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METHOD AND APPARATUS FOR CONTINUOUS VAPORIZATION OF LIQUIDS

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21 Claims

ABSTRACT OF THE DISCLOSURE

Material to be vaporized is deployed as a film forming a sheath about the turns of a vertical heating coil having the property of being wet by the liquid. The sheath is maintained by causing globules of the liquid to periodically travel down the coil. Liquid from the traveling globules distributes itself about the turns to replenish the sheath as liquid is vaporized.

This invention relates generally to the vaporization of materials by heating. More particularly, the invention relates to substantially continuous vaporization by electrical heating and has particular application to liquid metals such as molten copper and aluminum.

Essentially, the invention comprises means for specially discharging liquid from a container and for specially conveying the discharged liquid so as to be specially heated, the discharged liquid thereby being partly or wholly vaporized.

One main use of the invention is in vaporizing metals for the manufacture of foil or the coating of strip. Another main use is in vaporizing liquids for purification by distillation process. Another main use is in producing vapor for vapor heating purposes.

The chief advantages of the invention are in the simplicity, controllability and efficiency with which large quantities of heat are continuously furnished to liquids so as to continuously produce copious vapor.

These above and other features, uses, advantages and objects of the invention will be understood from the following sections of the disclosure of which:

Section I is an account of well known factors generally affecting vaporization;

Section II is an account of well known factors particularly affecting high rate vaporization for foil manufacturing and strip coating purposes; and

Section III is a description of preferred embodiments of the invention.

(I) Well known factors affecting vaporization

All materials have more energy in vapor form than in liquid form. The difference between the liquid and vapor energies is commonly termed "heat-of-vaporization." For example, a pound of copper vapor has about one kilowatt hour more energy than a pound of molten copper at the same temperature, which is to say the heat-of-vaporization of copper is about one kilowatt hour per pound. The heat-of-vaporization of a material is largely independent of temperature, atmospheric pressure or indeed anything else other than the inner physical nature of the material itself. Generally, the heat-of-vaporization of a material is many times greater than the specific heat, specific heat being a measure of the energy required to raise the temperature of the material. For example, the ratio of heat-of-vaporization (energy to vaporize one pound) to specific-heat (energy to raise one pound one degree centigrade) is about 500 to 1 for water and about 10,000 to 1 for copper.

When a liquid is supplied with energy, for example by heating, this energy is used up in three ways. Firstly,

energy goes into the liquid as specific-heat and raises the temperature; secondly, energy goes into the liquid only to come out again as heat loss to the surroundings; and thirdly, energy goes into the liquid as heat-of-vaporization and vaporizes liquid. Now as the temperature of a liquid increases so does the rate of heat loss and so does the rate of vaporization. Accordingly, in response to being steadily supplied with energy, a liquid increases in temperature up to the point that the rate of heat loss and the rate of vaporization have increased sufficiently to account entirely for the energy being supplied. At this equilibrium point there is then a steady heat loss to the surroundings and a steady issuance of vapor, the temperature remaining constant. This temperature, at which heat loss and vaporization entirely account for energy being supplied, is termed, for the purposes of this discussion, the "vaporization-temperature."

It follows from the above that the factors mainly determining vaporization-temperature are (a) the energy input, (b) the heat-of-vaporization, (c) the heat loss, (d) the relationship between rate of heat loss and temperature, (e) the relationship between rate of vaporization and temperature. The first four of these five factors will be already more or less understood, but the fifth factor—the relationship between rate of vaporization and temperature—warrants further explanation as follows:

As already stated, the amount of energy needed to vaporize a pound of liquid depends little upon the atmospheric condition surrounding the liquid. On the other hand, the temperature which a liquid must attain in order to vaporize at a particular rate depends almost wholly on atmospheric condition. The reason for this is that rate of vaporization is determined not only by how much vapor leaves the liquid in a given time but also by how much vapor returns to the liquid in the same time, and how much returns depends upon the atmospheric condition. In this respect two different attributes of the atmosphere are important. On one hand, the pressure of the atmosphere is significant, the greater the pressure the more vapor molecules being returned by collision with atmosphere molecules and hence the lower the vaporization rate at a given temperature. On the other hand, the composition of the atmosphere is significant, particularly insofar as containing vapor identical with that the liquid is issuing. The more of this identical vapor the atmosphere contains, irrespective of course of whether this vapor came from the liquid itself or anywhere else, the more will find its way into liquid so as to reduce the netrate of vaporization at a given temperature.

From the above it follows that in the case of vaporization into what is commonly termed a "vacuum atmosphere" the dominant factor in determining rate of vaporization at a particular temperature is the atmosphere afforded by the vapor itself as it issues from the liquid. This is to say, even through the vaporization is accomplished in the virtually complete absence of any atmosphere other than the issuing vapor itself, high vaporization rates are generally obtained only at high equilibrium temperatures. This is to say also, as a practical matter, that when high-rate vaporization is undertaken in a vacuum tank, the pressure commonly referred to as "tank pressure"—usually a small fraction of a millimeter of mercury—is of little significance in determining the vaporization temperature. For example, in the vacuum vaporization of aluminum which melts at about 650° C., commercially useful vaporization rates may well require temperatures in excess of 1500° C. despite a tank pressure of less than one ten thousandths of a millimeter of mercury.

It will by now be understood that high powers at high temperatures are generally required for rapid vaporiza-