USE OF SILVER SURFACES TO PROMOTE DROPWISE CONDENSATION

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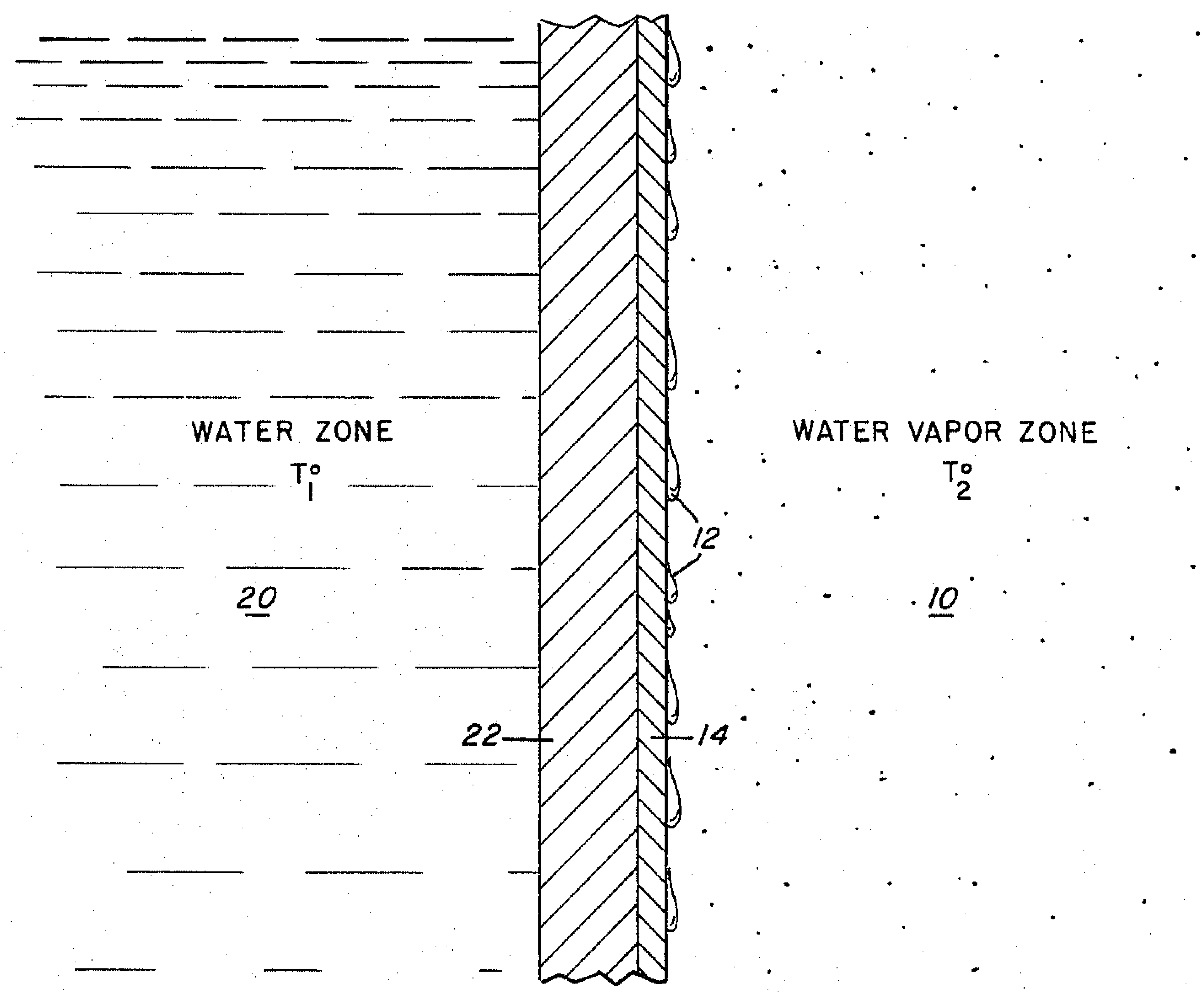

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USE OF SILVER SURFACES TO PROMOTE DROPWISE CONDENSATION

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5 Claims. (Cl. 165—133)

The invention herein described and claimed arose out of Contract Number 14–01–0001–293 with the Office of Saline Water in the Department of the Interior, entered into pursuant to the Saline Water Act, Public Law 87–295.

This invention is concerned with promotion of dropwise formation of water on the surfaces of heat transfer devices, particularly condensers.

Advantages of dropwise condensation over film-type condensation, particularly in decreased thermal resistance between vapors to be condensed and the cooling fluid, is well known in the prior art, e.g., U.S. Patent No. 2,248,909. This patent discloses the use of zirconium and tantalum to promote dropwise condensation. Other materials have also been employed for this purpose, e.g., chromium (U.S. Patent 2,259,024), oleic acid (U.S. Patent 2,919,115), resins such as polyfluoroethylene (U.S. Patent 2,923,640) and copper sulfide (Trans. A.I.Ch.E., vol 31, No. 4, December 1935, pages 593–621).

It has now been found that very effective dropwise condensation on condenser surfaces may be achieved by the use of silver as the surface on which the water condenses. This silver surface may be achieved by the use of solid silver or by coating another metal with silver.

The invention will be more fully understood when reference is made to the accompanying drawing wherein a heat transfer device according to the present invention is shown promoting the dropwise condensation of water vapor (steam). In that drawing, a water zone **20** at a temperature T_1° is in contact with an impervious partition comprising a substrate **22**, which may be a Cu-Ni alloy or steel, and a silver coating **14** which is in contact with a water vapor zone **10** having a temperature of T_2°. The temperatures of the zones are regulated so that T_1° is less than T_2°, thereby inducing condensation on the silver surface **14** which occurs in the form of drops **12**.

Silver coatings are usually achieved by means of electroplating. A base coat of nickel is usually advisable to enable the use of smaller amounts of silver. Any application technique from which a final smooth surface can

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be obtained may be employed. This could include, in addition to electrodeposition, vacuum deposition (including sputtering), chemical deposition, mechanical cladding or flame spraying.

Although distilled water was used in the examples below, the method of the invention is also beneficial in promoting dropwise condensation of vapor distilled from water containing impurities, e.g., sea water.

The invention will be more specifically illustrated by means of the following examples.

Example 1

The heat transfer apparatus used in this example consisted of a copper block having cooling water flowing through a hollowed out central portion. The block was suspended over boiling water in a heated vessel under atmospheric pressure. Attached to the block were 42 test 1 x 3 inch metal flats consisting of various test materials on different substrates, having a total thickness of about 0.05 inch. The block and flats were arranged so that the flats were disposed vertically over the boiling water. Steam arising from the boiling water condensed on the metal flats, which were in thermal transfer relationship with the cooled copper block. The water which condensed on the test flats dripped back into the boiling water.

Silver samples tested and results are given in Table 1. The silver coatings were achieved by electrodeposition. The dropwise quality, Q, defined by the following equation, has been found to give a reliable measure of the ability of a surface to promote dropwise condensation.

Q=1.0 times the percent sample area which is dropwise condensing +0.5 times the percent mixed area.

"Drop appearance" in the table is based on the following scale:

E (Excellent)—Drops have circular base line and high contact angle. Sliding drops are of small diameter.

G (Good)—Drops nearly circular ellipses. Base line convex.

F (Fair)—Drops often have base lines with straight line segments. Drops grow to large size before sliding.

P (Poor)—Drop base lines often have concave segments. Usually tracks and/or droplet residues result on sweeping. This class when seen is often a precursor to mixed condensation.

As is apparent from the data of the table, the silver surfaces exhibit dropwise condensation even after long periods of exposure to condensation.

TABLE 1.—CONDENSATION BEHAVIOR AS A FUNCTION OF TIME

Sample Type	1.5 Hrs.		1 Day		6 Days		10 Days		14 Days		17 Days		22 Days	
	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance
500 μinch Ag on 90-10 Cu-Ni alloy base.	100	G+	95	F	97.5	G−	95	G−	100	G	97.5	F+	97.5	F+
500 μinch Ag on mild steel base.	85	----------	97.5	G−	87.5	F+	87.5	G−	95	G	95	G+	97.5	G+
Control: 90-10 Cu-Ni (polished).	20	----------	0	----------	5	----------	10	----------	5	----------	0	----------	20	

Sample Type	28 Days		35 Days		42 Days		56 Days		70 Days		84 Days		98 Days	
	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance
500 μinch Ag on 90-10 Cu-Ni alloy base.	97.5	G−	97.5	F	97.5	F	97.5	F+	95	F+	95	F+	92.5	F−
500 μinch Ag on mild steel base.	90	G−	95	G−	85	G+	85	G	90	G+	90	G	90	G+
Control: 90-10 Cu-Ni (polished).	10	----------	50	----------	40	----------	25	----------	35	----------	32.5	----------	45	

Example 2

The heat transfer apparatus used in this example consisted of a pressure vessel containing distilled water in the bottom thereof and having 8 condensing tubes attached to the top plate by means of a compression fitting.

The condensing tubes were ½ inch in diameter and the condensing surfaces extended 5 inches into the pressure vessel. They were cooled by means of cooling water that flowed into a central tube concentric with the outer condensing surface, to the bottom of the condensing tube, then up in the annulus between the tubes to an outlet tube above the top plate of the pressure vessel. Inlet and outlet cooling water temperatures as well as temperature of the steam within the pressure vessel were measured by means of thermocouples.

The water in the pressure vessel was heated to produce steam at 115° C. by means of three 2000 watt silver-plated immersion heaters mounted in the bottom of the pressure vessel. Self-flushing, graduated drop-catchers were also provided within the pressure vessel for measurement of condensation rate of the water on the condensing tubes. Four electrically-heated observation windows were spaced at 90° intervals around the pressure vessel.

Results are given in Tables 2 and 3. The significance of Q and drop appearance are the same as described in Example 1. The advantages of the silver-plated surfaces in condensation characteristics and condensation rate are readily apparent from Tables 2 and 3. The superiority of silver over the chromium of the prior art is particularly noteworthy.

TABLE 2.—CONDENSATION BEHAVIOR AS A FUNCTION OF TIME WITH VERTICAL TUBE CONDENSERS

Sample Type	7 Days		21 Days		59 Days	
	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance
500 μinch Ag on 500 μinch Ni on 90-10 Cu-Ni base	100	E—	100	G+	100	E
90-10 Cu-Ni control	30	F	10	F	2.5	P
500 μinch Cr on 1,000 μinch Ni on 90-10 Cu-Ni base	2.5	F	2.5	F	1.5	P+
500 μinch Ag on Type 316 stainless steel base	100	E—	100	E—	100	E
Type 316 stainless steel control	2.5	P+	2.5	P+	1	P

TABLE 3.—CONDENSATION RATE FOR TUBE CONDENSERS AFTER 1,850 HOURS EXPOSURE TO CONDENSATION OF PURE STEAM AT 115° C.

Condensing Surface	Cooling Water Velocity at—	
	6 ft./sec.	10 ft./sec.
5 0 μinch Ag over 500 μinch Ni over 90-10 Cu-Ni	0.83	0.96
500 μinch Cr over 1,000 μinch Ni over 90-10 Cu-Ni	0.48	0.56
90-10 Cu-Ni control	0.64	0.71
500 μinch Ag over 316 Stainless steel	0.67	0.73
316 stainless steel control	0.41	0.46

The invention may be used in any heat transfer device in which heat is removed from a vapor through a heat transferring wall by means of a suitable cooling fluid, either liquid or gaseous, the vapor being condensed on the heat transferring wall. Examples of such devices are heat exchangers, evaporators, condensers, tubular heaters, tempering coils, etc.

What is claimed is:

1. In a heat transfer device comprising a liquid zone, a water vapor zone having a temperature greater than said liquid zone, means to conduct water vapor to said water vapor zone, and an impermeable partition disposed between said zones whereby mass transfer between said zones is prevented, said partition having a first surface in contact with said liquid zone and a second surface in contact with said water vapor zone, the improvement comprising utilizing silver as said second surface.

2. The device of claim 1 wherein said partition is metallic and said second surface comprises a silver coating.

3. The device of claim 2 wherein the partition is a Ni-Cu metal alloy.

4. The device of claim 2 wherein the partition is steel.

5. The device of claim 1 wherein the liquid zone contains water.

References Cited by the Examiner

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2,259,024	10/1941	Cleveland	165—133 X
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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,289,754 December 6, 1966

Robert A. Erb et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

In the sheet of drawing, the lower right-hand corner thereof, for "Richard D. Tharker" read -- Richard D. Varker --.

Signed and sealed this 26th day of September 1967.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents