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USE OF GOLD SURFACES TO PROMOTE DROPWISE CONDENSATION

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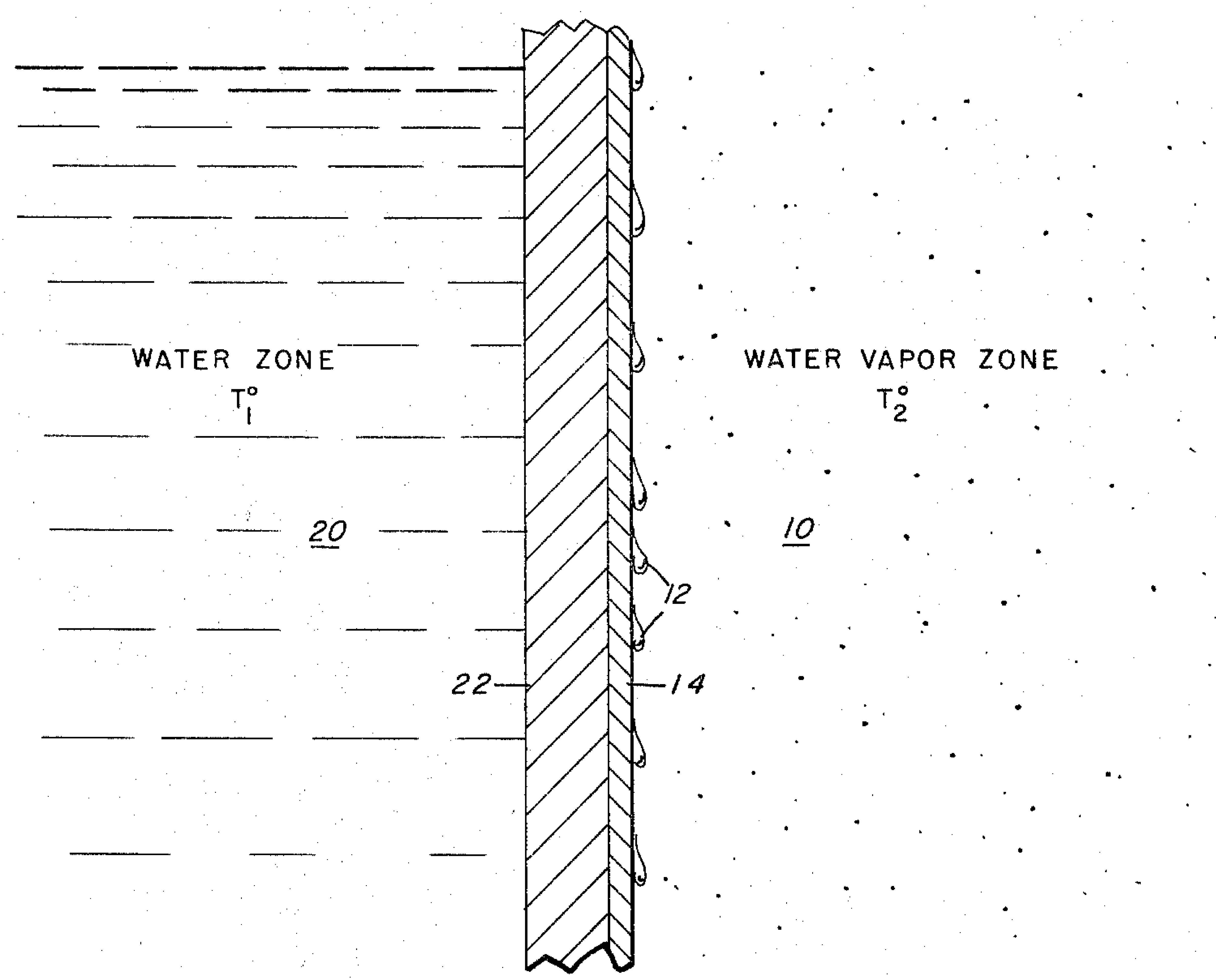

INVENTOR
ROBERT A. ERB
BY Ernest A. Cohen
ATTORNEY

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USE OF GOLD SURFACES TO PROMOTE DROPWISE CONDENSATION

Robert A. Erb, Valley Forge, Pa., assignor to the United States of America as represented by the Secretary of the Interior

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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 gold as the surface on which the water condenses. This gold surface may be achieved by the use of solid gold or by coating another metal with gold.

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 dropwise condensation of water vapor (steam). In that drawing, a water zone **20** at a temperature $T_1°$ is in contact with an impervious portion comprising a substrate **22**, which may be a Cu-Ni alloy, and a gold coating **14** which is in contact with a water vapor zone **10**, having a temperature of $T_2°$. The temperautres of the zones are regulated so that $T_1°$ is less than $T_2°$ thereby inducing condensation on the gold surface **14** which occurs in the form of drops **12**.

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

tionship with the cooled copper block. The water which condensed on the test flats dripped back into the boiling water.

Gold samples tested and results are given in Table 1. The gold flats were commercially rolled and polished sheet stock that was cleaned with detergent and rinsed with pure ethanol. The electroplated coating was aproximately 0.001 inch thick and was polished with Nos. 400 and 600 aluminum oxide and jeweler's rouge. The gold was heated in various atmospheres and made an anode in H_2SO_4 to determine the effects of such treatments on the wettability of the surface. As seen from the table, dropwise condensing characteristics were not adversely affected by these treatments. 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 in sweeping. This class when seen is often a precursor to mixed condensation.

As is apparent from the data of Table 1, the gold surfaces exhibits dropwise condensation even after long periods of exposure to condensation.

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, by means of three 2000 watt silver-plated immersion heaters mounted in the bottom of the pressure vessel. Self-flushing, graduated drop-catches 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 gold plated surfaces in condensation characteristics, condensation rate and heat transfer coefficient are readily apparent from Tables 2 and 3.

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.

TABLE 1.—CONDENSATION BEHAVIOR AS A FUNCTION OF TIME

Sample Type	1 Hr.		1 Day		11 Days		32 Days		40 Days		47 Days		56 Days		69 Days		90 Days	
	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance
Gold, polished	100	E	100	E—	97.5	F+	97.5	G	100	G—	97.5	G+	97.5	E—	97.5	E—	80	G
Gold, heated in N_2 to 600° C	100	E—	100	G+	95	F	97.5	F+	100	F—	95	G—	87.5	G+	65	G	67.5	G+
Gold, heated in O_2 to 600° C	100	G+	100	G+	95	F	97.5	G—	100	G—	100	G+	92.5	G	97.5	G+	75	G+
Gold, anode in H_2SO_4 solvent	100	G+	100	G+	95	F+	97.5	G	100	G+	100	G	97.5	G+	97.5	E—	95	G+
Gold plate on 90–10 Cu-Ni	100	F+	95	F+	95	F+	100	G	100	G—	97.5	G—	95	E	97.5	G+	80	E
Control, uncoated 90–10 Cu-Ni	20	-------	0	-------	10	-------	30	-------	40	-------	35	-------	25	-------	35	-------	37.5	

TABLE 2.—Dropwise Condensation Characteristics of Condensing Tube Surfaces as a Function of Time

Sample Description	0.5 Hour		48 Hours		408 Hours (17 Days)		2,000 Hours (83 Days)	
	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance	Q	Drop Appearance
30 µin. Au over 200 µin. Ni over 90–10 Cu-Ni base	100	G	100	G+	100	E—	100	E
50 µn. Au over 300 µin. Ni over 90–10 Cu-Ni base	95	F+	100	E	100	E—	100	E
90–10 Cu-Ni control	85	F	40	P+	15	P+	5	

TABLE 3.—Condensation Rate and Heat Transfer Characteristics of Tube Concensers After 2000 Hours Exposure to Air-Free Steam Followed by 41 Hours Exposure to Steam Containing 0.3% O_2. Inlet Water Temperature: 28° C. Steam Temperature: 114.5° C.

Sample Description	At 6 ft/sec Cooling Water Velocity		At 10 ft/sec Cooling Water Velocity	
	Condensation Rate (cc./sec.)	Heat Transfer Coefficient (B.t.u./hr./sq. ft./° F.)	Condensation Rate (cc./sec.)	Heat Transfer Coefficient (B.t.u./hr./sq. ft./° F.)
300 µin. Au over 200 µin. Ni over 90–10 Cu-Ni base	0.67	690	0.80	930
50 µin. Au over 300 µin. Ni over 90–10 Cu-Ni base	0.72	740	0.91	1120
500 µin. Cr over 1,000 µin. Ni over 90–10 Cu-Ni base	0.49	580	0.55	690
90–10 Cu-Ni control	0.48	540	0.56	750

What is claimed is:

1. In a heat transfer device comprising a liquid zone, a water vapor zone having a temperature greater than that of 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 employing metallic gold as said second surface.

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

3. The device of claim 2 wherein said metallic partition comprises a Cu-Ni alloy.

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

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MEYER PERLIN, *Primary Examiner.*

ROBERT A. O'LEARY, *Examiner.*

N. R. WILSON, *Assistant Examiner.*