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APPARATUS FOR VAPOR CONDENSATION

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FIG. 1.

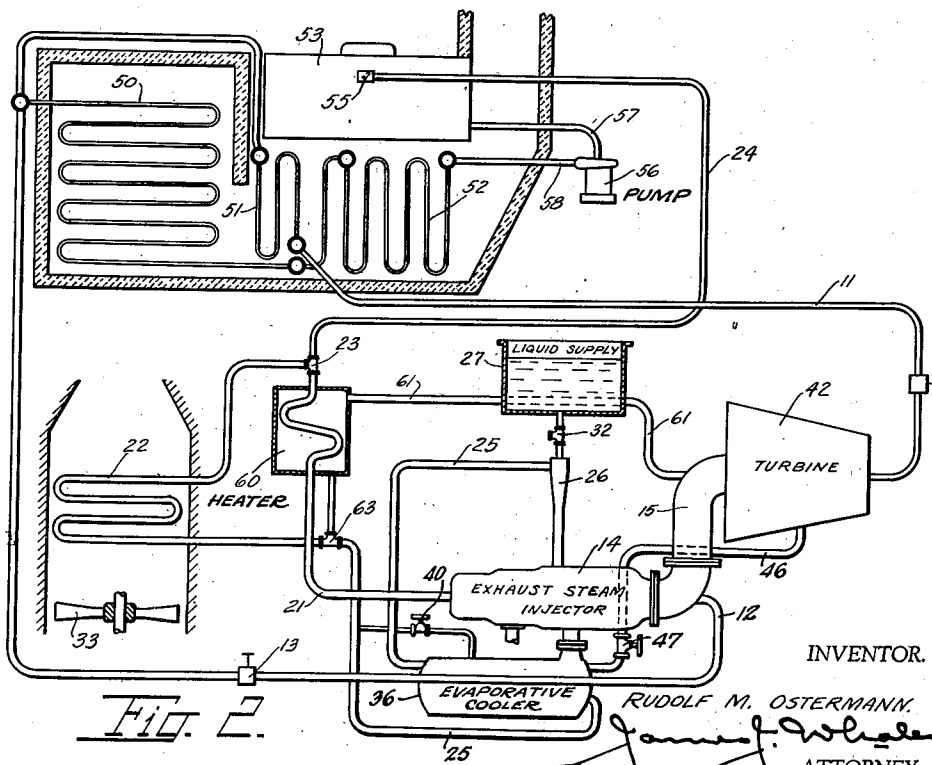
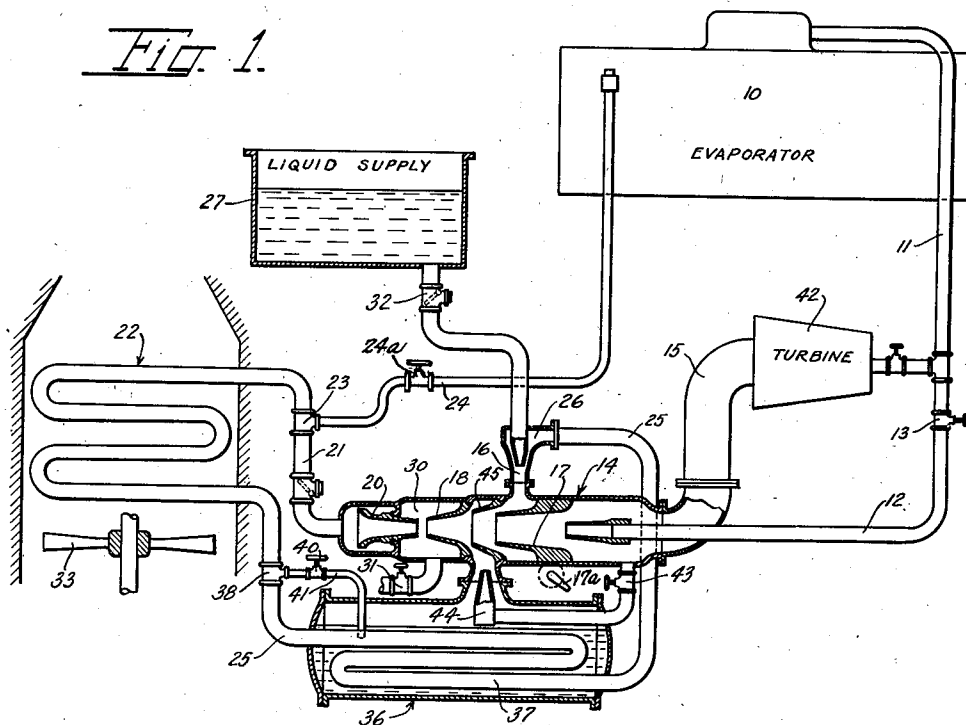


FIG. 2.

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APPARATUS FOR VAPOR CONDENSATION

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6 Claims. (Cl. 60—94)

This invention relates to an improved method of and apparatus for condensing vapors.

Although exhaust steam injectors have found their principal use on locomotives and in other noncondensing steam plants, they are capable with the water which they pump to the boiler of condensing only about one-sixth of the available exhaust steam. Consequently, five-sixths of the engine's exhaust steam is wasted to the atmosphere and five-sixths of the required boiler feed water has to be supplied directly from the tender. The object of this invention is to provide apparatus utilizing an exhaust steam injector in such a manner that the percentage of the engine exhaust steam which is condensed can be materially increased.

Injectors are in reality jet condensers functioning without water and vacuum pumps. Their use is restricted to steam plants in which the steam to be condensed is exhausted at a pressure exceeding the condensing pressure so much that its expansion imparts the kinetic energy to the condensing water thereby enabling the latter to discharge itself, together with the condensate, from the condensing chamber against a pressure appreciably above atmospheric. Those experienced in the design and operation of exhaust steam injectors recognize that injector jets stop working if the weight ratio of steam and water is not maintained within certain narrow limits. Thus it is not possible to condense more than about one-sixth of the exhaust steam of an engine or turbine with the amount of water required for boiler feed, without wasting a part of the water delivered by the injector. Such waste, though representing a substantial heat loss, might be permissible in stationary power plants with a plentiful supply of water but it is entirely objectionable in movable power plants such as steam locomotives.

In practicing my invention, I propose, in the case of a steam locomotive or similar power plant, to place that portion of the water which can not be admitted to the boiler through apparatus designed to abstract its sensible heat and to thereafter return it to the water inlet of the injector for further condensing duty.

My invention will be best understood upon consideration of the following detailed description of illustrative embodiments of the invention when read in conjunction with the accompanying drawing in which:

Figure 1 is a diagrammatic view of a steam power plant utilizing an exhaust steam injector of conventional form both to feed and heat water

for a boiler and as a condenser in accordance with my invention; and

Figure 2 illustrates a modified arrangement.

Referring first to Fig. 1, an evaporator or boiler 10 furnishes steam through piping 11, 12 and regulating valve 13 to the steam nozzle 17 of an exhaust steam injector 14. Low pressure steam or vapor is simultaneously admitted through pipe 15, whereas water or liquid enters at 16. The area for the entrance of water is varied in this instance by shifting the nozzle 17 axially; this shifting alters the area between said shifting nozzle and the fixed nozzle 45. This is one method for regulating the liquid that flows through the injector nozzles. As others are possible, I do not wish to limit my invention to any particular detail. The water and condensate which form in the combining nozzle 18 of the injector, pass to the delivery 20, where, as is well known, the velocity of the mixture is transformed into pressure, with which pressure it enters the pipe 21 leading to an atmospheric cooler 22 and also through a T 23 and piping 24 and finally to the evaporator 10. The liquid which is not forced to the evaporator, returns through the cooler 22, a return pipe 25 and ejector 26, to the inlet 16 of the injector. The ejector 26 is provided in order to combine the recuperated flow energy of the liquid with the one fed from the liquid supply tank 27 in an orderly manner and without energy-dissipating shock. The gap between combining and delivery nozzle 18, 20, respectively, is, as in all injectors, closed in an overflow chamber 30 which can be opened to the atmosphere by valve 31.

The operation of the apparatus thus far described in Fig. 1 is as follows: Upon opening the overflow valve of the injector which is indicated conventionally at 31, liquid is admitted by opening non-return check valve 32. High pressure vapor is admitted by opening valve 13 and low pressure vapor through line 15. At this time, the fan 33 which produces the cooling air is started. The water regulator 17a of the injector is now turned in either direction until a jet is formed and liquid stops flowing out of the overflow opening. The overflow valve 31 is then closed and the injector delivers a quantity of liquid to the evaporator 10 and also causes another quantity to flow through the cooler 22 through pipe 25 to the ejector 26 and back through it into the injector 14. A separate liquid regulating valve 24a may be placed in pipe 24 if desired, but if it is not provided, the ratio of the quantities of liquid going to the evaporator 10

and being recirculated through the cooler 22 is solely determined by the ratio of flow resistance in these two paths. Thus when nozzle 17 is shifted so as to admit more liquid to the jet, more will flow to the evaporator and more will also flow to the cooled bypass.

The cooling of a part of the liquid composing the injector jet, and the recuperation of its mechanical energy will have, in this particular application, the result of providing a greater feed range for the injector than it would have without a cooled bypass.

Referring further to Fig. 1, the arrangement is for a steam plant, and includes an evaporative cooler 36 through which the bypassed water is made to flow after it has passed through the atmospheric cooler 22. The evaporative cooler serves in this instance as a means for mechanical refrigeration of the recirculated water, the required power being furnished by the flow energy of the recirculated water which would not otherwise be utilized. The shell of the evaporative cooler 36 contains heat exchanger coils 37 forming part of the bypass circuit, by being inserted in pipe 25. After water has been cooled to some extent in the atmospheric cooler 22, it is taken at T 38 and discharged through a regulating valve 40 and pipe 41 into the shell of the evaporative cooler 36 in which the water level is maintained so as to keep coils 37 submerged. The low pressure steam to be condensed is in Fig. 1 shown to be exhausted from a steam turbine 42. A portion of it flows through the main low pressure steam nozzle 17, whereas another portion of it flows through valve 43 to an exhauster nozzle 44 in the outlet from the evaporative cooler 36 so as to entrain in the manner of a thermo compressor vapors coming off the water in the shell of the evaporative cooler, and thereby establishing a pressure in the shell of the cooler which is below the atmospheric. The low pressure vapor that is disengaged from the water in the evaporative cooler, plus its compressing operating steam, are then condensed on the outside of the water jet of the injector, after the latter has passed through vacuum nozzle 45. Although the design of an injector which utilizes a water jet sandwiched as it were between two portions of steam flow to be condensed by said water is very efficient and suitable for this particular purpose of combining an injector with an evaporative cooler, I do not wish to limit my invention to this particular nozzle arrangement. For instance, instead of using steam in the exhauster nozzle 44, which has done all of its work of expansion and is therefore of exhaust steam pressure, I may wish, in the case of a steam turbine or compound steam engine, to employ steam of higher than exhaust pressure obtained either from the receiver of the compound engine or from an intermediate stage of a steam turbine for the purpose of compressing low pressure vapors of the evaporative cooler to the condensing pressure at the water jet of the injector. The latter is indicated in Fig. 2 by showing a pipe 46 and regulating valve 47. Another method of increasing the kinetic energy of the injector jet and therewith its capacity of entraining low pressure vapors from the shell of the evaporative cooler 36 would be to admit an amount of supplementary steam from the boiler through pipe 12 to nozzle 17. The use of any one of the mentioned methods for getting adequate capacity out of the evaporative cooler may become desirable, possi-

bly singly or in combination, depending upon the operating problem which has to be met.

Referring to Fig. 2, which represents a piping diagram for a high pressure steam plant having a steam turbine the exhaust from which is condensed by my method of recuperative injection condensation, there is shown a boiler with evaporator section 50, superheater 51, an economizer 52, and an intermediate pressure feed tank 53 (which may also take the form of a steaming economizer). Tank 53 receives the feed water from the injector through pipe 24 and feed check valve 55. A pump 56 sucks from this tank through pipe 57 and forces the feed water through pipe 58 into the economizer 52. As in Fig. 1, pipe 21 from the injector 14 also has a T 23 connecting with the cooling coil 22. The recirculated water flows through 21, the atmospheric cooler 22 and finally through pipe 25 to the ejector 26, where it combines with the water from the supply tank 27, eventually reaching the injector through its water inlet. In this diagram there is also shown a non-contact feed water heater 60 heated by steam turbine exhaust steam through pipe 61. Where the atmospheric air is of relatively high temperature and dryness and it is the only cooling medium that is available, such as is the case in vehicles driven by condensing steam prime movers, the problem of heat dissipation is particularly acute, because the heat transfer resistance from the metal of a tube to flowing air is rather high. As a result of it, it is best to effect heat transfer by air cooling, with relatively large temperature differences between the liquid to be cooled and the cooling air. In order to make sure that the water entering the atmospheric cooler is of the highest possible temperature, one may offer to the by-passed water an added flow resistance by forcing it through a supplementary feed water heater before admitting it to the atmospheric cooler. This feed water heater would be heated by exhaust steam, or by steam partially expanded, as one would therefore make sure that the water entering the atmospheric cooler is heated to a high degree. A similar consideration may determine one to utilize the flow energy of the recirculated water by forcing it to flow through an evaporative cooler after it has been cooled part way in the atmospheric cooler. Heater 60 is piped so that the water delivered by the injector 14 flows through it on its way to the intermediate tank 53 and on its way to the atmospheric cooler 22. The condensate which collects in the shell of feed water heater 60 enters return pipe 25 by means of an ejector 63.

The method of operation of the apparatus shown in Fig. 2 is virtually the same as the one referred to in Fig. 1.

In general, it should be understood that changes in climatic conditions which govern the temperature and dryness of the air used in the operation of an air-cooled heat exchanger, and therewith its economic capacity, have a distinct bearing upon the manner in which the surplus kinetic water energy generated by by-pass cooling of an exhaust steam injector is best employed. It may be practical to utilize this surplus energy for supplementary cooling by mechanical refrigeration in summer, and to employ it in winter for increasing the temperature of the boiler feed, thus decreasing the heat loss incidental to condensation as much as possible.

What I claim is:

1. In a steam plant having a boiler, a water

supply, an injector for feeding water to the boiler, means for admitting steam at low pressure to the injector, and means for admitting a variable supply of water to the injector; means for recirculating part of the water delivered by the injector to the water inlet thereof so as to recuperate the mechanical energy of the recirculated water for aiding the jet action of the injector; and an air cooled heat exchanger for cooling the recirculated water between the point of issue from the injector delivery and the point of re-entrance into the water passages of the injector.

2. In a steam plant having a boiler, an enjector for feeding the boiler, a water supply tank, means for admitting boiler steam to the injector, means for admitting lower pressure steam to the injector, and means for admitting a variable supply of water to the latter; means for recirculating part of the water delivered by the injector to the water inlet of the latter so as to recuperate the mechanical energy of the recirculated water to aid the jet action of the injector; means for cooling the recirculated water between the point of issue from the injector and the point of re-entrance; and means for preheating the mixture delivered by the injector with exhaust steam, before its entry to said cooling means or said boiler.

3. In a steam plant having a boiler, a prime mover supplied with steam therefrom, and an injector condenser for condensing prime mover exhaust steam; a water tank for priming the injector, a by-pass connection between the delivery side of the injector and its water inlet side; an aircooled heat exchanger in said by-pass for cooling and dissipating from said by-pass to the atmosphere some of the heat of the liquid which is recirculated; an intermediate pressure receptacle for the delivery water from the injector condenser; and a supplementary boiler feed pump for handling the boiler feed from the injector delivery pressure to boiler pressure.

4. In a steam plant having a boiler, a prime mover supplied with steam therefrom, and an injector condenser for condensing prime mover exhaust steam; a water tank for priming the injector, a by-pass connection between the delivery side of the injector and its water inlet side; an aircooled heat exchanger in said by-pass for cooling and dissipating from said by-pass to

the atmosphere some of the heat of the liquid which is recirculated; an intermediate pressure receptacle for the delivery water from the injector condenser; and a supplementary boiler feed pump for handling the boiler feed from the injector delivery pressure to boiler pressure; an evaporative cooler in series with said air cooled exchanger; a connection for supplying vaporizing liquid to said evaporative cooler from said by-pass after it has passed through the air-cooled exchanger, means for supplying steam from the prime mover to said evaporative cooler, the vapors coming off the water in said cooler being compressed by a thermal compressor operated with the help of said steam, and being condensed by the water within the injector.

5. In a steam plant having a steam engine, an injector condenser for condensing exhaust steam therefrom and a source of water supply for the injector; a by-pass connection between the delivery side of the injector and its water inlet side; an air cooled heat exchanger in said by-pass for cooling and dissipating to the air some of the heat of the recirculated water; an evaporative cooler in said by-pass connected to receive water from said heat exchanger; a connection between said injector and said evaporative cooler so arranged that vapors from the latter are condensed by the water within the injector.

6. In a steam plant having a steam engine, an injector condenser for condensing exhaust steam therefrom and a source of water supply for the injector; a by-pass connection between the delivery side of the injector and its water inlet side; an air cooled heat exchanger in said by-pass for cooling and dissipating to the air some of the heat of the recirculated water; an evaporative cooler in said by-pass connected to receive water from said heat exchanger; a connection between said injector and said evaporative cooler so arranged that vapors from the latter are condensed by the water within the injector; a thermal compressor for vapors coming off the water in said cooler; means for supplying steam from said engine to said compressor for operating the latter; and a connection from said compressor to said injector so arranged that vapors compressed thereby enter the injector to be condensed by the water therein.

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