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H. F. MAY

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COMBINED JET AND DIRECT AIR CONDENSER

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FIG. 1

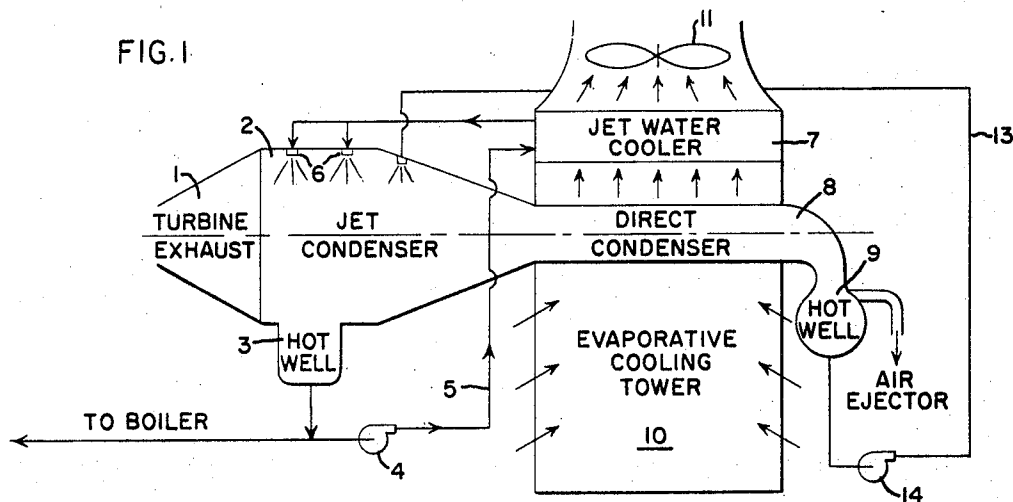


FIG. 2
PRIOR ART

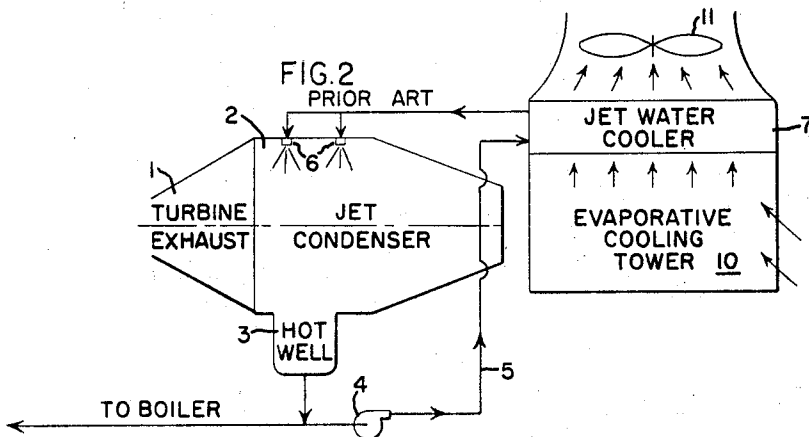
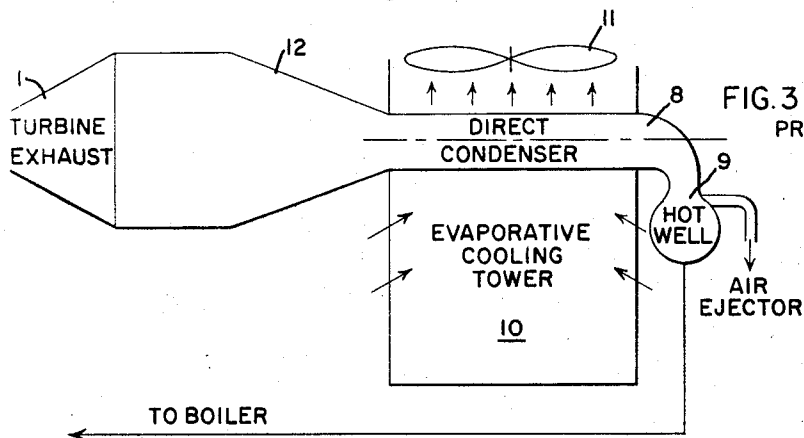


FIG. 3
PRIOR ART



INVENTOR:
HOWARD F. MAY,
BY *W. C. Cutcher*
HIS ATTORNEY.

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COMBINED JET AND DIRECT AIR CONDENSER
Howard F. May, Schenectady, N.Y., assignor to General

Electric Company, a corporation of New York

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1 Claim

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ABSTRACT OF THE DISCLOSURE

A steam condenser system having a recirculation loop connecting a first hot well with a first jet spray condenser and circulation loop including a pump connecting a second hot well with a second jet spray condenser. A pump is provided in said recirculation loop to motivate condensate from said first hot well through an air-cooled heat exchanger to said first jet condenser.

This invention relates to apparatus for condensing steam, especially exhaust steam from powerplants such as steam turbines. More particularly, the present invention concerns air condensers of the jet spray and direct air type in novel combination.

In a "typical" steam turbine-generator powerplant, the exhaust steam from the low pressure turbine is condensed in a heat exchanger, giving up its latent heat of vaporization to cooling water which flows through the heat exchanger or condenser. This cooling water typically comes from a river or the like and for that reason, generating stations are usually located beside a body of water. However, in some geographical areas, water is not so readily available in such quantities as are required by powerplants presently being planned. It is thus desirable that alternate methods of steam condensation be used in such water-scarce areas.

One alternate method of steam condensation is shown in U.S. Patent 2,356,404 to Heller. In the Heller system, turbine exhaust steam passes into a condenser in which it is directly contacted with a cool water spray. The spray water and condensate is then collected in a hot well from which a portion is pumped back to the boiler and some is recirculated to an air-cooled cooler and then back to the condenser injection or jet sprays.

Another method of steam condensation is shown in U.S. Patent 2,951,687 to Schulenberg et al. In the Schulenberg system, turbine exhaust steam passes into a condenser direct air in which the cooling medium is air. In normal operation, the circulating air is the only coolant used in the condensing system. Under certain conditions, where the ambient air is below a preselected temperature, the resulting condensate is considered to be "too cold" and some of it is recirculated and sprayed into direct contact with turbine exhaust steam. This has the effect of condensing a small portion of the steam and of heating up the recirculated condensate. This in effect is a first stage of feedwater heating.

Both of the aforementioned systems of steam condensation, the jet spray condenser and the direct air condenser, are air condensers since they both use air as the ultimate coolant or heat sink. Both systems, by their very natures, have limitations which it is the object of the present invention to overcome.

A jet spray condenser is a heat exchanger in which latent heat (from exhaust steam) becomes sensible heat (in the jet spray water). Thus there is a temperature rise in the jet water as it absorbs latent heat from the steam, condensing the steam. Accordingly, there is necessarily a temperature differential between the exhaust steam and the jet spray such that, even when the spray is heated by the

steam, there remains a temperature spread between the exhaust steam and the highest spray water temperature. This temperature differential must be present for the heat to transfer from the steam to the spray water. In addition to this, a jet spray condenser is often combined with an air cooler according to the Heller patent to cool the water as it is recirculated and before it is again sprayed into the condenser. In order that the air be effective to cool the spray water, there must be another and similar temperature differential between the spray water and the ambient air to which the water gives up heat in the air cooler. Therefore, in a jet spray condenser system, there must be a twofold heat exchange and two temperature differentials between the condensing steam and the ambient air.

A jet spray condenser is most effective at the point where turbine steam enters it. As the steam travels through a jet spray condenser, the sprays, the condensing and cooling steam, and the rapid volume decrease cause a turbulent or erratic flow within the condenser. Thus at the later stages of the condenser (that is, farther downstream from the turbine exhaust) there is a smaller temperature differential between spray water and steam and in general less heat exchange effectiveness. As a result, in a system employing only a jet spray condenser, the great bulk of the steam is condensed in only a relatively small physical portion of the condenser. In other words, the law of diminishing returns applies, the lower or last stages of a jet spray condenser producing relatively very little condensate per unit of coolant spray.

A direct air condenser, on the other hand, is a heat exchanger in which steam passing on one side gives up heat directly to air passing on the other side thereof. In a direct air condenser, there is but a single heat exchange and a single temperature differential, as discussed above, between the condenser steam and the ambient air. Size, however, is a limiting factor on direct air condenser systems. A typical size central station turbine would require a direct air condenser of such size as to make the system uneconomical in many applications. And the problem of diffusing the full turbine flow to such an air condenser also makes a system of condensing turbine steam solely in a direct air condenser very difficult.

Accordingly, it is an object of the present invention to provide an air-cooled condensing system for turbine exhaust steam, which will operate at a minimum ambient airstream temperature difference, while handling a large volume of steam in a practicable size unit.

Another object is to provide a novel combination of the principles of operation of a jet spray condenser and a direct air condenser which realizes the advantages of each and overcomes the inherent limitations of each.

Other objects, advantages and features of the present invention will become apparent from the following detailed description taken in connection with the accompanying drawings in which like numerals designate like elements.

Summary of the invention

Briefly stated, the present invention is practised in one form by a steam turbine exhausting into a jet spray condenser which in turn exhausts to a direct air condenser. The water sprayed into the jet spray condenser is continuously recirculated through an air cooler. The jet spray condenser reduces the steam volume to a quantity which the direct air condenser can handle. The direct air condenser provides more efficient condensation of the residue of uncondensed steam.

Drawing

In the drawing:

FIG. 1 is a schematic representation of the combined jet and direct air condenser of this invention.

FIG. 2 is a schematic of a prior art system employing only a jet spray condenser.

FIG. 3 is a schematic of a prior art system employing only a direct air condenser.

Description

Referring now to FIG. 1 particularly, a system is shown in which a steam turbine 1 is connected to a jet spray condenser 2. Jet spray condenser 2 has a hot well 3 which is connected by piping to a condensate recirculation pump 4. Pump 4 is connected by a recirculation loop 5 with the interior of the condenser 2. Recirculation loop 5 passes through a heat exchanger or jet water cooler 7 before reaching jet sprays 6. Water cooler 7 is air-cooled, that is, the water in its tubes gives up heat to air passing around the tubes.

Directly connected to and communicating with the casing of jet spray condenser 2 is a direct air condenser 8 in which turbine exhaust steam passing through its tubes from the jet spray condenser 2 gives up heat to air passing around the tubes.

The direct air condenser 8 has a hot well 9 which is piped through a circulation loop 13, including a pump 14, to the last stages of the jet condenser 2. This introduces the lowest temperature water available to the jet spray condenser making possible the best performance and reheats the direct condenser water for return to the boiler feedwater system. All boiler feedwater is supplied from the jet spray condenser hot well 3.

The heat exchanger tubes of jet water cooler 7 and direct air condenser 8 are located within an evaporative cooling tower 10. The heat exchange tubes are preferably of the extended surface type, such as helically finned tubing. A fan 11 is located so as to force coolant air through evaporative cooling tower 10 and over the direct air condenser 8 and water cooler 7.

The FIG. 2 and FIG. 3 systems of the prior art each include a portion of the FIG. 1 system of this invention with similar elements similarly numbered. The operation of each of these prior art systems will now be briefly described for a better understanding of the operation of the combination system of the present invention.

In FIG. 2, turbine 1 exhausts steam into jet spray condenser 2 where it is condensed by jet sprays 6 as it passes through the condenser body. Condensate is collected in hot well 3 from which a portion is pumped through recirculation loop 5 to jet water cooler 7 and then to jet sprays 6 where the continuous cycle repeats itself. Air is moved over the tubes of water cooler 7 and this cools the water recirculating through cooler 7. For an advantage in cooling, the cooling air is first passed through evaporative cooling tower 10 and thereby cooled below the dry bulb temperature to a temperature approaching the wet bulb temperature.

The previously mentioned unavoidable temperature differentials in this system are that which exists between steam and spray water (in jet condenser 2), and that which exists between spray water and cooling air or heat sink (in the cooler 7). Since there are two separate temperature differentials between the condensing steam and the heat sink, the turbine vacuum created by the condenser is not as low as it would be if there were less temperature spread (assuming the same temperature of the heat sink).

In FIG. 3, turbine 1 exhausts steam through diffuser 12 into direct air condenser 8 where it is cooled and condensed by air passing over the condenser tubes. Condensate is collected in hot well 9 from which it is pumped back to the boiler. Again, for an advantage in cooling, the cooling air is first passed through an evaporative cooling tower. This system, involving a direct heat exchange between steam and air requires only a single temperature differential to effect the exchange. However, the physical aspect of diffusing the full flow through diffuser 12 from a large turbine to low velocities and conveying it to a direct air

condenser, as well as the size of the direct air condenser itself, are such obstacles as to usually make this system impracticable for a large turbine.

In the system of this invention as shown in FIG. 1, turbine 1 exhausts steam into jet spray condenser 2 where it is condensed by jet sprays 6 as it passes through the condenser body. The condensate is collected and recirculated as described above in FIG. 2. However, the jet spray condenser of the present invention does not condense all the steam, but only so much of it as will be most effectively condensed by the spray water. By way of illustration and not of limitation, this amount of steam condensed in the jet spray condenser would be something like 75% of the total turbine flow. This has the effect of reducing the volume of steam flow and the velocity of steam flow to a point where piping is manageable, and piping losses between the jet spray condenser and the direct air condenser are minimized. Continuing, the remainder of the steam passes from the jet spray condenser to the direct air condenser which condenses it with a single heat transfer and therefore a single temperature differential between steam and heat sink. The direct air condenser thus establishes the lowest temperature and hence the vacuum level for the system, which vacuum level is lower than can possibly be attained by a jet spray condenser operating in the same ambient air temperature. The hot well 9 is piped through circulation loop 13 to the last stages of jet condenser 2 to introduce the lowest temperature condensate available to the jet spray condenser for maximum performance.

The evaporative cooling tower 10 supplies either uncooled or cooled air to the direct air condenser and to the jet water cooler 7. It is understood that this system is to be used in areas where water is not plentiful, so that the evaporative cooling tower would not operate at all times but only during that part of each day when high ambient air temperature and maximum power output demand coincide. Such is the case, for example, in southwestern areas where daytime temperatures commonly exceed 100° F. and the air conditioning load at that time is heavy. Though water may not be available for full-time evaporative cooling, ground water is generally available for full-time pumping to storage, for part-time evaporative cooling during peak daytime hours.

Thus it will be apparent that an air condensing system has herein been disclosed which overcomes the limitations of the prior art. The combination system of the present invention achieves a vacuum level of the direct air condenser while avoiding its size limitations by the action of the jet spray condenser in reducing volume.

What is claimed is:

1. A steam condensation system comprising in combination:

- a jet spray condenser having a plurality of water sprays disposed in communication with a source of exhausting steam,
- a first hot well disposed to receive condensate from said jet spray condenser,
- a direct air condenser disposed in communication with said jet spray condenser,
- a second hot well disposed to receive condensate from said direct air condenser,
- an air-cooled heat exchanger,
- a recirculation loop operatively connecting in series said first hot well, said heat exchanger, and at least one of the sprays in said jet spray condenser,
- a pump in said recirculation loop to motivate condensate therein from said first hot well, through said heat exchanger, to said jet spray condenser,
- a circulation loop operatively connecting in series said second hot well and at least one of the sprays in said jet spray condenser, and
- a pump in said circulation loop to motivate condensate therein from said second hot well to said jet spray condenser,

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said recirculation loop and said circulation loop communicating with said jet spray condenser at respectively earlier and later stages thereof relative to each other.

References Cited

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RONALD R. WEAVER, *Primary Examiner*.

U.S. Cl. X.R.

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