

[54] DRY TYPE, LIQUID-SOLID COOLING
SYSTEM

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[58] Field of Search 165/107, 2, 1, 104

[56] References Cited

FOREIGN PATENTS OR APPLICATIONS

821,003 9/1959 Great Britain 165/107

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[57]

ABSTRACT

To cool a hot first material it is brought into heat exchange with a particulate solid second material which liquefies through such heat exchange, the liquefied second material is removed from heat exchange with the first material, cooled and converted into solid particulates, and the solid particulates of the second material are brought into heat exchange recontact with the hot first material. The system is useful in the cooling of hot water from an electric power generating plant.

29 Claims, 5 Drawing Figures

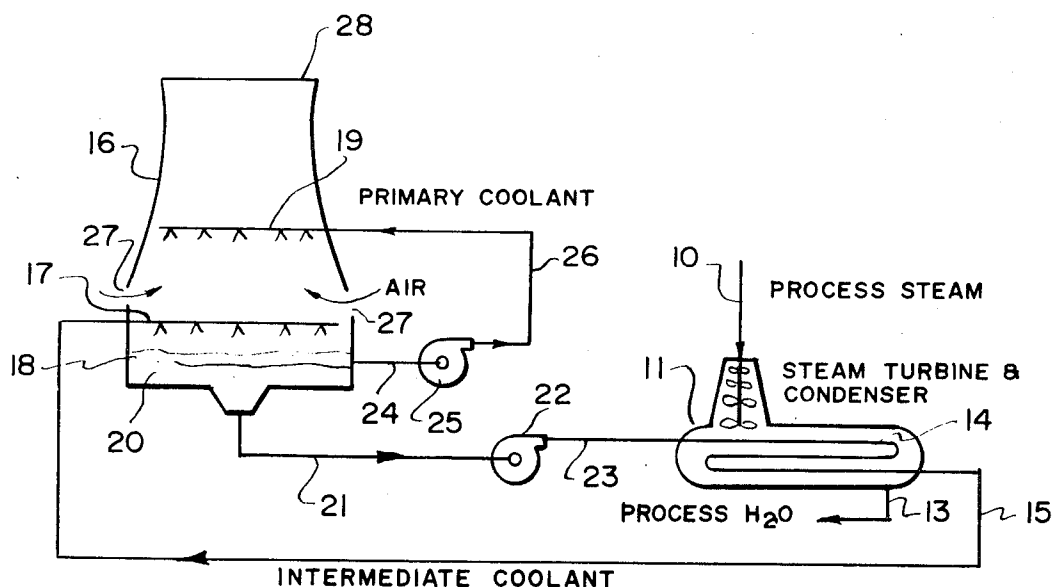
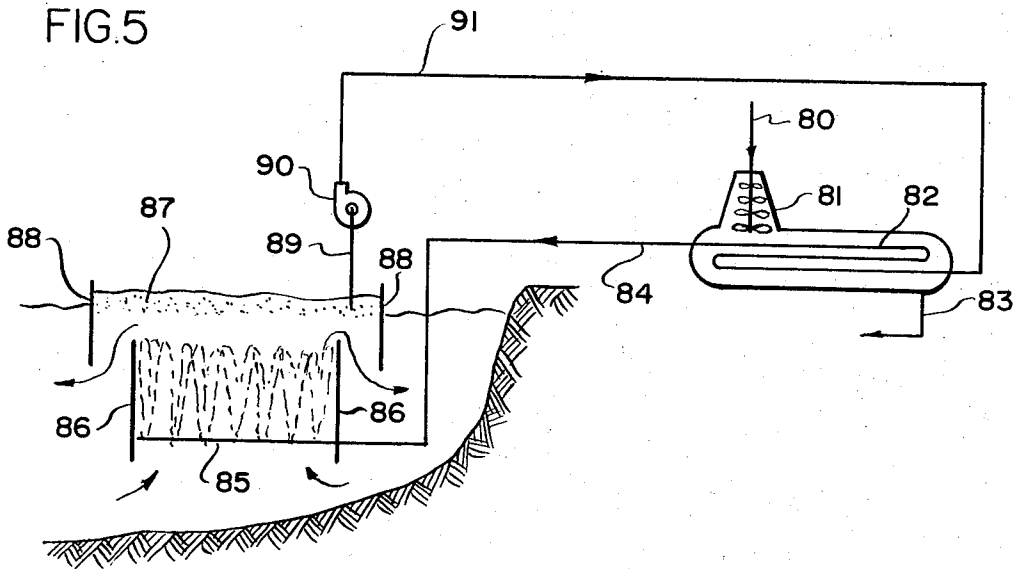


FIG. 5



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DRY TYPE, LIQUID-SOLID COOLING SYSTEM

This invention relates to processes and systems for cooling. More particularly, this invention is concerned with processes and apparatus useful for removing heat from a cooling fluid, such as is employed in power generating plants.

There are many instances in which it becomes necessary to remove heat in material processing operations as well as heat from electric power or steam generating plants. The heat removal is generally accomplished by means of an intermediate cooling fluid, which can be a gas but most often is a liquid i.e. water, although other liquids are also used. After the intermediate cooling liquid has absorbed heat, its reuse as a cooling liquid requires that its heat content be reduced to an acceptable level. This can be achieved by a number of procedures but for large scale cooling it is common to cool the liquid in a cooling tower which employs air as the heat sink.

The previously described cooling system can be illustrated further by reference to a power generating plant. In the production of electric power, heat is first produced by atomic energy or combustion of a fossil fuel such as oil or coal. The heat produced is then used to convert water into steam. The steam is conducted at high pressure to a turbine which it drives. The turbine is of course coupled to a generator which produces electric power. The spent steam from the turbine is then condensed by indirect heat exchange with cooling water. The condensed steam is recycled and reheated to steam again. The cooling water becomes very hot in condensing the steam. The large amount of hot water is commonly disposed of, without significant cooling, into rivers and lakes but this is undesirable in some areas because it causes the temperature of natural bodies of water to rise excessively leading to ecological imbalance. In the newer power generating plants the hot water is cooled in an evaporative cooling tower by contacting it with a stream of air. Huge hyperbolic natural draft cooling towers are now quite extensively used for this purpose. While a large amount of the hot water is cooled in this manner, extensive amounts are expelled as water vapor forming huge artificial clouds which contaminate the atmosphere for miles, form fog and condense to artificial rain. An evaporative cooling tower serving a 1,000 megawatt electric generating plant intrudes approximately 900,000 gallons per hour of water vapor into the atmosphere, causing not only air pollution but a significant usage of water resources. Also, the emissions contain minute droplets of dirty circulating water, called drift, which adds 100,000 gallons per hour to the water consumption rate and also carries 1.6 tons per day of solids into the air. A cooling system is thus required which reduces or avoids the problems and disadvantages present in the described methods.

According to the present invention there is provided a novel cooling method, and apparatus therefore, which provides advantages over prior cooling methods and which lowers or eliminates undesirable characteristics or short-comings of other processes. The cooling method of the present invention is broadly characterized by the use of a material as a primary coolant which is a solid at ambient temperature and pressure. The coolant is employed as solid particulates which become melted and liquid while providing cooling by absorbing heat from a hot material. The cooling ability i.e. the

heat absorbing capacity, of the solid particulates is very high because of the heat of fusion as well as sensible heat absorbed by the melted particulates. After the coolant has absorbed heat and has become liquefied it is reconverted by cooling into solid particulates. The solid particulates can then be recycled into heat exchange with the hot material. Cooling of the liquefied solid material is advisably, but not necessarily, accomplished in a cooling tower by means of air flow. Since the coolant is a solid at ambient temperature, no undesirable water vapor, clouds or fogs are emitted from the cooling tower to contaminate the atmosphere. Instead, contact with air flowing through the tower cools the material to solid particulate form. The particles settle by gravity and are reused for further cooling. Only hot air need be expelled from the tower under properly controlled operation.

The invention in a broad embodiment thus comprises a process of cooling a hot first material in which the hot first material is brought into heat exchange relationship with a stream of particulate solid second material which liquefies through such heat exchange, the stream of liquefied second material is removed from heat exchange with the first material, the liquefied second material is cooled and converted into solid particulates and the solid particulates are recontacted in heat exchange with the hot first material. Advisably, the first material is a liquid, and the second material is a solid, at ambient temperature. Furthermore, the heat exchange between the first and second materials is advisably effected by direct contact between these materials. It is also an important feature of the invention to employ first and second materials which remain essentially mutually insoluble during the process. When the process is employed in a power generating plant the first material is advisably water and the second material is one which is essentially insoluble in water. It is also advantageous that the second material be one which has a specific gravity less than water.

When the heat exchange between the first and second materials is effected by direct contact between the materials, they can be separated by gravity settling, centrifugation or some other suitable means. When gravity settling is used, the layer of first material can be circulated through a power generation plant as an intermediate coolant to condense spent steam. The liquid layer of normally solid second material can be dispersed, as by spraying, with cooling to form solid particulates which can then be recycled and reused for cooling as appropriate.

It is also an aspect of the invention to effect cooling by means of a dispersion or slurry of the solid particulate material in a separate liquid which can be water in the case of a power generating plant. An aqueous dispersion of the solid material can be used to condense spent steam. The absorbed heat melts the solid material and results in a liquid-liquid dispersion. This liquid-liquid dispersion is then separated into its components and the liquid formed from the normally solid material is cooled and reconverted into solid particulates. The solid particulates can then be reused in forming a coolant dispersion in water.

The invention will now be described further in conjunction with the attached drawings in which:

FIG. 1 illustrates one embodiment of the invention as applied to a power generating plant in which an intermediate coolant (water) is cooled by solid particulate

material which thereby melts and is thereafter recon-
verted to particulate material;

FIG. 2 is similar to FIG. 1 except that in the embodi-
ment of FIG. 2 the liquefied solid material is sprayed
upwardly, instead of downwardly as in FIG. 1, to cool

and reform solid particulates;

FIG. 3 illustrates another embodiment of the inven-
tion in which a dispersion of solid particulates in water
is used as a coolant to condense spent steam;

FIG. 4 is similar to FIG. 3 except that in FIG. 4 the
solid particulates are reformed by spraying the lique-
fied solid upwardly in a cooling tower instead of down-
wardly as in FIG. 3; and

FIG. 5 illustrates still another embodiment of the inven-
tion using a dispersion of solid particulates in water
as the coolant and a lake or river as the heat sink.

With reference to FIG. 1, process steam developed
by heat from an atomic reactor or fossil fuel furnace
(not shown) is delivered by conduit 10 to combined
steam turbine-condenser 11. The spent steam from the
turbine is condensed and recycled by conduit 13 in a
closed loop for reformation into steam. Cooling water
is circulated through coils 14 to condense the spent
steam. The water is thereby heated. The hot water
leaves coils 14 by conduit 15 which conveys it into hy-
perbolic cooling tower 16. By means of sprayhead 17
located on the end of conduit 15 inside of the cooling
tower the hot water is sprayed downwardly onto a float-
ing layer 18 of liquefied, normally solid, primary cool-
ant material. The water is cooled as it drops down-
wardly by contact with solid particulates which form
from liquefied primary coolant material sprayed from
sprayhead 19. Additional cooling is effected when the
hot water from sprayhead 17 contacts layer 18. The
cooled water settles through layer 18 to provide a
cooled water reservoir 20 in the bottom portion of the
cooling tower. Cooled water is removed from reservoir
20 and conveyed by conduit 21, pump 22 and conduit
23 to condenser coils 14.

Liquefied solid material is removed from layer 18 by
conduit 24, pump 25 and conduit 26 and is conveyed
to sprayhead 19 from which it is sprayed to form small
droplets which are cooled by air entering cooling tower
ports 27 and flowing upwardly countercurrent to the
downward flow of the droplets and out mouth 28. The
small droplets solidify as they fall through the air.
These solid particulates then fall through the hot water
spray emitted from sprayhead 17 thereby cool the hot
water. In doing so the solid particles are liquefied or
melted and combine with layer 18 of melted primary
coolant.

The solid primary coolant used in the process de-
scribed in conjunction with FIG. 1 should not be solu-
ble in water, should have a specific gravity less than wa-
ter, be non-corrosive, be nontoxic with essentially no
odorous fumes, be essentially non-oxidizing and have
appropriate thermal properties. It can be an inorganic
or organic material. Its melting point should be gener-
ally no less than 10°F. above the seasonally highest am-
bient temperature. For example, during the summer
months, the melting point might be 110°F. while during
the winter months, the melting point might be 60°F.
Some representative materials which can be used are
butyl stearate (s.g. 0.855; m.p. 68°F), docosane (s.g.
0.778; 112°F), tricosane (s.g. 0.779; m.p. 118.4°F) and
cetyl alcohol (s.g. 0.818; m.p. 120°F). It is also feasible
to use industrial paraffin waxes which are blends of the

pure paraffin waxes such as docosane, tricosane and
other materials.

The system shown diagrammatically in FIG. 2 is es-
sentially identical to that shown in FIG. 1 so that the
same identifying numbers have been used for the same
elements. The only difference between the figures is
that sprayhead 30 in FIG. 2 sprays the melted or lique-
fied primary coolant upwardly instead of downwardly
as does sprayhead 19 in FIG. 1. Upward spraying may
be more useful since it provides more time for the drop-
lets to be in contact with the cooling air.

Another embodiment of the invention is shown in
FIG. 3 in which process steam is conducted by conduit
40 to combined turbine-condenser 41. Spent steam
from the turbine is condensed by cooling coil 42 and
the condensed water is recycled by conduit 43 in a
closed loop for regeneration into process steam by an
atomic reactor or fossil fuel furnace.

Solid particulate material 44 in the bottom portion of
cooling tower 45 is conveyed by conduit 46 to the in-
tersection 47 with conduit 48. Water is supplied by
conduit 48 to intersection 47. The solid particulates
mix with the water at intersection 47 to form a slurry
or dispersion which is conveyed by conduit 49 to coil
42. The solid particulates in the dispersion melt or liq-
uefy in coil 42 to form a liquid-liquid dispersion. This
dispersion is conveyed from coil 42 by conduit 50 to
reservoir tank 51. The liquid-liquid dispersion sepa-
rates into two layers in tank 51 with the water layer 52
below the layer 53 of liquefied solid material which of
course in this instance must have a specific gravity less
than water and be insoluble in water. Water is con-
veyed from layer 52 by conduit 54 and pump 55 to con-
duit 48 for recycling.

Liquefied material is conveyed from layer 53 by con-
duit 56, pump 57 and conduit 58 to sprayhead 59 from
which it is sprayed into hyperbolic cooling tower 45. As
the spray falls downwardly it is cooled by air which en-
ters the cooling tower through ports 60 and flows up-
wardly and out tower mouth 61. This cooling converts
the material into solid particulates which settle onto the
reservoir 44 of solid particulates. This system avoids
emission of water vapor into the atmosphere and the
artificial formation of fog and rain. It also provides ex-
cellent cooling because of the large amount of heat
which can be absorbed as sensible heat and heat of fu-
sion by the conversion of the solids to a liquid.

The system of FIG. 4 is identical to that shown in
FIG. 3 with one exception. The exception is sprayhead
70 in FIG. 4 which sprays the liquefied solid material
upwardly instead of downwardly as is done by spray-
head 59 in FIG. 3.

FIG. 5 illustrates still another embodiment of the inven-
tion. In this embodiment, process steam is conveyed
by conduit 80 to combined turbine-condenser 81. The
spent steam from the turbine is condensed by coils 82
and the resulting water is conveyed by conduit 83 in a
closed loop for reconversion into steam.

Conduit 84 conveys a liquid-liquid dispersion or
slurry from coil 82 to sprayhead 85 located below the
surface of a body of water such as a river or a lake. Ver-
tical wall 86, surrounding sprayhead 85, has its bottom
edge raised above the bed of the body of water so that
cool water can circulate thereunder and flow upwardly
within the space enclosed by wall 86.

The liquid-liquid dispersion sprayed from sprayhead
85 consists of water and a liquefied or melted solid ma-

terial dispersed therein. The cooling effect of the river or lake water solidifies the liquefied solid material into solid particulates which float as a mass 87 on the body of the water. Wall 88 surrounds an area wider than that surrounded by wall 86 to assure retainment of the floating particulates without escape. Wall 88 extends above the surface of the body of water sufficiently far to prevent loss of the floating particulates through wind or wave action. The lower edge of wall 88 is spaced outwardly from, and lower than, the upper edge of wall 86 to provide a path through which water can flow from within the space surrounded by wall 86 and beneath the floating particulate mass 87 to effect continual circulation of water.

An aqueous slurry or dispersion of the particulates is removed from the floating mass 87 by conduit 89, pump 90 and conduit 91 and conveyed to coil 82 for cooling and condensing the spent steam as previously described.

Solid materials which have already been described in conjunction with the system of FIG. 1 can be used equally well in the systems illustrated by FIGS. 2 to 5.

Although the invention has been described with particular reference to an electric generating plant it is not intended to restrict the invention to such use. The cooling system has much wider applicability whether the heat ultimately is exhausted to the air or to a body of water.

The embodiments which employ air-cooling permit a power company to choose a plant site away from water resources, often on less expensive real estate and in closer proximity to the electric consumers, thereby reducing transmission line costs. The expense of cooling water treatment facilities may be reduced and the plant may be located near to a fossil fuel source.

The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom as modifications will be obvious to those skilled in the art.

What is claimed is:

1. A process of cooling a hot liquid first material, the material being liquid at the ambient temperature, comprising:

bringing the hot liquid first material into heat exchange relationship with a particulate solid second material which is solid at the ambient temperature and which liquefies through such heat exchange, removing the liquefied second material from heat exchange with the first material, cooling and converting the removed liquefied second material into solid particulates, and recontacting the solid particulate second material in heat exchange with the hot liquid first material.

2. The process of claim 1 in which the heat exchange is effected by direct contact between the first and second materials.

3. The process of claim 2 in which the first material is water and the second material is essentially insoluble in water.

4. The process of claim 3 in which the second material has a specific gravity less than water.

5. The process of effecting heat exchange and cooling which comprises directly contacting a hot liquid first material, said material being liquid at ambient temperature, with a second material, which is solid at ambient temperature and essentially insoluble in the first

material, in solid particulate form to liquefy the second material,

separating the liquid second material from the first liquid material,

cooling and converting the separated liquid second material into solid particulate form, and recycling the solid particulate second material into contact with hot liquid first material.

6. The process of claim 5 in which the first material is hot water.

7. The process of claim 6 in which the hot water is an intermediate coolant obtained from a power generation plant.

8. The process of claim 5 in which the liquid second material has a specific gravity less than the hot liquid first material and the liquids are separated from each other by gravity.

9. The process of effecting heat exchange and cooling which comprises directly contacting a hot liquid first material, said material being liquid at ambient temperature, with a second material, which is solid at ambient temperature and essentially insoluble in the first material, in solid particulate form to liquefy the second material,

said liquid second material having a specific gravity less than the hot liquid first material, separating the liquid second material from the first liquid material by gravity into two layers, circulating the liquid first material through a power generation plant as an intermediate coolant, dispersing and cooling the second material liquid layer in air into solid particulates, and recycling the solid particulates of the second material into contact with the hot first liquid material recycled from the power generation plant.

10. The process of claim 9 in which the first material is water and the second material melts at 10°F. above the ambient air temperature.

11. The process of effecting heat exchange and cooling which comprises spraying hot water obtained as an intermediate coolant from a power generation plant into intimate contact with a second material, which is solid at ambient temperature and essentially insoluble in hot water in solid particulate form to liquefy the second material,

separating the liquid second material from the water by settling the liquids into two layers in a reservoir chamber,

cooling and converting the separated liquid second material into solid particulate form, and recycling the solid particulate second material into contact with hot water.

12. The process of claim 11 in which liquid second material from the layer thereof is removed and sprayed into a cooling tower through which air flows upwardly to cool the sprayed liquid second material into solid particulates.

13. The process of claim 12 in which the reservoir is located in the bottom portion of the tower.

14. The process of claim 12 in which the water is sprayed into contact with the solid particulate material in the cooling tower below the flow of air.

15. The process of claim 12 in which the solid particles fall downwardly countercurrent to the air flow.

16. The process of effecting heat exchange and cooling which comprises:

forming a dispersion comprising a first liquid material and a second solid particulate material dispersed in the first liquid material, said first material being liquid at ambient temperature and said second material being solid at ambient temperature and insoluble in liquid form in the first material,

feeding the dispersion in indirect heat exchange through a heat source adequate to melt the second material to thereby form a liquid-liquid mixture, separating the liquid-liquid mixture into liquid first material and liquid second material,

cooling and converting the liquid second material into solid particulate form,

recycling the solid particulate second material into contact with the separated liquid first material to reform the dispersion, and

repeating the described process.

17. The process of claim 14 in which the first material is hot water.

18. The process of claim 17 in which the hot water is an intermediate coolant obtained from a power generation plant.

19. The process of claim 17 in which the liquid second material has a specific gravity less than the hot liquid first material and the liquids are separated into two layers by gravity settling in a reservoir chamber.

20. The process of claim 19 in which the liquids are separated into two layers by gravity, the second material liquid layer is dispersed and cooled in air into solid particulates and the solid particulates are dispersed in liquid from the first material liquid layer to reform the dispersion.

21. The process of claim 17 in which the second material melts at 10°F. above the ambient air temperature.

22. The process of claim 16 in which liquid second material from the layer thereof is removed and sprayed into a cooling tower through which air flows upwardly to cool the sprayed liquid second material into solid particulates.

23. The process of claim 22 in which the solid particulates are removed from the cooling tower and dis-

persed in liquid first material withdrawn from the reservoir.

24. The process of effecting heat exchange and cooling which comprises:

feeding a dispersion comprising a first liquid material and a second solid particulate material dispersed in the first liquid material, said first material being liquid at ambient temperature and said second material being solid at ambient temperature, insoluble in and of a different specific gravity in liquid form than the first material, in indirect heat exchange through a heat source adequate to melt the second material to thereby form a liquid-liquid mixture, spraying the liquid-liquid mixture into a reservoir of the first material having a temperature low enough to solidify the second material in particulate form dispersed in the reservoir of first material, and removing particulate second material with liquid first material from the reservoir and refeeding it in indirect heat exchange through the heat source.

25. The process of claim 24 in which the second material has a specific gravity less than the first material.

26. The process of claim 25 in which the first material is water.

27. The process of claim 24 in which the heat source is a power generation plant.

28. The process of claim 27 in which the reservoir of the first material is a portion of a river or lake of fresh water.

29. A process of cooling a hot first material comprising:

bringing the hot first material into heat exchange relationship with a particulate solid second material which liquefies through such heat exchange, removing the liquefied second material from heat exchange with the first material, cooling and converting the removed liquefied second material into solid particulates, and recontacting the solid particulate second material in heat exchange with the hot first material.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,788,385 Dated January 29, 1974

Inventor(s) Terry Wayne Delahunty

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 63, "dis-persion" should be --dispersion--;
Column 7, line 18, "claim 14" should be --claim 16--.

Signed and sealed this 21st day of May 1974.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents