Nov. 29, 1960 F. W. VAN LUIK, JR 2,962,265

VAPOR-LIQUID PHASE CONVERSION

Filed Oct. 22, 1956 2 Sheets-Sheet 1

Fig. 1

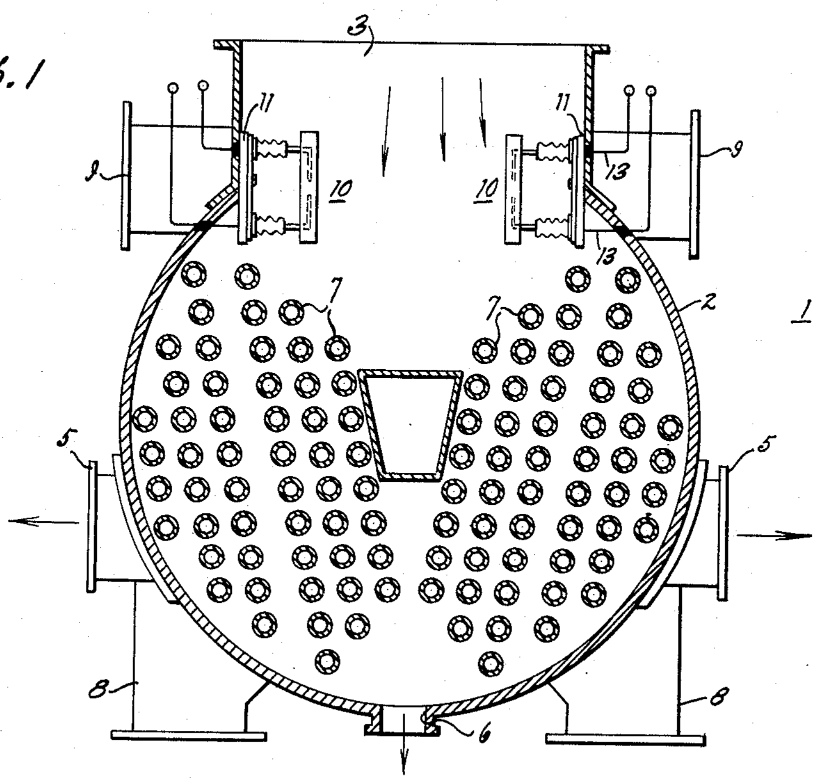

Fig. 2

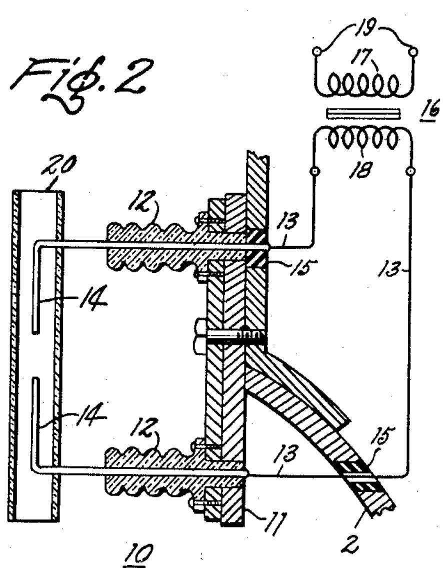

Fig. 3

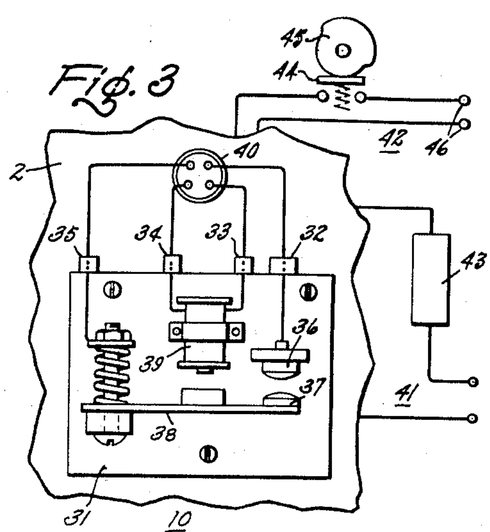

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Fig. 4

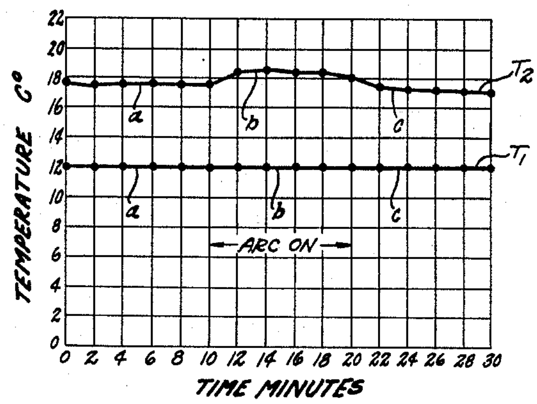
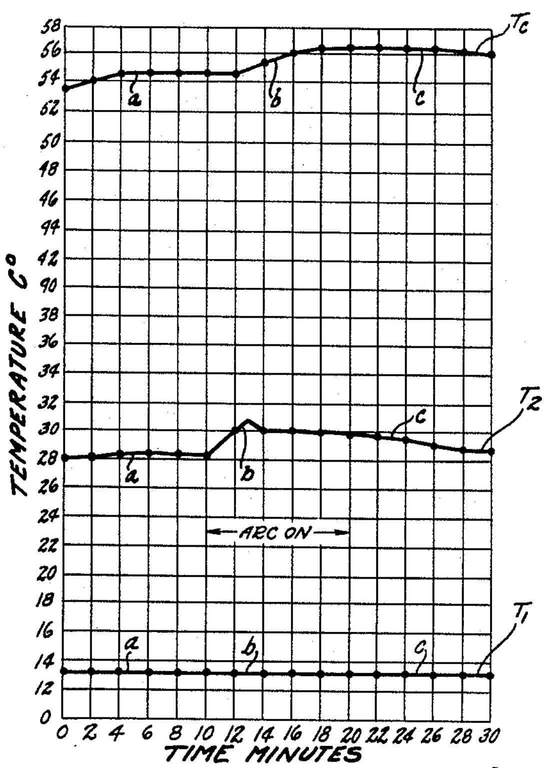


Fig. 5



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VAPOR-LIQUID PHASE CONVERSION

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8 Claims. (Cl. 257—43)

This invention relates to a method and apparatus for vapor-to-liquid phase conversion. More particularly, it relates to a method and apparatus for increasing steam condensation rates.

Vapor-to-liquid phase conversion systems are of great importance in many industrial as well as household areas. Thus, turbine power plants, refrigeration systems, distilling processes, chemical processes, household appliances such as dishwashers, represent but a fragmentary recital of their utility. In all such systems it is desired, at some stage, to convert a vapor into a liquid condensate. Probably one of the most important and well known of the applications listed above is steam condensation in a turbine power plant system. In such a system it is desired to change the steam vapor coming from the turbine into a condensate; this process taking place in a piece of apparatus called, aptly enough, a condenser.

Such steam condensers may be either of the direct contact type or of the surface type. That is, condensation is either by direct contact between the vaporized steam and water, as in the case of the so-called jet condensers; or by surface condensation, where a wall of metal acting as a heat transfer surface prevents the mixing of the steam and the cooling medium. In a surface condenser of the water cooled type, water flows through a series of tubes positioned within the condenser, and steam is condensed by being brought into contact with the outside of the tubes which act as heat transfer surfaces. For condensation to take place at the heat transfer surfaces, it is necessary that either one of two conditions be present; that is, either condensation nuclei must be provided within the condenser, or the relative humidity within the condenser must be raised to an extremely high value, (around 400%) so that the vapor will condense spontaneously.

In present practice, condensation nuclei within the condenser must be provided by impurities on the heat transfer surfaces or by stray condensation nuclei present within the condenser due to air leakage around flanges, gaskets, and so forth. These prior art steam condensers, which utilize the randomly positioned condensation nuclei on the heat transfer surface and the accidental leakage introduced nuclei, leave much to be desired in supplying condensation nuclei in sufficient quantities to provide for increased condensation rates with given heat transfer surface areas.

Condensation nuclei is a generic name given to small particles which are characterized by the fact that they serve as the nucleus on which water, for example, will condense to produce droplets. Such condensation nuclei encompass microscopic and submicroscopic particles, the most important segment of the size spectrum lying in a size range extending from approximately 2.5×10^{-7} cm. radius to 1×10^{-5} cm. radius.

It has been observed that during electrical arcing phenomena an extremely high concentration of condensation nuclei is present in the vicinity of the arc. It is believed that when an electric arc is formed the extremely high temperature—about 3000° K.—present in the arc vaporizes the contact or electrode material and causes it to be diffused into the air surrounding the contact elements. This vaporized material cools rapidly and results in the creation of a large number of extremely minute particles only a few angstroms in radius (1 angstrom$=10^{-8}$ cm.). The number of particles produced per discharge may run in the order of 10^{13}. These particles immediately start recombining by collision. This recombination rate is extremely rapid and is a function of the square of the number of particles present and of their average kinetic energy. In only a few microseconds, the major portion of the particles have collided one or more times and recombined to form larger particles. This recombination process continues and the average particle becomes of the order of magnitude of 10^{-6} cm. radius. Thus, after a few milliseconds the air surrounding the electrodes between which the arc discharge took place contains several million particles ranging in size from 10^{-8} to 10^{-4} cm. radius with the largest number in the range of 10^{-7} to 10^{-6} cm. radius. These metallic particles produced by an electrical arc discharge act as condensation nuclei and may be utilized as a convenient source thereof.

By utilizing a condensation nuclei source of this, or similar, type and injecting the condensation nuclei thus produced into the vapor space of a steam condenser, it becomes possible to increase the condensation rate of such an apparatus substantially.

It is an object of this invention, therefore, to provide a method and apparatus for substantially increasing the rate of vapor-to-liquid phase conversion.

A further object of this invention is to provide a method and apparatus for increasing the rate of vapor-to-liquid phase conversion utilizing condensation nuclei injection.

Yet another object of this invention is to provide a vapor condensation apparatus in which condensation occurs in the vapor space as well as at a heat transfer surface.

Still another object of this invention is to provide a steam condenser having an increased condensation rate including condensation nuclei injecting means to permit condensation in the condenser vapor space as well as at the heat transfer surface.

Further objects and advantages will become apparent as the description of this invention proceeds.

In accordance with this invention, there is provided a steam condenser of standard configuration having a condensation nuclei source positioned therein which periodically injects a quantity of nuclei into the vapor space of the condenser. By thus causing condensation of the steam in the vapor space as well as at the surface of the water cooled heat transfer surfaces, the rate of condensation is increased for a given amount of heat transfer surface. In a preferred embodiment the condensation nuclei source is shown as an arc discharge between two spaced electrode elements. In an alternative embodiment solenoid operated contact elements may be utilized to produce the electrical arc discharge which forms the necessary condensation nuclei.

The novel features which are believed to be characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings in which:

Fig. 1 shows a view partially in cross-section of a steam condenser embodying the novel features of the invention;

Fig. 2 is an enlarged view of a portion of Fig. 1;

Fig. 3 is an alternative embodiment of the structural feature illustrated in Fig. 2; and

Figs. 4 and 5 are graphs illustrating the effects of nuclei injection.

Referring now to Fig. 1, there is shown a preferred embodiment of a vapor-to-liquid phase conversion apparatus, of the steam condenser type, illustrating the principles of the instant invention. There is provided a chamber means **1** adapted to hold a vaporized liquid such as steam. Said chamber comprises a tubular shell member **2**, shown in cross-section, constituted of welded steel and reinforced against collapsing pressure. Positioned at the top of the condenser shell **2** is a steam inlet conduit **3** for introducing the steam vapor at a reduced pressure into the condenser proper. The steam inlet conduit **3** may be connected to the exhaust piping of a turbine, not shown, by means of a flexible connection such as an expansion joint or a packing box. Positioned along the lower periphery of the condenser shell **2** and communicating therewith are a pair of conduits **5** arranged to be connected to air pumps, not shown, to remove any uncondensed steam and air residue in the condenser. An outlet **6** is provided at the bottom of the condenser to permit flow of condensate out of the condensing apparatus.

Positioned within the condenser shell **2** are heat transfer surfaces designed to abstract heat from the steam to induce at least a portion of the steam to condense thereon. To this end there are provided a multiplicity of hollow metallic tubes **7** extending axially along the length of the condenser shell and adapted to have cooling water flowing therethrough. A pair of conduits **8** provide a cold water inlet, while a pair of conduits **9** positioned near the top of the condenser provide a warm water exit for the cooling water flowing through the tubes **7**. Both the conduits **8** and **9** as well as the heat transfer tubes **7** are connected to a water box or header, not shown, positioned at one end of the condenser apparatus to provide a chamber in which the cooling water may be introduced, caused to pass through the heat transfer tubes **7**, and then withdrawn by means of the warm water exit conduits **9**. In this fashion a continuous flow of cooling water is occasioned through the tubes **7** establishing a temperature differential between the tube surface and the steam within the chamber **2**. Hence, the tubes **7** act as a heat transfer surface, and in conjunction with condensation nuclei present at their surface, cause condensation of the steam within the chamber.

There is provided a source of condensation nuclei for periodic injection of nuclei into the vapor space of the condenser **1** in order to occasion condensation of the steam in the vapor space as well as at the heat transfer surfaces. To achieve these results, electrical arc discharge condensation nuclei sources **10** are positioned within the condenser shell **2** to provide a supply of nuclei. The specific configuration of the condensation nuclei source may be most easily seen with reference to Fig. 2 which is an expanded fragmentary view of a portion of Fig. 1. The condensation nuclei source **10** comprises a terminal board **11** fastened to the chamber wall **2** by means of bolts or any other similar fastening means. Mounted on the terminal board **11** are a pair of standoff insulators **12** of the ceramic or porcelain type having conductors **13** extending therethrough to constitute a pair of spaced discharge electrode elements **14** forming a discharge gap. The conductors **13** are connected to a source of energizing voltage through a pair of insulating bushings **15** extending through the chamber wall **2**. This source of voltage provides the energization for periodically causing a nuclei producing spark discharge between the electrodes **14** and consists of a high voltage step-up transformer **16** of the iron core type. The transformer **16** has a primary winding **17** and a secondary winding **18**. The primary winding **17** is connected to a source of alternating voltage **19**, not shown, which may be a standard 115 v. 60-cycle power line. The secondary winding **18**, which is connected to the conductors **13**, contains a very large number of turns and steps up the 115 volts applied to the primary to a voltage sufficiently large to cause an arc discharge between the electrodes **14**. Thus, for example, the construction of the transformer **16** may be such that the voltage across the secondary winding **18** is stepped up to 2000 volts at 60 cycles. Hence, there is applied to the electrodes **14** a voltage of sufficient magnitude to cause an arc discharge which generates condensation nuclei constituted of small particles of electrode material. Since the voltage applied to the electrodes **12** is an alternating voltage having a repetition frequency of 60 cycles per second, there will be produced 120 discharges per second each of which produces a large number of condensation nuclei to aid in the condensation rate of the steam.

Surrounding electrodes **14** and the discharge gap is a hollow, slitted tubular member **20**, which prevents the diffusion of the vaporized contact material into the air, and assures that this vaporized material recombines into fairly large condensation nuclei by maintaining these particles in close proximity to each other and increasing the recombination probability. In this fashion, it is possible, to a certain extent, to control the size of the condensation nuclei which will be injected into the condenser vapor space, and in turn the efficiency of the process.

An alternative embodiment of the condensation nuclei source of Figs. 1 and 2 is illustrated in Fig. 3. This alternative condensation nuclei source comprises an electromagnetic relay in which a pair of contacts are periodically operated to produce condensation nuclei by means of electrical arcing. The condensation nuclei source **10** illustrated in Fig. 3 comprises a terminal board **31** fixedly mounted on the condenser wall **2**. Positioned at the top of the terminal board **31** are a number of terminals **32, 33, 34,** and **35**. The terminal **32** is electrically connected to a fixed contact member **36** positioned on the terminal board **31** while the terminal **35** is connected to a spring biased armature member **38** having a contact element **37** mounted thereon. A solenoid element **39** positioned in juxtaposition with the armature member **38** is positioned on the terminal board **31** and actuates the armature member **38** to operate the contact elements **36** and **37** periodically. The solenoid coil **39** has a pair of output leads connected to the solenoid terminals **33** and **34**.

The terminals **32, 33, 34,** and **35** are connected, through an insulating bushing **40** extending through the condenser wall, to a pair of external electrical circuits **41** and **42** which function respectively to operate the solenoid relay **39** and to provide a load circuit for the contact elements. Contact terminals **32** and **35** are connected to a load circuit **41** comprising a load element **43** to cause flow of current through the circuit when the contacts **36** and **37** are closed.

Terminals **33** and **34** are connected to a solenoid actuating circuit **42** which functions to energize the solenoid periodically in order to operate the contact elements. The solenoid circuit **42** comprises a pair of terminals **46** connected to a source of suitable voltage for operating the solenoid coil **39**. This energy is periodically applied to the coil by means of a microswitch and timing arrangement. A contact element **44**, which may be a microswitch or the like, is connected in series in one lead extending between the solenoid coil **39** and one of the voltage terminals **46**. A timing mechanism **45**, which may be a cam member or the like, is mechanically coupled to the contact member **44** and periodically closes the contacts. Upon closing of the contacts **44**, a circuit connection is made between the source of energy applied at the terminals **46** and the solenoid **39** energizing the solenoid and actuating the contact members **36** and **37**.

The timing mechanism **45** may be adjusted to provide any desired frequency of operation. In this manner the contact elements within the condenser may be operated at any desired frequency to produce an adequate supply of condensation nuclei to be utilized in increasing the condensation rate of the steam within the condenser.

While it is not intended that the scope of the invention be limited by any particular theory of operation, it is believed that the following mechanism takes place within the condenser by the injection of condensation nuclei into the vapor space. Steam at reduced pressure, which in some cases may be as low as two inches of mercury, is brought into the condenser via the steam inlet conduit from a turbine or other similar device. The incoming steam is at saturation for the steam temperature at the particular pressure. Thus, at two inches of mercury pressure the steam temperature at saturation would be 101° F. The incoming steam flows over the heat exchange surfaces represented by the tubes **7** which, being traversed by cooling water, are naturally at a lower temperature than the incoming steam. Should the incoming steam be super-heated to any extent, the passage of the steam across the heat transfer surfaces removes whatever degree of super-heat is present. The steam in the condenser chamber continues to lose heat to the heat transfer surfaces and consequently the steam keeps cooling until it becomes super-cooled and consequently supersaturated. At this stage, condensation begins about any nuclei present at the surface of the tubes and a film of water begins forming thereon which, as time progresses, drips off the tubes and out of the condenser through the condensate exit.

Up to this point, the condensing mechanism has been described without considering the injection of additional condensation nuclei into the condenser vapor space. If, now, a quantity of condensation nuclei, several orders of magnitude greater than the number normally present, is injected into the condenser vapor space between the heat transfer surfaces, condensation of the steam about these nuclei will occur within the vapor space. Such condensation is in addition to that taking place at the heat transfer surface which normally occurs in all condensers. The formation of water droplets in the vapor space occasioned by condensation about the nuclei causes a release of heat in the space from the conversion from the vapor to the liquid stage. This heat is partially absorbed by the droplets formed within the chamber, but a portion of it is transferred to the heat transfer surface across the boundary water film. This is believed to occur since the additional heat given off in the vapor chamber by condensation in the vapor space increases the temperature differential between condenser vapor space and the heat transfer surface. Thus, a greater amount of heat is transferred across the surfaces for a given surface area.

In addition, it is though that the droplets formed in the vapor space by the injection of the condensation nuclei strike the heat transfer surfaces in falling and lose a portion of their heat to those surfaces. However, in striking the heat transfer surfaces in this manner, the film of liquid at the heat transfer surface is ruptured so that drop-wise condensation is effectively achieved. As is well known, the heat transfer coefficient for drop-wise condensation on a heat transfer surface is much larger, on the order of four times, than that for film-wise condensation. It is believed that this manner of condensing droplets within the vapor space in addition to that occurring at the heat transfer surface causes drop-wise condensation and thus permits an additional removal of heat by the heat transfer surface.

Thus, by establishing a greater temperature differential between the vapor space and the heat transfer surface due to the heat of condensation given off, and due to the improved heat transfer coefficient achieved by means of the partial drop-wise condensation, a substantial improvement in the condensation rate for a given heat transfer surface is achieved by virtue of the instant invention.

It is clear that if the injection of condensation nuclei into the vapor space actually increases the rate of steam condensation for a given heat transfer surface that two specific effects should be observed. First, the amount and temperature of the condensate per unit time for any fixed head of steam should increase with the injection of condensation nuclei. That is, if condensation is taking place in the vapor space in addition to that occurring at the heat transfer surface, obviously, a greater amount of condensate should be present per unit time during the period of such injection. Furthermore, the temperature of the condensate should increase since, as was pointed out before, the additional droplets condensing in the vapor space give off heat of condensation which is partially absorbed by the droplets thus formed within the vapor space. Secondly, the temperature differential of the cooling water should show an increase since, as was pointed out previously, both an increased temperature differential as well as drop-wise condensation is believed to occur which increases the amount of heat abstracted from the chamber by means of the heat transfer surface.

In order to establish the validity of the nuclei injection technique in increasing the rate of steam condensation, a series of experiments were run which demonstrate the relationship of the quantity of condensate produced for a given time period with nuclei injection and without nuclei injection. Furthermore, another series of tests was run to determine the effects on the cooling water temperature and on the condensate temperature of the injection of nuclei into the vapor chamber. The experiments bearing on the amount of condensate produced in a given period of time with and without condensation nuclei injection brought the following typical results which are tabulated as follows:

Test	Cooling Water cc./min.	Condensate cc./10 min. Before Arcing	Condensate cc./10 min. During Arcing	Percent Increase
1	142	42	54	28.5
2	93	45	58	29.0
3	65	42	58	38.2
4	77	40	50	25.0
5	97	42	50	19.0
6	70	24	28	17.0

The above data clearly indicates that the provision of condensation nuclei injection means within a steam condenser caused a substantial increase in the amount of condensate produced within a fixed time period. Clearly then, condensation nuclei injection means in a vapor-to-liquid phase conversion device such as a steam condenser provides substantial increase in the operating efficiency of the device.

The results of the experiments to determine temperature changes in the cooling water and in the condensate are best illustrated by means of the graphs of Figs. 4 and 5 which clearly show the effects on the temperature of the injection of condensation nuclei. Referring now to Fig. 4, there is shown a graph in which time is plotted along the abscissa whereas temperature is plotted along the ordinate. The graph of Fig. 4 illustrates two curves denominated at T–1 and T–2. The curve T–1 shows the results of a number of temperature measurements at the cooling water inlet of the condenser whereas the curve T–2 illustrates the temperature at the warm water outlet of the condenser. The curves T–1 and T–2 are subdivided into three distinct portions: *a*, *b*, and *c*. Portions *a* and *b* being the times during which no condensation nuclei are being injected into the vapor chamber, whereas portion *b* reflects data during a period of time when condensation nuclei are injected into the vapor chamber by means of an electrical arc. As can be seen from

Fig. 4, the temperature at the cooling water inlet T–1 does not change with the injection of condensation nuclei, which is as it should be since this temperature is the temperature of an external source of cooling water being brought into the condenser at a constant rate. The curve T–2 indicates quite clearly, however, that the initiation of nuclei injection into the chamber causes a fairly substantial rise in the temperature of the cooling liquid as measured at the exit conduit. This indicates that a greater quantity of heat is transferred from the condenser chamber to the cooling liquid during the period when condensation nuclei are injected into the chamber than during the period when no nuclei injection takes place. This would seem to indicate that either a greater temperature differential exists between the vapor chamber and the heat transfer surface during nuclei injection or that a better heat transfer coefficient is achieved during this period, or both, since experimentation has shown that the heat added from the arc itself cannot account for the observed temperature rise. Thus, the results of the experiments illustrated in the graph of Fig. 4 seem to bear out the hypothetical condensation mechanism proposed in the earlier explanation.

Fig. 5 is a graph similar to that of Fig. 4 with the exception that an additional curve showing the temperature of the condensate is plotted thereon. That is, once more time is plotted on the abscissa while temperature is plotted along the ordinate. Similarly, curve T–1 illustrates the temperature at the cooling water input, T–2 the temperature at the warm water output conduit, while curve T–*c* illustrates the temperature of the condensate produced during various periods. Again, it can be seen from Fig. 5 that the temperature of the cooling water at the warm water exit conduit rises substantially with nuclei injection into the water vapor space. Similarly the curve T–*c* indicates the temperature of the condensate rising substantially during the period of nuclei injection. These curves thus seem to buttress the hypothesis put forward previously. That is, that the injection of the nuclei produces additional heat of condensation which is reflected both in the temperature of the cooling liquid as well as of the condensate.

Hence, it can be seen from these experimental results that the principle of nuclei injection into a vapor-to-liquid phase conversion system provides a very effective and powerful tool for increasing the rate of conversion of such processes without simultaneously having to increase the heat transfer surface as was previously believed to be necessary. Thus, a very effective tool has been presented to designers of such equipment by means of which great improvements in the efficiency of such apparatus may be achieved.

In the preceding description, the condensation nuclei producing and injecting source has been described and illustrated as an electrical arcing source which, by means of the arcing, produces condensation nuclei. It is to be understood, however, that although electrical arcing systems are the preferred embodiments of a condensation nuclei injection source, that many other possible condensation nuclei sources may be utilized with this invention. Thus, combustion products, vaporization of salt, liquid sprays, metallic carbonyls, dust sprays, as well as conversion of gases such as SO_2 by means of ultraviolet light, may be utilized as condensation nuclei. Thus, the particular condensation nuclei source utilized will be determined by its applicability and feasibility in a particular piece of equipment.

In the preferred embodiments illustrated in Figs. 1–3, the condensation nuclei sources are shown mounted within the condensation chamber 2. It is obvious, however, that the nuclei sources may be positioned external to the chamber and nuclei injected into the vapor space by means of a conduit system. In certain circumstances where maintenance is difficult, it may be preferable to utilize such an alternate construction. Similarly, where

nuclei sources other than electrical, such as those enumerated in the preceding paragraph are utilized, injection by means of such conduits would be preferable.

In a similar fashion, the instant invention has been described primarily in connection with a steam-to-water condenser as the example of the vapor-to-liquid phase conversion. It is obvious, of course, that many other areas of utilization besides steam condensers for turbines are possible for the instant invention. Thus, this condensation nuclei technique is obviously applicable to distillation processes, refrigeration processes, drying chambers of dishwashers, as well as many other similar processes in which a vapor-to-liquid phase transition is brought about.

Fluids other than water may, of course, be converted from the vapor to the liquid phase by means of condensation nuclei. Thus, for example, vaporized oil may be converted to its liquid phase by means of this injection technique. In a like manner, refrigerants such as freon or the like are susceptible to this type of phase conversion.

From the foregoing description, it can be appreciated that the instant invention provides an apparatus and method for increasing the conversion rate of vapor-to-liquid phase transitions such as steam condensation.

While a particular embodiment of this invention has been shown it will, of course, be understood that it is not limited thereto since many modifications both in the circuit arrangement and in the instrumentalities employed may be made. It is contemplated by the appended claims to cover any such modifications as fall within the true spirit and scope of this invention.

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

1. In a vapor-to-liquid phase converting apparatus, the combination comprising chamber means adapted to hold a saturated vaporized liquid, heat transfer surface means positioned within said chamber means to effect the condensation of at least a portion of the vapor at said surface, periodically actuated electrical arc producing means positioned in said chamber for injecting particles formed by said arc producing means into the chamber vapor space, said injected particles acting as condensation nuclei to produce additional condensation of the saturated vapor in said chamber vapor space whereby the condensation rate is increased.

2. In a vapor-to-liquid phase converting apparatus, the combination comprising chamber means adapted to hold a saturated vaporized liquid, heat transfer surface means positioned within said chamber means to effect the condensation of a portion of the vapor at said surface, electrical arc means including spaced arc discharge electrodes positioned in said chamber, said arc means producing additional condensation nuclei from the arc erosion particles to produce additional condensation in said chamber space whereby the condensation rate is increased.

3. In a vapor-to-liquid phase converting apparatus, the combination comprising chamber means adapted to hold a saturated vaporized liquid, heat transfer surfaces positioned within said chamber means to effect condensation of a portion of the vapor at said surfaces, periodically operated electrical arc producing contact means positioned within said chamber providing condensation nuclei to produce additional condensation in the chamber vapor space whereby the condensation rate is increased.

4. In a vapor-to-liquid phase converting apparatus, the combination comprising chamber means adapted to hold a saturated vaporized liquid, heat transfer surfaces positioned with said chamber means to effect condensation of a portion of the vapor at said surfaces, electrical arc producing contact means positioned within said chamber to inject condensation nuclei formed from the erosion products of said arc producing means into the chamber vapor space and produce additional condensation, actuating means for operating said contacts periodically whereby the condensation rate is increased.

5. In a vapor-to-liquid phase conversion apparatus, the

combination comprising chamber means adapted to hold a saturated vaporized liquid, heat transfer surfaces positioned with said chamber means to effect condensation of a portion of the vapor at said surfaces, spaced electrodes forming an arc producing discharge gap positioned within said chamber to inject condensation nuclei formed from arc erosion products into the chamber vapor space whereby the condensation rate is increased.

6. In a steam condensing apparatus, the combination comprising a chamber adapted to hold saturated steam, heat transfer surfaces including a multiplicity of cooling fluid containing hollow members to effect the condensation of a portion of the steam at said surfaces, electrical contact means positioned within said chamber to inject condensation nuclei into the chamber vapor space to produce additional condensation to increase the condensation rate, and actuating means for operating said contacts periodically.

7. In a method for increasing the rate of vapor to liquid phase transition, the steps comprising introducing a saturated vapor into a condensing chamber, extracting heat from said vapor to initiate condensation, injecting additional condensation nuclei into the remaining vapor for producing additional condensation of vapor about the nuclei including the step of producing electrical arc discharges to produce the additional nuclei.

8. In a method for increasing the rate of vapor to liquid phase transition in a steam condensing system, the steps comprising introducing saturated steam into a condensing chamber, extracting heat from said steam to initiate condensation, injecting additional nuclei into the remaining steam for producing additional condensation of said steam including the step of producing periodic electrical arc discharges to produce the nuclei forming arc erosion particles.

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