low heat demand will be adequate but not exorbitant and the rate will increase with demand. In some installations, the higher rates of steam release would be exorbitant, even prohibitive, if constantly maintained but become economically justified when occurring only concurrently with increased demand for heat from the system by the traveling sheet material.

With respect to intermittent release of steam

as a mode of control, one important advantage is the economy inherent in intermittent release and a further important advantage is the jarring effect on condensate film of intermittent or pulsating flow. In some practices, any suitable control means may be employed to achieve simple intermittent steam release at a rate sufficient for all levels of demand. In other practices, however, the control means is designed to modify the intermittency in accord with the demand for heat by the sheet material. In some practices of our invention, a demand for heat exterior to the system such as a demand for hot water for outside use is one of the factors determining the rate at which steam is released from the system, but in such practices, it is contemplated that in the absence of such outside demand, the remaining factors including the demand for heat by the material in process will be sufficient to maintain the internal steam velocity at a sufficiently high rate to bring the heat output into the new higher range of levels.

Some of the important concepts that may be found singly or in combination in various practices of our invention include: releasing steam in a pulsating intermittent manner by employing a steam valve that will completely cut off when a thermostat is heated to a predetermined temperature; employing the feed water supply as means for causing the rate of steam release to vary in accord with the heat demanded by the material in process; employing a thermostatic valve responsive to temperature changes of the feed water as a means for automatic control; employing a body of feed water as a thermal-responsive means that is heated whenever new water is required by the steam generator; setting a controlling thermostat at a high temperature relative to environment to insure that steam is continually released from the system regardless of demand, i. e., to insure inherently a sufficiently high rate of steam release to enter the new range of heat output; to insure the required high range of flow velocity by releasing steam both in response to the feeding of water to the steam generator and in response to the requirement for steam release to meet the tendency of a thermostat to cool below a relatively high temperature setting; to release steam in direct response to changes in the temperature of heat exchange walls; to release steam in accord with automatic variation in fuel feed to meet different levels in heat demand by the material in process; to achieve a desirable intermittent action by making a steam system inherently unstable; to set up a chain of causes in a steam system to achieve a desired steam releasing effect; to take advantage of lag factors in a steam system for the purpose of the invention; to combine the release of steam with the deaeration of feed water both in the sense of using released steam for deaeration and in the sense of using deaeration together with high velocity steam flow to minimize the effects of non-condensable gases in the system.

Additional objects of the invention include the following:

To provide a novel and efficient manner of deaerating feed water and condensate which is delivered to the boiler; to provide a steam flow system which combines with it appropriate means for deaerating not only new make-up water but also condensate return from the system; to use for auxiliary purposes the steam exhausted from the system to maintain the requisite steam flow through the system and to automatically control the application of the exhaust steam for this purpose; and, to provide a system and apparatus which is adaptable for use with existing steam plants having a wide range of capacity.

The above and other objects and advantages of our invention will be apparent in the following detailed description taken with the accompanying drawings.

In the drawings, which are to be considered as merely illustrative;

Fig. 1 is a diagrammatic view in side elevation of a laundry plant employing one form of the invention,

Fig. 2 is a diagrammatic view in section of two tanks shown in the upper portion of Fig. 1,

Fig. 3 is a diagrammatic view with parts in section showing a portion of the system for deaerating feed water.

Fig. 4 is a horizontal section taken as indicated by the line 4—4 of Fig. 3,

Figs. 5 and 6 are diagrammatic fragmentary views indicating how means may be incorporated in a steam system for different modes of control in response to demand,

Fig. 7 is a section taken as indicated by line 7—7 of Fig. 6,

Fig. 8 is a diagrammatic view of a steam syster incorporating another mode of control in response to demand,

Fig. 9 is a wiring diagram indicating how an electrically heated thermal means may be employed for controlling intermittent release of steam,

Fig. 10 is a diagrammatic view showing an electrical-mechanical control arrangement for intermittent release of steam,

Fig. 11 shows the arrangement of Fig. 10 modified for a different mode of control in response to demand,

Fig. 12 is a wiring diagram of a control arrangement incorporating an electrical timer,

Fig. 13 is a diagrammatic view indicating how the arrangement in Fig. 12 may be modified for a particular mode of control in response to demand,

Fig. 14 is a diagrammatic view of an arrangement for varying the periods of intermittent steam release in response to demand without varying the frequency of the periods,

Fig. 15 is a wiring diagram of a simple arrangement for providing intermittent steam release, and

Fig. 16 is a wiring diagram of an arrangement for obtaining delayed steam release of adjustable duration.

General description

The steam system for a laundry shown by way of example in Figs. 1 to 4 includes the following: a steam generator or boiler **20**; means to provide a supply of feed water including a water softener **21**, two upper tanks **22** and **23**, and a lower tank **25**; a high pressure steam pipe **26** fed by the boiler; branch pipes **27** with individual valves **28** for delivering the steam to various steam-consuming devices; a main return pipe **30** on the low pressure side of the system; branch pipes **31** equipped with individual valves **32** connecting the various steam-consuming devices or heat exchangers to the main return pipe; and an upright steam pipe **33** connecting the main return pipe **30** with the feed water supply. Tank **22** containing one portion of the feed water supply may be termed a soft water storage plant; tank **23** containing another portion may be termed a make-up water tank; and tank **25**

containing a third portion may be termed a boiler feed water heater tank. The return side of the pipe system near the lower end of the pipe 33 may be provided with a steam trap 35 and a pipe 36 for conducting condensate from the steam trap to the feed water supply. In Fig. 1 the condensate pipe 36 is shown connected to the previously-mentioned lower tank 25. The system is operated at above atmospheric pressure and back pressure is maintained in the return pipes 30 and 33.

By way of example, the various steam-consuming devices in the above-described system are indicated as a dry tumbler 37, a flat work ironer 38, a press 40, and a drying form 41. It is economical in the use of steam to draw on the feed water supply to meet demands for hot water outside of the system. Illustrating such an extraneous demand on the feed water supply, we show in Fig. 1 a pipe 42 for conducting hot water from tank 23 to a washer 43, the pipe being provided with a suitable valve 45.

The feed water arrangement

In this first form of the invention, it is contemplated that the steam released primarily for the purpose of achieving effective velocity in the system will be utilized to heat the supply of feed water, that the quantity of the feed water supply, and indirectly the temperature thereof (the latter being affected by the rate at which feed water is called for by the boiler) will in turn have an important role in the control of velocity by steam release, and that provision will be made in the feed water arrangement for deaeration of the feed water. The particular feed water arrangement shown in Figs. 1 to 3 is only one of many possible arrangements to provide the contemplated relationships.

The water softener 21 receives its supply from a suitable source through a pipe 46 controlled by a valve 47 and delivers the treated water through a pipe 48. The pipe 48 extends upward to terminate in a discharge valve 50 in the upper tank 22 (Fig. 2), the discharge valve being controlled by a suitable float 51. Water from tank 22 may flow to the tank 23 by gravity through a connecting pipe 52 provided with a hand regulating valve 53 and terminating in a discharge valve 55 controlled by a suitable float 56. Water from the softener 21 may also flow through a pipe 57 branching from the pipe 46 to a heat exchange coil 58 (Fig. 3) associated with the lower tank 25 and may then flow upward through a pipe 60 to a discharge valve 61 controlled by a float 62 in the tank 23.

Steam is released from the steam pipe 33 at the end of the system for the dual purpose of promoting velocity and of preheating the feed water. The steam pipe 33 extends over and then down into the tank 23 to terminate in a plurality of branch pipes equipped with nozzles 63, each of which nozzles may be an ordinary Penberthy water heater or steam injector. To control the release of steam into the tank 23, the pipe 33 is provided with an electrically-actuated thermally controlled valve 65, the valve being responsive to a thermostat bulb 66 within the tank 23.

Preferably the thermostat bulb 66 is directly above one of the steam nozzles 63 as indicated in Fig. 2 and preferably the thermostat control is highly sensitive to cause valve operation in response to a temperature drop as small as 1° F. The valve of the indicated construction may be of the normally closed type which opens proportionately to provide various rates of flow through the valve in response to a lowering of the water temperature or it may continually bleed a certain amount of steam into the water at all times and open proportionately wider in response to falling temperature of the water. Valves of both types are commercially available and well known and further description is deemed unnecessary. For convenient regulation of steam release a bypass 64 may be provided around valve 65, the bypass being controlled by a bypass valve 69.

A water pipe 67 having a valve 68 for control of flow therethrough leads from the bottom of tank 23 to a downwardly extending jet or injector 70, and steam for operation of the injector is supplied thereto by a steam pipe 71 branching from the previously-mentioned steam pipe 33 at the end of the system. Flow of steam through the pipe 71 is controlled by a suitable steam valve 72 best shown in Fig. 3. The injector 70 is connected to and directed axially into a pipe 73 that leads to a plurality of downwardly directed spray heads or nozzles 75 in the interior of the lower tank 25. Preferably, but not necessarily, both the water valve 68 and the steam valve 72 are snap-acting type valves.

Any suitable electrical or mechanical means may be employed to appropriately control the two valves 68 and 72 as required in the operation of the system. As best shown in Fig. 3, the control means may comprise a lever 76 operated by a float 77 inside the tank 25, the lever having an external arm 78 carrying a pin 80 in engagement with a slot 81 at the lower end of a link 82. The link 82 is operatively connected to both of the valves 68 and 72. The vertical length of the slot 81 should be of minimum dimension to accommodate the snap action of the valves thereby to minimize the drop in liquid level in tank 25 necessary to cause the two valves to open.

The tank 25 is provided with a suitable overflow pipe 83 and below its liquid level connects with a pipe 85 leading to an electrically operated boiler feed pump 86, the feed pump in turn being connected to the boiler 20 by a pipe 87. For control of the pump 86, the boiler is provided with an automatic water level control switch 90 which switch preferably is responsive to relatively small differences in liquid level in the boiler.

The provision for deaeration

In the above described system, three different means are employed to heat the feed water in preparation for deaeration in accord with the well known principle that with rising temperature water tends to release any content of permanent gases such as oxygen and air. The three heating means are the heat exchange coil 58, the plurality of steam nozzles 63, and the steam injector 70. In addition to simply raising the temperature of the feed water, we further encourage gas separation by causing at least a substantial portion of the heated water to flash in the lower tank 25. Since the interior of the tank 25 is in communication with the atmosphere through an upper condenser shell 91 surrounding the heat exchange coil 58, it is necessary to bring the water up to certain pressure and temperature values prior to release of the water from the spray nozzles 75. The steam applied to the water through the injector 70 serves to the required extent both to give final heat to the water and to exert pressure on the water. The kinetic energy of the steam introduced through the injector 70 is transmitted to the water by virtue of the injector

being directed in the direction of water flow through the pipe 73, and the spray nozzles 75 sufficiently restrict flow from the pipe 73 to cause the kinetic energy to be transformed into pressure. The interior of the pipe 73 below the injector 70 may aptly be referred to as a pressure zone.

When the water is released from the pressure zone, a portion flashes into steam immediately thereby releasing permanent gases and the remainder of the water is finely atomized also with release of gases. The released non-condensable gases and the vapor created by the flash action flow upward into the condenser shell 91 where the vapor is largely, if not entirely condensed by contact with the relatively cool coil 58, and the released gases escape to the atmosphere.

Condensate accumulating on the coil 58 trickles downward to a circular condensate tray 92 supported by suitable brackets 93. Preferably the tray is provided with an upstanding concentric collar 95 into which the condensate is directed by a conical skirt 96 at the bottom of the condenser shell, the concentric collar having a serrated lower edge to permit the condensate to flow radially outward along the bottom of the tray. The condensate finally escapes from the tray by dripping over a conical flange 97 around the rim of the tray. This mode of flow by the condensate characterized by thin streams exposed to the upwardly moving vapor and gases effectively insures that the condensate will be substantially free of permanent gases when it reaches the main body of water in the lower end of the tank 25.

Deaeration is an important factor in attaining efficiency not only because non-condensable gases, and especially pockets of gases reduce the heat output of heat exchangers, but also because oxygen in feed water is highly detrimental to the system, especially the steam generator. In the practice of our invention, there is an important relationship between deaeration and high velocity flow both in the common purpose of high productivity and in the means of accomplishing the purpose. Thus, deaeration removes a large proportion of the non-condensable gases at the boiler feed and the high velocity of steam flow through the system effectively sweeps away any residual gases surviving the deaeration treatment. In another view of the cooperation between deaeration and high velocity flow, a function of high velocity flow is to continuously scavenge the system of permanent gases and a function of deaeration is to reduce the gas-scavenging task that is left for accomplishment by high velocity flow.

Operation with substantially continuous steam release

In the operation of the described system with substantially continuous release of steam, the thermostat bulb 66 causes the valve 65 to reduce steam flow through the valve to a minimum or to restrict flow to the bypass 64 whenever the temperature of the water in the tank 23 reaches a predetermined value, a temperature, say, in excess of 160° F.

The setting for minimum flow through the valve 65 or the bypass 64 need not be regarded as critical. The minimum rate of steam released by the valve may in one practice of the invention be sufficient to cause steam to flow through the whole system with such velocity as to scavenge condensate from the system and to keep all of the heat exchange walls at relatively high temperatures for a high rate of heat output. In another practice, the minimum rate of steam release may be lower so that the periodic release of steam at higher than the minimum rate is required for maintaining efficiency of operation. In this latter practice, it is necessary only that the temperature of the water in the tank 23 drop often enough to cause sufficient flow through the steam valve at higher than the minimum rate. A factor entering into the frequency of operation is the continuous loss of heat from the tank 23 to its environment. The demand by the washer is also a factor that keeps the minimum setting of the thermostat valve from being critical since the thermostat valve will open for greater than minimum flow whenever any quantity of water is withdrawn from the tank 23 for the washer.

It is apparent that with the liquid level in tank 23 high enough to close both valves 55 and 61, the withdrawal of water from the tank will cause one or both of the discharge valves 55 and 61 to open for replenishing flow of relatively cool water. Relatively cool water is supplied by the pipe 60 from the condenser coil 58 and even cooler water is supplied by the pipe 52 from the upper tank 22. If the temperature of the water in tank 23 prior to the lowering of the liquid level therein is sufficiently high at the moment to cause thermostatically controlled valve 65 to operate at minimum flow, the addition of relatively cool water immediately consequent to the drop in water level will cause the thermostat to open the valve 65 immediately for greater steam release, the higher rate of steam release continuing until normal temperature of the water in the tank 23 is restored after valves 55 and 61 close.

A feature of the described system is the flexibility of operation and the diversity of controls that may be manipulated to vary the character of operation to meet various operating conditions. Among the possible adjustments are: adjustment of the minimum rate of steam flow through the thermostatically controlled valve 65; variation in the temperature setting of the thermostat; adjustment of various valves among valves 28 and 32 in the steam system thereby to control steam flow through the system and/or to set the maximum rate of flow through the steam valve 65; adjustment of the rates of flow through the various float-controlled valves 55 and 61 in tank 23; adjustment of the valve 53 to control the rate of water flow from tank 22 to tank 23; adjustment of the valve 47 to determine the maximum rate at which fresh water may be supplied through the pipe 48; variation in the relative rates of concurrent flow through the water valve 68 and the steam valve 72; and variation in the rate at which the pump 86 transfers water from the tank 25 to the boiler 20. All of these controls should be set to meet particular conditions under which the system operates.

In general, operation of the system with continuous release of steam through the thermostatic valve 65 may be adjusted between the one extreme of steam flow with minimum variation in rate and the other extreme of steam flow of highly pronounced pulsating character, both extremes of adjustment being based on adequate consideration for the load or heat demand imposed on the system.

In adjusting the system for minimum variation in continuous flow, the operator seeks a sufficiently high constant rate of steam release to cause sufficiently high substantially constant

velocity through the system for the desired high rate of heat output.

Since the valve **65** responds to changes in the temperature of the water in the tank **23**, the operator adjusts the rate of flow of water into the tank in accord with periodic withdrawal from the tank with a view to maintaining substantially continuous water flow into the tank at a substantially constant rate. In other words, if a given volume of water is withdrawn from the tank at the end of a given time period, the operator seeks a rate of replenishment that will add to the tank content the same quantity over the given period of time. If such an adjustment of replenishing flow is approximated, the steam valve **65** will automatically release steam substantially continuously at a substantially constant rate to bring the continuously added water up to the desired temperature and to compensate for continuous heat losses from the water by radiation. In a laundry having the described arrangement, the washer **43** will require a new supply periodically through most of the day and will be idle the rest of the day. The operator will therefore regulate the flow into the tank **23** at a constant rate equivalent to the feed water demand of the boiler **20** plus the periodic demand of the washer **43**. When the washer **43** is shut down, the operator will lower the rate of water delivery to the tank **23** to a level for the rest of the day equivalent to the feed water demand alone. Regulation of replenishing flow into the tank **23** may be achieved, for example, by adjusting valve **53** and/or other valves in the system as suggested above. The adjustment of replenishing flow is not to be regarded as highly critical since slightly excessive replenishing flow will merely mean that steam released by the valve **65** will be periodically reduced just before periodic delivery of hot water to the washer **43** and on the other hand somewhat deficient replenishing flow would not be particularly damaging provided it does not permit the tank **23** to run dry.

In adjusting the rate of replenishing flow in the tank **23**, the operator, of course, takes into account the load or demand on the system since the feed water demand by the boiler **20** is a function of the load on the system and once the rate of replenishing flow is set, thereafter the thermostatic valve **65** will automatically vary the rate of steam release in accord with any variations in demand that may occur. The automatic response of the thermostatic valve to demand on the system may be readily understood when it is considered that the faster water is withdrawn from tank **23** for boiler feed, the more steam is required to maintain the tank content at the temperature setting of the thermostat. With respect to automatic adjustment of velocity through the system in accord with demand, it is to be further borne in mind that the more often the pump **86** operates to replenish the boiler from tank **25**, the more often valve **72** releases steam from the system in response to lowering of the liquid level in the tank **25**.

The temperature setting of the thermostat is a factor in the volume of steam release effected in a given system under given operating conditions. If the volume of steam flow at a given thermostat setting is not sufficient for efficient operation of the system, the volume may be increased by raising the temperature setting.

If continuous flow of highly pulsating character is desirable in a given installation, the operator provides, by proper valve adjustment, a relatively high rate of replenishing water flow into the tank **23**. As a result of such high rate of flow, the liquid level in the tank **23** will be restored in a relatively short time after any withdrawal of hot water for boiler demand or washer demand and the liquid level will thereafter be maintained until the next withdrawal. In fact, the rate of replenishing flow may be greater than any peak rate of withdrawal so that the liquid level in the tank **23** will remain substantially constant. In either event, the sudden withdrawal of a substantial volume of the tank **23**, for example, the volume required to refill the washer **43**, will result in a period of relatively high steam flow to restore the temperature in the tank **23** followed by a period of minimum steam flow as determined by the minimum flow adjustment of the valve **65**.

The desirability of pulsating continuous flow under some operating conditions may be readily understood when it is considered that periodic high velocity steam flow tends to flush out the system with more than usual effectiveness, especially peak velocity of flow resulting from relatively wide opening of the valve **65** simultaneously with operation of the steam valve **72**. The described system inherently favors such periodic simultaneity. Another advantage of pulsating continuous flow is that the lower rate of steam release may not alone be sufficient to sustain a required rate of heat output indefinitely but may suffice if assisted by periodic increase in the rate of steam release. In other words, there may be a downward drift in the level of heat output by the system during the periods of rather moderate steam velocity with complete restoration during the recurring periods of higher steam velocity, the drift being tolerable and more than justified by the resulting saving in fuel cost.

While the described system does have a steam trap **35**, it will be noted that this trap is in effect merely a condensate receiver in branch line serving as a bypass for delivering some of the condensate direct to the lower tank **25**. The system may aptly be termed "trapless" since the trap **35** does not interfere with the main return flow through pipe **48** and no traps whatsoever prevent free flow at effective velocity in response to steam release. A feature of the invention is this concept that steam traps may be omitted from the main circulating channels provided that steam is released in sufficient quantity to result in such velocity of flow as to sweep the condensate effectively through the main channels of circulation. The elimination of traps reduces the cost of a steam system and also reduces the servicing expense.

Operation with intermittent release of steam

For pulsating intermittent flow, i. e., for intermittent operation with periodic complete cessation of steam release, it is merely necessary to arrange for the thermostatic valve **65** to cut off steam release entirely in response to relatively high temperature at the thermostat bulb **66** instead of merely reducing steam flow to a minimum. Here again an important feature of the described feature is the exceptional flexibility of operation arising from the adjustability of the numerous factors that determine the character of intermittent operation. The governing factors of intermittency within the system apart from the washer include: the rate at which replenishing water flows into the tank **23** when re-

quired; the extent to which heat loss from the environment from the thermostatic bulb is favored; the temperature setting of the thermostat; the degree to which the arrangement favors lowering the temperature of the thermostat bulb by the flow of replenishing water into the tank 23; the extent to which the introduction of steam into the tank 23 favors raising the temperature of the thermostat bulb; the sensitivity with which the water valve 68 and the steam valve 72 respond to lowering of the liquid level in the tank 25; and the sensitivity with which the feed pump 86 responds to lowering of the liquid level in the boiler 20.

In some installations and under some operating conditions we may favor a relatively slow tempo of intermittency or relatively long periods of relatively static conditions. In general, however, we favor seeking high frequency in the intermittent action and relatively high short periods in which the steam releasing valves are closed. Relatively high frequency in the intermittent release of steam may be sought by various expedients suggested by the above list of governing factors. Several of these expedients will now be mentioned.

Rapid inflow for replenishment of the tank 23 may be favored by adjustment of the water valves involved. The tank 23 is of course exposed to the atmosphere and the resulting loss of heat to the atmosphere, together with the flow of replenishing water, causes relatively frequent operation of the valve 65. We have already stated that the thermostatic valve is highly sensitive, the sensitivity being within 1° F. and favoring frequent valve operation.

With reference to favoring the effect of newly added water on the thermostat bulb 66, it will be noted, first, that the thermostat bulb is at a relatively low level since the relatively cool water in the present temperature range tends to gravitate downward and, second, that the bulb is immediately under the discharge valve 55 that discharges the cool water into the tank 23.

As for favoring thermostatic response to the introduction of steam into the tank 23, it is important to note that the thermostat bulb 66 is directly above one of the steam nozzles 63 to lie in the path of bubbles streaming upward from the steam nozzle. Steam discharged from the steam nozzle axially thereof impinges against the adjacent wall of the tank to favor the setting up of an eddy of steam-laden currents of hot water across the thermostat bulb. When the water body in the tank 23 is at a relatively low temperature, the condensing effect of the water on the released steam will tend to keep the thermostat from closing the steam valve. The condensing effect is especially pronounced when new water is being discharged into the tank. The movement of new water into the region of the thermostat bulb counter to the upward movement of steam bubbles is favored by the higher specific gravity of the relatively cool water, by the downwardly directed kinetic energy of the newly added cool water, and by the location of the discharge valve 55 directly above the thermostat bulb.

It is readily apparent that the location of the thermostat bulb 66 relative to the steam nozzle immediately below is such as to favor prompt closing of the steam valve 65 when replenishing water flow into the tank 23 is cut off. The temperature adjustment of the thermostat and the position of the thermostat relative to the steam nozzle below may be such that steam will continue to be released as long as new water is being added and/or as long as the tank water is below the temperature setting. At some temperature settings of the thermostat and within some limits of temperature of the tank water, the tank water in the absence of steam will tend to cool the thermostat below its temperature setting thereby to initiate steam release whereupon the steam bubbles immediately tend to heat the thermostat for closing of the steam valve, the resultant frequency of intermittent action being desirable.

It will be obvious to those skilled in the art that suitable baffles or wall elements may be arranged inside the tank 23 to favor the effect of replenishing flow and/or the effect of steam flow on the thermostat bulb.

Since, as explained, the thermostatic steam valve 65 tends to open and close in response to the starting and stopping of water flow into the tank 23 and since in the specific practice of the invention here under discussion the water valves are adjusted for rapid replenishing flow, steam release by the thermostatic valve 65 tends to occur in response to the boiler feeding operation. In other words, when a drop in the level of the boiler water results in operation of the boiler feed pump, withdrawal of water from the lower tank 25 causes withdrawal from the upper tank 23 with consequent initiation of steam release by the valve 65. Obviously a shorter sequence of causes results in opening of the lower steam valve 72 also in response to operation of the feed water pump. Since the frequency with which both steam valves 65 and 72 open under a given heat load on the system depends both upon the responsiveness of the valves 68 and 72 to drop in liquid level in the tank 25 and upon the responsiveness of the feed water pump 86 to drop in liquid level in the boiler 20, we may give special attention to the factors involved in such responsiveness in adjusting our system for intermittent action at relatively high frequency.

In attaining highly frequent intermittent action we may substitute electrically actuated valves responsive to changes in level in tank 25 or responsive to the automatic water level switch 90. In the latter arrangement the automatic switch will be sufficiently sensitive to drop in level in the boiler to cause frequent operation of the feed water pump 86 as well as frequent operation of the two valves 68 and 72.

For a complete understanding of our invention as adjusted for intermittent action at relatively high frequency, it is necessary to give some consideration to the aspect of inherent instability, the tendency of the system to behave as if it were inherently oscillatory.

When the system is adjusted for high frequency operation, it acts as if it were continually hunting or overshooting in restoring some state of balance or equilibrium. Thus a feature of our invention is the concept of designing a system to "hunt" at some desired tempo as a method of attaining intermittent action at that tempo. The high temperature setting of the thermostat is per se a cause of inherent instability since the setting is higher than the temperature of the environment around the feed water supply and can be sustained only by periodic release of steam. Another cause of inherent instability appears to arise from effects appearing alternately at the opposite ends of the system. Thus, condensation of steam or the release of steam towards one end of the system causes flow of steam thereto which flow in

turn creates a corresponding demand for additional water by the boiler at the other end of the system. The feeding of additional water to the boiler, however, involves the release of steam to again create demand at said one end of the system.

Upon closer analysis, it is found that the intermittent operation of the system, especially at high frequency, involves a chain of causes as follows: condensation in the system causes a drop in boiler pressure with a consequent tendency for the boiler to form more steam for replacement; the drop in liquid level in the boiler calls for or actually causes approximately a corresponding amount of water to be delivered from the tank 25 to the boiler; the resultant drop in liquid level in the tank 25 causes two actions, namely, momentary opening of the steam valve 72 and replenishing flow of water into the tank 23; the replenishing flow into the tank 23 causes responsive opening of the steam valve 65; the bleeding of steam from the system by the valves 65 and 72 causes a drop in pressure on the return side of the system to tend to bring about repetition of the chain of causes. In other words, there exists what may be called a closed chain of causes which, once set in operation, has a certain tendency to repeat itself regardless of the effect of loss of heat from the environment of the thermostat bulb.

In this approach to the invention, then, we find inherent intermittency of operation arising both from the thermostat setting and the closed chain of causes and upon such inherent intermittent action is imposed the demand of heat from the system, the demand or load desirably modifying the intermittent action for automatic regulation of the system.

Certain lag factors of importance are found in the system since appreciable time is required for the release of a quantity of steam to cause corresponding drop in boiler water level and since appreciable time is required for the drop in boiler water level to cause the addition of new water to the tank 23 and such addition in turn to cause the thermostat bulb 66 to be affected. Because of such lagging factors, when one cycle of causes is closed, lagging forces set in motion during the cycle are effective to tend to repeat the cycle. Because of inherent lag, moreover, steam released may be periodically cut off briefly without causing complete cessation of flow in the system.

A maximum of fourteen per cent of exhaust steam is required to heat feed water to 212° F., the amount being lower when condensate also is used. Since usually more than this relative amount of steam must be bled off to attain the required velocity within the system, economy in the use of the released steam is important. Utilizing the released steam to meet an outside hot water demand seldom solves the problem completely because of variations in the outside demand and because of possible long periods of no outside demands.

Releasing steam intermittently is desirable not only because of the dynamic jarring and sweeping action on condensate, but also because of the economy in periodically cutting off stem release.

In some installations intermittent operation may be a desirable compromise between, on the one hand, conserving steam at too great cost in lowering of temperature of the heat exchange surfaces and, on the other hand, bleeding steam continuously to maintain effective velocity in the system at too great fuel cost. In explanation, let it be assumed that the efficiency of the heat exchangers in the system are considered as one hundred per cent in the absence of films of condensate on the heat exchange walls but dropping to only fifty per cent in the presence of films of given thickness. Let it be assumed further that a given high velocity of steam flow will substantially remove such condensate film in x seconds and that after cessation of flow the film will be restored progressively over a like period of x seconds.

If steam is released for x seconds and is then cut off for $2x$ seconds with efficiency at fifty per cent at the beginning of each cycle, the average efficiency of the system will be 66⅔% (an average of 75% for x seconds, an average of 75% for the next period for x seconds, and 50% efficiency for the third period of x seconds). If x seconds of steam release alternates with x seconds of no steam release, the average efficiency will rise to 75%. If the intermittent action consists of $2x$ seconds of steam release alternating with x seconds of no steam release, efficiency will climb to 83⅓%. Each of these successive levels of efficiency involves stepping up the volume of steam bled from the sytem and an optimum ratio or at least a compromise ratio between the periods of steam release and no release may be found somewhere in such a progressive series. In practice, a desirable mode of intermittent operation may be found in tabulating the fuel costs, labor costs and production for the different modes of operation in the progressive series, the increased production and resulting drop in labor cost per unit of production being weighed against the increase in fuel cost with increase in the proportion of steam bled from the system.

The invention embodied as a sub-combination for adaptation to conventional systems

The three tanks 22, 23 and 25 with associated control elements including the thermostatic steam valve 65, the water valve 68, the steam valve 72, and other valves, constitute a sub-combination that may be manufactured as an assembly or unit for addition to existing conventional steam systems to convert such systems to the mode of operation contemplated by our invention. While in the described form of our invention the means for providing heated deaerated feed water involves the use of three separate tanks and the use of two separate valves for releasing steam from the system, it will be readily apparent to those skilled in the art that this sub-combination may be simplified and embodied in other forms.

When such a sub-combination is added to a conventional steam plant of the type widely used in laundry and drying fields, production may be increased fifty to seventy-five per cent. For example, it has been commercially demonstrated that a clothes mangle ordinarily capable of drying fabric at a maximum speed at forty feet per minutes will efficiently dry the same material at a speed of seventy feet per minute after the present sub-combination is added to the system.

The described adjustments incorporated in the sub-combination result in such flexibility that a given embodiment of the sub-combination may be adapted to the needs of existing steam systems varying over a wide range of capacities and characteristics. When such a sub-combination is added to an existing installation, the required adjustments to cause the desired mode of operation on the part of the system may be readily

found empirically in a short period of time without requiring any great skill. If the sub-combination is designed for intermittent action as distinguished from continuous and substantially constant steam release, it will be found that the tempo of the intermittency will rise with increase in the temperature setting of the thermostat. Usually adjustment of the thermostat is all that is required to "tune" the system, i. e., to arrive at the desired frequency of intermittency. If necessary, attention may be given to other elements in the sub-combination with special attention to sensitivity, as anyone skilled in the art will readily understand upon reviewing the factors in intermittent action heretofore listed.

Other embodiments of the invention

In the various forms of our invention now to be described, it will be understood that the steam-release valves employed may be adjusted either for pulsating continuous release of steam, or for pulsating intermittent release of steam, i. e., may operate either merely to reduce steam release or to stop steam release entirely. It will also be understood that the released steam may be used to heat the feed water or may be disposed of in some other manner.

In the first described form of our invention, steam is released from the system in accord with demand and demand is measured by the rate at which feed water is required by the system. Another manner in which the release of steam may be related to demand is indicated in Fig. 5.

Fig. 5 shows, by way of example, a heat exchanger in the form of a steam chest 100 having a heat transfer wall 101. Steam is conducted from the stem chest through a pipe 102 to a valve 103 for releasing steam at a sufficient rate to result in the required velocity of flow. In intimate contact with the heat transfer wall 101 is the thermostat bulb 104 of the illustrated electric arrangement for thermostatically controlling the valve 103 in response to changes in temperature of the wall. As the temperature of the wall 101 tends to drop in response to increased condensation of steam with increased heat demand, the valve 103 tends to open for greater velocity of flow in response to the increase in demand.

Another method of functionally relating the actuation of a system-release valve with the heat load on the system is to vary the fuel feed automatically as required to maintain a given boiler pressure and to vary the release of steam from the system simultaneously with the automatic variation in fuel feed. In Fig. 6 illustrating this conception, a casing 105 of a familiar type encloses a diaphragm 106, the underside of which is exposed to boiler pressure communicated through the pipe 107 and the upper side of which presses against a plunger 108 that opposes the boiler pressure. The magnitude of the opposing force is determined by the adjustment of a weight 110 slidably on a lever 111. The lever 111 which is fulcrumed on a suitable bracket 112 and is connected to the plunger by a link 113 carries at its outer end a switch contact 115 intermediate two spaced switch contacts 116 and 117. When pressure in the boiler of the steam system drops below a value predetermined by the setting of the weight 110, the contact 115 drops against the contact 117 to close the following circuit for energizing a motor 118 in one direction: contact 115, contact 117, wire 120, field winding 121, the armature of the motor, wire 122, battery 123, and wire 125 back to the contact 115. On the other hand, when the boiler pressure rises above the predetermined value, contact 115 touches contact 116 to close the following circuit for reverse rotation of the motor 118: contact 116, wire 126, the reverse field winding 127, the armature of the motor, wire 122, battery 123, and wire 125 back to the contact 115.

It is apparent that by virtue of this automatic control through a reversible motor, a worm shaft 128 operated by the motor will seek a position of rotation in accord with the load or heat demand on the system. One worm 130 on the shaft 128 controls a worm gear 131 for valve regulation of flow through a fuel pipe 132 to the burner for the boiler, and a second worm 133 on the shaft controls a worm gear 135 that operates a valve 136 (Fig. 7) for releasing steam from the system through a pipe 137. The pipe 137 may lead to a feed water supply to transfer heat thereto or may simply release steam into the atmosphere.

In the arrangement shown diagrammatically in Fig. 8, the rate of steam release from the system varies with the load or demand on the system as measured at a number of points along the system. In Fig. 8 a boiler 140 supplies live steam through a pipe 141 to four different heat exchangers 142, steam passing from the four steam exchangers through four pipes 143 respectively to a low pressure pipe 145 on the return side of the system. The pipe 145 communicates with an exhaust pipe 149, the function of the exhaust pipe being to release sufficient steam from the system to maintain the velocity of flow required for productive efficiency.

Each of the pipes 143 is provided with an electrically actuated valve 146 each of which valves is responsive to the temperature changes of the corresponding heat exchanger 142. To provide for such response, each of the four valves 146 is operatively connected by a multiple conductor cable 147 with a corresponding thermostat control 148 at the corresponding heat exchanger 142, each of the thermostats controlled including a thermostat bulb 150 lying against the heat-transfer wall of the heat exchanger.

When the heat demand imposed on any one of the heat exchangers 142 is relatively low, the corresponding valve 146 will be automatically adjusted to a relatively low rate of steam flow through the heat exchanger sufficient to maintain the heat exchanger wall at the temperature predetermined by the setting of the thermostat. Whenever an increase in the demand for heat tends to lower the temperature of the heat exchange wall, the corresponding valve 146 will automatically operate to increase the rate of steam flow through the heat exchanger to meet the increased demand.

The first described form of our invention as illustrated in Figs. 1–4 may be analyzed as employing the feed water supply simply as thermal means for controlling intermittent action in response to demand, the thermal means being heated in response to release of steam and being thereby maintained at an artificial temperature sufficiently high for the particular system. The same principle of operation will be recognized in the electrical arrangement shown in Fig. 9. In Fig. 9 an ordinary alternating current circuit includes in series a solenoid 154 for operating a steam-release valve 155 and a relay 156 for controlling the solenoid. When the solenoid is de-energized, a spring 157 moves the valve towards closed position. The coil 158 of the relay 156 is in a control circuit energized by a transformer

160. The control circuit includes in series the relay coil 158, the secondary of the transformer 160, a heating coil 161 for heating a thermostat means such as a bimetallic element 162, a contact 163 movable by the thermostat means, a complementary stationary contact 165, and a rheostat 166 for adjusting current flow through the circuit.

The control arrangement in Fig. 9, as described to this point, may be employed for intermittent steam release independently of variations in demand, that is to say, for a substantially constant level of intermittent steam release high enough to meet peak demands on the system. When the thermostat means 162 cools sufficiently to close the control circuit, the resultant current flow through the circuit energizes the heating coil 161 to initiate a heating period for again causing separation of the contacts 163 and 165. It is apparent that the circuit will open and close for intermittent current flow with the alternating periods determined by the design of the thermostat means, the design of the heating coil, the current in the circuit, and the adjustment of the rheostat 166. In a control circuit of a given design, the character of the intermittent action may be varied simply by adjustment of the rheostat.

To introduce the factor of demand where variation in steam release in accord with variation in heat demand is desired, we may add to the control circuit in Fig. 9 a shunt 167 controlled by a shunt switch 168, such that closing of the shunt switch will energize the coil 158 of the relay independently of control by the thermostat means 162. The shunt switch 168 may be operatively connected to the steam system in various ways to respond to changes in the load. For example, the shunt switch 168 may be caused to close in response to operation of the feed pump 36 or in response to the changes in water level in tank 25 that cause opening of the water valve 68.

Fig. 10 illustrates the fact that under our basic concepts timing devices of other than the thermal type may be employed in some practices of our invention. Fig. 10 shows an electric clock or constant-speed motor 170 in parallel with the primary of a transformer 171 and in parallel with an actuating circuit. The actuating circuit has in series a solenoid 172 to actuate a steam-release valve 173 and a relay 175 to control the solenoid. The coil 176 of the relay is in a control circuit that is energized by the transformer 171 and is intermittently opened and closed by a switch means 177.

In the construction shown in the drawings, the switch means 177 comprises a pair of stationary contacts and a rotary switch member, the rotary switch member being keyed to a square shaft 178. Slidingly mounted on the square shaft 178 for actuation thereof is a sleeve 180 integral with a friction wheel 181, the sleeve being controlled by a suitable fork 182. The fork 182 is integral with a nut 183 governed by a worm 185, there being a thumbpiece 186 on the end of the worm for manual adjustment thereof. The friction wheel 181 which has a periphery of rubber or other suitable material is in frictional contact with the face of a driving disc 187 actuated by the motor 170 so that the speed with which the switch means 177 operates is governed by the position of the friction wheel 181 radially of the driving disc. It will be readily understood that the radial position of the friction wheel 181 with respect to the driving disc 187 as set by manipulation of the thumbpiece 186 will determine the rate at which the switch means 177 will intermittently close and open the operating circuit.

The arrangement illustrated in Fig. 10 as described to this point may be employed to cause intermittent release of the steam independently of variations in demand, the rate of steam release being high enough to satisfy peak loads on the system. To introduce demand as a factor, it is merely necessary to add a shunt 188 controlled by a shunt switch 190 and to arrange for the shunt switch to close automatically whenever the feed pump operates to replenish the boiler water.

Fig. 11, which is similar to Fig. 10 in many details, as indicated by the use of corresponding numerals for corresponding parts, illustrates how the factor of demand may vary adjustment of the nut 183 rather than shunt the control circuit. Fig. 11 differs from Fig. 10 in having the worm 185 integral with a shaft 191 driven by a reversible motor 192. The motor 192 is reversibly controlled in the same manner as the motor 118 in Fig. 6; thus, Fig 11 shows the same reversing circuits as Fig. 6 including the two oppositely wound field windings 121 and 127, wire 122, battery 123, wire 125, the two fixed contacts 116 and 117, and the intermediate contact 115 carried by the pressure-responsive lever 111.

Rotation of the worm shaft 191 in response to demand not only shifts the position of the nut 183 to vary the rate of intermittent steam release but also changes the rotary position of a worm gear 193 for valve control of fuel through a pipe 195, the fuel rate being increased and decreased as required to maintain a predetermined boiler pressure. Thus, when demand or the heat load on the system increases, the friction wheel 181 in Fig. 11 is moved radially outward with respect to the drive disc 187 to increase the frequency with which the switch means 177 intermittently closes the control switch for actuation of the steam release valve. If desired, a suitable dash pot 189 may be operatively connected with the valve 173 to have retarding effect only on the valve closing movement, the retarding effect being variable by adjustment of a needle valve 194 as shown.

Fig. 12 shows another electrical arrangement for intermittent release of steam from a system as required for the creation of effective steam flow. The usual circuit for energizing a solenoid 196 for actuation of a steam-release valve 197 is controlled by a relay 198. The coil 200 of the relay is energized and controlled by an electric or electronic timer 202. The timer 202 is of a familiar type including a battery or other E. M. F. source, a condenser and suitable resistance, the timing function being provided by the charging or discharging of the condenser. Since such timers are well known in the art, it is not deemed necessary to make a detailed disclosure of its construction. With the periodic rise and decay of current incidental to the charging and discharging of the timer condenser, the relay coil is periodically energized to cause periodic operation of the steam valve 197.

For time adjustment of the periods of relay energization, it is merely necessary to vary the capacitance and/or resistance in the timer 202. For such purpose, the timer is shown in Fig. 12 as having a manual condenser adjustment 203 and a manual resistance adjustment or rheostat knob 205. If it is desirable to introduce demand on the steam system as a factor, it is merely

necessary to provide a shunt 206 controlled by a shunt switch 207, the switch closing in response to replenishment of the boiler or replenishment of the feed water supply.

Fig. 13 indicates how demand may be introduced as a factor to vary the adjustment of a timer rather than to shunt the timer. The valve 197 in Fig. 13 responds to the same actuating circuit as in Fig. 12, the circuit including the solenoid 196 and being controlled by the same relay 198. The coil 200 of the relay is controlled and energized by an electric timer 210 of the same type as the electric timer 202 but having only a single timing adjustment in the form of a worm gear 211. No switch corresponding to the switch 207 of Fig. 12 is shown in Fig. 13, but such a switch may be added if it is desired to have the release of steam from the system augmented by means responsive to replenishment of the boiler or of the feed water supply. A shaft 212 operated by a reversible motor 213 carries a worm 215 in mesh with a timing worm gear 211 and also carries a second worm 216 in mesh with a second worm gear 217 for valve regulation of fuel flow through a fuel pipe 218. The motor 213 is controlled in response to demand on the steam system by the previously described reversing circuits as indicated by the use of numerals for motor circuit elements in Fig. 13 corresponding to numerals in Figs. 6 and 11.

When, in the operation of the apparatus illustrated in Fig. 13, pressure in the boiler of the system drops below a predetermined value the contact 115 on the boiler-pressure-responsive lever 111 drops against the contact 117 to close the motor circuit through the field winding 127 for energizing the motor 213 in one direction. On the other hand, when the boiler pressure rises above a predetermined value contact 115 on the lever 111 touches contact 116 to close a circuit through the reverse field winding 121 to energize the motor 213 in the opposite direction.

It is apparent that by virtue of this automatic control through a reversible motor the worm shaft 212 operated by the motor will seek a position of rotation in accord with the load or heat demand on the system. When the demand is high the worm gear 217, controlled by the worm 216, will cause the fuel valve to supply fuel to the boiler at a relatively high rate, and the worm gear 211, controlled by the worm 215, will cause the timer 210 to be adjusted for intermittently opening the valve 197 to release a relatively great quantity of steam in a unit of heat.

Fig. 14 illustrates an arrangement for intermittent steam release in which the frequency of the intermittency is constant but the intervals of relatively great steam release are varied in length in accord with heat demand. A valve 220 for controlling the release of steam from a heat exchanger 221 is operated by a solenoid 222 in series with a relay 223. The coil of the relay 223 is connected to a brush 225 mounted on a carriage 226 and is in series with a transformer 227 and a second brush 228. The first brush 225 presses against the face of a rotating disc 230 of non-conducting material and the second brush 228 presses against a metal band 231 around the periphery of the disc. For intermittently closing the relay coil circuit the metal band 231 is in turn connected to a plate 232 of conducting material covering a portion of the surface of the disc 230.

The carriage 226 which slidingly engages a guide rod 233, is controlled by a worm 235 and is adapted for moving the brush 225 along a radius of the disc 230. The shape of the plate 232 is such that the proportion of a rotation of the disc during which the brush 225 is in contact with the plate 232 depends upon the radial position of the brush. Thus, when the brush is positioned near the axis of the disc the relay 223 will be energized substantially continuously but at positions of the brush away from the axis, the relay will be energized periodically, the duration of the energization periods decreasing with the radial distance. The frequency of the intermittent relay action is constant since the disc 230 is driven by a clock or constant speed motor 236.

A motor 237 for controlling the worm 235 is reversibly controlled by circuits of the character previously described, energization of the motor being determined by the position of a switch arm 238 and the position of the switch arm 238 being in turn determined by the surface temperature of the heat exchanger 221. In Fig. 14 the switch arm 238 is operated by a thermostat arrangement including a thermotat bulb 240 in contact with the heat exchanger 221. At a predetermined surface temperature of the heat exchanger the switch arm 238 is in the central position shown: at higher temperatures, the switch arm is swung to one limit position to shift the brush 225 radially outwardly along the disc 230; and at lower temperatures the switch arm is swung to the opposite limit position to shift the brush 225 radially inward. It is apparent that the position of the brush radially of the disc and therefore the rate of steam release will vary with the heat load imposed on the heat exchanger 221.

Fig. 15 illustrates another arrangement for obtaining intermittent steam release. The solenoid 241 for operating the steam release valve 242 is controlled by a relay 243. The circuit for closing the relay 243 is adapted by any suitable mechanical or electrical arrangement to close whenever replenishing water is periodically added to the boiler or whenever replenishing water is periodically added to the feed water supply. For example, the relay circuit may in turn be controlled by a normally closed back contact relay 245, the coil of which is energized by the motor circuit of the feed water pump 86. The described arrangement magnetically holds the release valve 242 at its maximum open position whenever the feed water pump is idle, but releases the valve to reduce or cut off steam flow whenever and as long as the feed water pump is energized. The arrangement therefore is inherently intermittent in operation.

The arrangement shown in Fig. 16 provides for periodic release of steam in lagging response to periodic boiler feed operation and further provides for variation in the duration of the responsive steam release. A relay 246 shown in its de-energized position in Fig. 16 incorporates three switches, namely, a normally closed switch 247, a normally open switch 248, and a normally closed switch 249. A solenoid 250 for operating a steam release valve 251 is in the plate circuit of a vacuum tube 252, the plate circuit being energized by a battery 253 or other electromotive source and including the normally closed switch 249.

The grid of the vacuum tube 252 is connected to one side of a condenser 255, preferably a variable condenser as shown, and the other side of the condenser is connected to a grid-washing battery 256. A circuit for charging the con-

denser 255 is provided by a battery 257 in series with the normally open switch 248 and a conducting path for discharging the condenser is provided by a variable resistance 260 in series with the normally closed switch 247.

Normally, with the boiler feed pump de-energized and the relay 246 in the position shown, the plate circuit of the vacuum tube is closed but the solenoid 250 is not energized to hold the steam valve 251 in a maximum open position because the normal negative bias given to the grid of the tube by the battery 256 prevents current flow through the plate circuit. Normally the condenser 255 is completely discharged since the charging circuit is held open by the switch 248 and the discharging circuit is closed by the switch 247.

When the feed water pump is periodically energized, relay 246 is likewise energized to open switches 247 and 249 and close switch 248 thereby causing the battery 257 to charge the condenser 255. Immediately the grid of the vacuum tube becomes positive but the switch 249 is open to prevent current flow through the plate circuit. When the feed water pump ceases to operate, relay 246 returns to its normal position whereupon the valve 251 is open to its maximum position and stays open substantially as long as the grid potential is positive in response to discharge of the condenser through the resistance 260. When the condenser is completely discharged, the battery 256 assumes its normal negative control of the grid potential to de-energize the solenoid 250.

It is apparent that the condenser 255 and the resistance 260 provide a timing circuit in which the duration of the condenser discharge may be controlled by adjustment of the resistance and/or adjustment of the condenser. Only ordinary skill is required to adjust the duration of the responsive delayed-action steam release to cause the steam heating system to operate efficiently. The rate and duration of the delayed steam release to be sought is such as will cause the cycle of operation to be repeated often enough for effective removal of condensate from the system.

We have disclosed various expedients for causing velocity in the system to vary with the volume of feed water utilized, one expedient involving the use of a thermal-responsive means, another the use of a liquid-level-responsive means. Other expedients are suggested by our disclosures. In Fig. 2, for example, the rate at which steam condenses in the submerged portion of pipe 34 varies inversely as the temperature of the water and such condensing action as affected by the addition of relatively cool water to the supply may be utilized to affect the velocity of steam flow in the system.

It should be understood that in the claims the use of the expression "continual flow" or the expression "substantially continual flow" should not be literally interpreted to mean that the flow of steam may not be momentarily halted through the closing of automatic valves or controls.

Within the sense of the expressions there may be interruption in the flow of steam. In other words, the term "continual" is to be construed as having either of two meanings given by Webster's new International dictionary, the first meaning being occurrence without interruption and the second meaning being occurrence at frequent intervals. Thus, under either meaning of the term a steam condition prevails that provides sufficiently continuous pressure and movement to effectively remove non-condensable gases and water from the condensing surfaces of the steam apparatus and to maintain the surfaces substantially free from non-condensable gases and any water film of material thickness whereby additional heat units reach such surfaces to increase the rate of heat transfer. Any steam condition, pressure, or flow that accomplishes this end should be construed to be within the terms and meaning of continual flow of steam.

Through the specification, we have emphasized the importance of maintaining the interior surfaces of the heat exchange surfaces substantially free of condensation in order to obtain maximum heat transfer between the steam and the heat exchanger wall. We wish to make clear, however, that this does not mean that the interior surfaces of the heat exchanger are maintained in an absolutely dry condition but rather that the thickness of the film of condensate is held to such limits that the desirable results may be obtained. We have found that an interior heat exchange wall, which is merely moist as distinguished from one having a substantial layer of condensate thereover, does not impair the heat transfer characteristics of our system and may even assist in obtaining the desired results. Hence, in the appended claims, statements to the effect that condensate is to be removed from the walls do not exclude moist walls. In fact, moist walls necessarily result from the passage of saturated steam even at exceedingly high velocities.

It should be understood that throughout the specification and the appended claims, the expressions "intermittent release of steam" and "operation with intermittent release of steam" and the like are intended to denote the release of steam at a varying rate, which may vary from some positive value to zero, or from some positive value to a lower value, such as the case when the valve does not completely close or because a bypass is provided. This is not to be confused with the definition heretofore given for "pulsating intermittent flow of steam" in which it is contemplated that there will be a complete cessation of steam flow between pulsations, in contra-distinction to "pulsating continuous flow of steam" in which the rate of steam flow varies between different positive values.

The various practices and forms of our invention set forth in detail herein will suggest to those skilled in the art various changes and substitutions based on our underlying concepts. We reserve the right to all such departures from our description that properly lie within the scope of our appended claims.

We claim:

1. In a steam system, a heat exchanger, a boiler connected with said heat exchanger to supply steam thereto, means to release steam from the system on the low pressure side of said exchanger, and means responsive to the boiler pressure to vary the rate of fuel consumption by the boiler inversely with changes in the boiler pressure and to vary the rate of steam release in accord with the rate of fuel consumption.

2. In a steam system, a heat exchanger, a steam generator connected with said heat exchanger to supply steam thereto, variable fuel feeding means for said generator inversely responsive to steam pressure at the boiler to maintain steam pressure at the boiler at different levels of demand, and means responsive to said fuel feeding means to

release steam from the system on the low pressure side of said heat exchanger at a rate varying with the heat demand on the system.

3. A heat exchange system comprising a steam using device for heating primarily by the release of latent heat with consequent formation of condensate, a steam generator connected to said device for supplying steam thereto at relatively high pressure, an exhaust steam pipe in open communication with said steam generator through said device, a valve controlling the release of steam from said exhaust pipe into a pressure much lower than that maintained within the system by the generator, timing means operatively connected with said valve to operate the valve intermittently to cause pulsating flow through said device, and means apart from the system to energize said timing means.

4. A heat exchange system comprising a steam using device for heating primarily by the release of latent heat with consequent formation of condensate, a steam generator connected to said device for supplying steam thereto at relatively high pressure, an exhaust steam pipe in open communication with said steam generator through said device, a valve controlling the release of steam from said exhaust pipe into a pressure much lower than that maintained within the system by the generator, and electrically actuated timing means operatively connected with said valve to operate the valve intermittently to cause pulsating steam flow through said device.

5. A heat exchange system comprising a steam using device, a steam generator connected to said device for supplying steam thereto at relatively high pressure, an exhaust pipe in open communication with said steam generator through said device, means to release steam from said exhaust pipe into a pressure much lower than that maintained within the system by said generator, an electrically actuated timing means to operate said release means intermittently to cause pulsating steam flow through said device, means to supply water to said steam generator as required, and means to operate said release means in response to operation of said water supply means.

6. A heat exchange system comprising a steam using device, a steam generator connected to said device for supplying steam thereto at relatively high pressure, an exhaust pipe in open communication with said steam generator through said device, means to release steam from said exhaust pipe into a pressure much lower than that maintained within the system by said generator, an electrically actuated timing means to operate said release means intermittently to cause pulsating steam flow through said device, means to supply water to said steam generator as required, means to operate said release means in response to operation of said water supply means, and means to vary the operation of said timing means to meet various levels of heat demand on the system.

7. A heat exchange system comprising a steam using device, a steam generator connected to said device for supplying steam thereto at relatively high pressure, an exhaust pipe in open communication with said steam generator through said device, means to release steam from said exhaust pipe into a pressure much lower than that maintained within the system by said generator, an electrically actuated timing means to operate said release means intermittently to cause pulsating steam flow through said device, means to supply water to said steam generator as required, means to operate said release means in response to operation of said water supply means, and automatic means to vary the operation of said timing means in response to changes in the heat load on said device.

8. A heat exchange system comprising a steam using device, a steam generator connected to said device for supplying steam thereto at relatively high pressure, an exhaust pipe in open communication with said steam generator through said device, means to release steam from said exhaust pipe into a pressure much lower than that maintained within the system by said generator, an electrically actuated timing means to operate said release means intermittently to cause pulsating steam flow through said device, means to supply water to said steam generator as required, means to operate said release means independently of said timing means in response to operation of said water supply means, and means to vary the frequency at which said timing means operates to meet various levels of heat demand on said device.

9. A heat exchange system comprising a steam using device, a steam generator connected to said device for supplying steam thereto at relatively high pressure, an exhaust pipe in open communication with said steam generator through said device, means to release steam from said exhaust pipe into a pressure much lower than that maintained within the system by said generator, an electrically actuated timing means to operate said release means intermittently to cause pulsating steam flow through said device, means to supply water to said steam generator as required, means to operate said release means independently of said timing means in response to operation of said water supply means, and means operatively connected to said timing means to vary the duration of the steam release to meet various levels of heat demand on said device.

10. In a heat exchange system comprising a steam using device for heating primarily by the release of latent heat with consequent formation of condensate, a steam generator connected to said device for supplying steam thereto at relatively high pressure, means to release steam from said system on the low pressure side of said steam using device to promote steam flow through the system, timing means including a continuously driven timing switch, and means to operate said release means intermittently in response to said timing means.

11. In a heat exchange system comprising a steam using device, a steam generator connected to said device for supplying steam thereto at relatively high pressure, means to release steam from said system on the low pressure side of said steam using device to promote steam flow through the system, a timing means operatively connected with said release means to release steam from the system intermittently, means responsive to variations in the steam pressure at said steam generator to vary the rate of fuel consumption by the steam generator thereby to minimize the changes in steam pressure with changes in heat demand on the system, and means responsive to said fuel-consumption-varying means to vary the operation of said timing means thereby to vary the release of steam in accord with changes in the heat demand on the system.

12. In a heat exchange system comprising a steam using device for heating primarily by the release of latent heat with consequent formation of condensate, a steam generator connected to

said device for supplying steam thereto at relatively high pressure, means to release steam from said system on the low pressure side of said steam using device to promote steam flow through the system, a timing means operatively connected with said release means to release steam from the system intermittently, and means including a thermostat responsive to temperature changes of said steam using device to vary the operation of said timing means and thereby vary the rate of steam release in accord with changes of heat demand on said device.

13. In a heat exchange system comprising a steam using device for heating primarily by the release of latent heat with consequent formation of condensate, a steam generator connected to said device for supplying steam thereto at relatively high pressure, means to release steam from said system on the low pressure side of said steam using device to promote steam flow through the system, a timing means operatively connected with said release means to release steam from the system intermittently, and means including a thermostat responsive to temperature changes of said steam using device to vary the frequency of operation of said timing means in accord with changes of the heat load on said steam consuming device.

14. In a heat exchange system comprising a steam using device for heating primarily by the

release of latent heat with consequent formation of condensate, a steam generator connected to said device for supplying steam thereto at relatively high pressure, means to release steam from said system on the low pressure side of said steam using device to promote steam flow through the system, a timing means operatively connected with said release means to release steam from the system intermittently, and automatic adjustment means for said timing means to vary the duration of the recurring periods of steam release, said adjustment means including a thermostat responsive to temperature changes of said steam consuming device thereby to vary the steam release in accord with changes in demand on said device.

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