June 15, 1971 K. HILTON ET AL 3,584,389

PRINT DRYING

Filed Feb. 3, 1969 2 Sheets-Sheet 1

FIG.1.

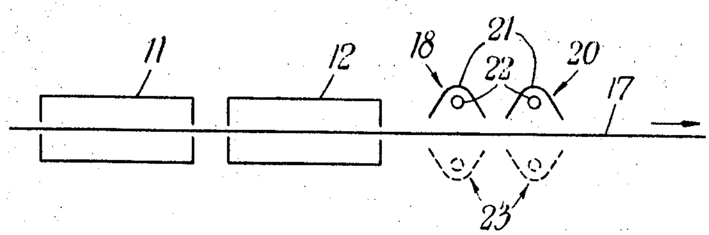
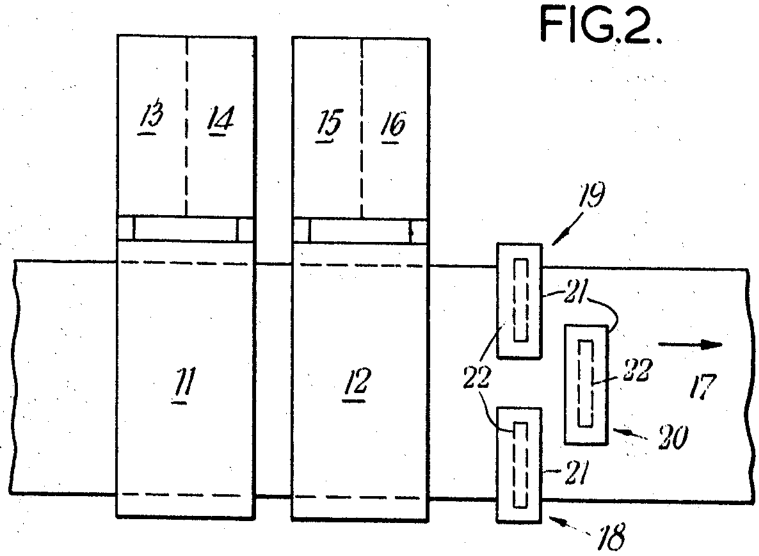


FIG.2.



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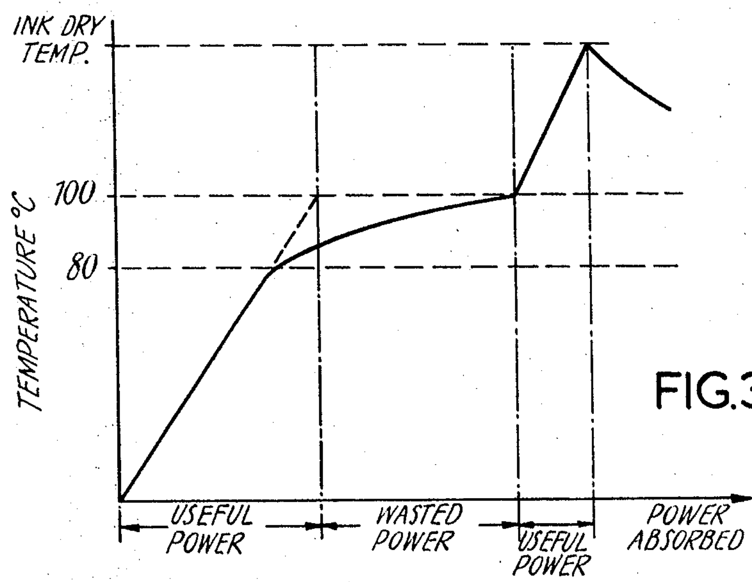

FIG.3.

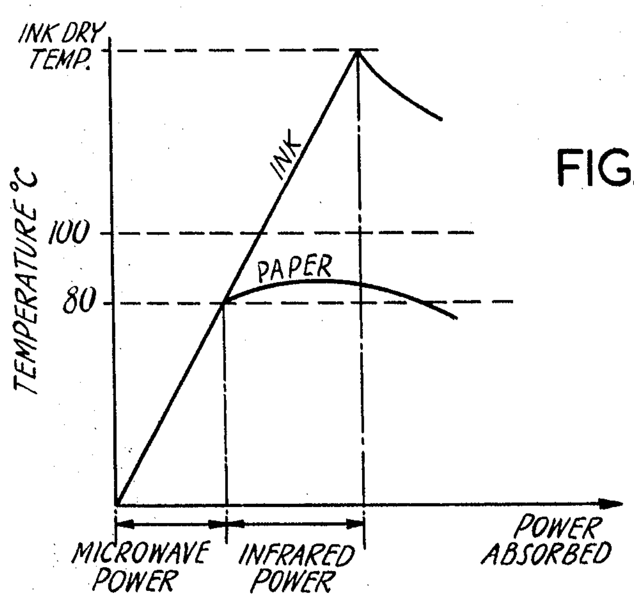

FIG.4.

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PRINT DRYING

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ABSTRACT OF THE DISCLOSURE

The invention relates to method and apparatus for heating a dielectric member, such as for drying printing ink on paper, in which both microwave and infra-red radiation are used for heating. This enables a uniform rise in the temperature of the surface of the member, e.g. the coating up to the required temperature, e.g. the ink drying temperature, to be achieved.

This invention relates to heating dielectric members such as for drying a coating, e.g. printing ink, on a member, e.g. paper, which has an appreciable water content.

It is known to dry printed matter on paper by means of microwave energy applied by passing the paper through a serpentine slotted waveguide as described in British patent specification No. 1,050,493, for example; and this is effective with inks which dry at temperatures not greater than about 80° C. However, other considerations than drying temperature have to be taken into account when formulating inks, and normal printing inks dry at temperatures above 100° C. If ink temperatures in excess of 100° C. are to be achieved solely by microwave heating of paper on which the ink is printed, the heating must first vaporise the water content of the paper, and this is disadvantageous for two reasons. Firstly, the substantially complete drying of the paper itself consumes energy which is "wasted," inasmuch as it would be saved if the ink temperature could be raised above 100° C. without the paper temperature rising substantially above 80° C. Secondly, the evaporation of the water from the paper takes place at the paper/ink interface, and not only holds the ink temperature down until evaporation is complete, but also tends to reduce the adhesion of the ink on the paper surface.

On the other hand, if the ink is dried by infra-red heating alone, a long drying time (and thus a long drier, if the printed paper being dried is being moved continuously through the drier) is required, partly because of the "heat sink" effect of the paper and partly because the exposed ink surface dries fastest and tends to become sealed, thus slowing down the release of solvents from within the ink.

This problem, although described with respect to drying print, may exist in any situation in which it is desired to heat the surface of or a coating on the surface of a member to a temperature higher than the temperature to which it is desired to raise inner portions of the member.

The present invention proposes to solve the problem by a method and apparatus in which both microwave heating and infra-red heating are utilised.

An embodiment of print-drying apparatus according to the invention is described below with reference to the accompanying drawings, in which:

FIGS. 1 and 2 are respectively a schematic side elevation and a schematic plan view of apparatus according to the invention,

FIG. 3 is a graph representing the consumption of power, in a known print-drying apparatus, by a freshly printed moisture-containing sheet, and

FIG. 4 is a graph representing the consumption of

power, by a similar sheet, in print-drying apparatus according to the invention.

The illustrated embodiment of print-drying apparatus, as shown in FIGS. 1 and 2, comprises two serpentine slotted waveguides **11** and **12**, each fed at both ends by a pair of magnetrons **13, 14** and **15, 16** respectively, as described in our co-pending application No. 710,804. A web **17** of printed paper on which the print is to be dried passes, from left to right in FIGS. 1 and 2, through these slotted waveguides in succession, and thereafter passes under three infra-red heaters **18, 19** and **20** disposed, as shown in FIG. 2, to span the whole width of the web **17**. As shown, each infra-red heater comprises a parabolic reflector **21** and a linear heater element **22** disposed along the focal axis of the reflector, and the part of the web **17** under a given heater at any moment is thus subjected to substantially uniform radiation per unit area.

FIG. 3 shows schematically the effect of heating, with microwave energy only, and at constant power, a sheet of moisture-containing paper carrying undried printing ink whose drying temperature is above 100° C. Initially, and until a temperature of about 80° C. is reached, the temperature of the paper and of the ink rises linearly, proportional to the power absorbed (mostly by the paper, the ink being heated principally by conduction). Between 80° C. and 100° C., the ink and paper temperature rises much more slowly, since much of the absorbed power is used in vaporising water contained in the paper, and 100° C. is reached only when virtually all the water has been vaporised. Thereafter, the temperature of the ink and of the paper again rises at a steeper rate (not necessarily the same as the rate below 80° C.), proportional to the absorption of power, until the temperature at which the ink dries is reached. The power is then shut off, and the temperature of the dried ink and paper falls again. The relative flatness of the portion of the curve between 80° C. and 100° C. represents waste of power in removing water from the paper.

FIG. 4 shows schematically the different situation which obtains when ink carried on a similar moisture-containing sheet is dried in accordance with the present invention. Initially, the paper and ink are heated, at substantially constant rate, to a temperature of about 80° C. by means of the slotted waveguides **11** and **12**. By suitable adjustment of the power output of the magnetrons **13, 14** and **15, 16**, or of the speed at which the web **17** is passed through the waveguides, it can be arranged that the web emerges from the waveguide **12** with the desired temperature of about 80° C. The infra-red radiation from the heaters **18, 19** and **20** is absorbed principally by the ink rather than by the lighter coloured paper, in which also the infra-red penetration depth is small, with the result that the paper temperature does not rise substantially above 80° C., whereas the ink temperature continues to rise steeply so that it achieves the drying temperature of the ink before emerging from under the infra-red heaters. In this case, the ink has been dried without substantial consumption of energy to remove water from the paper, though the total drying time has been minimised by initial rapid microwave heating of the ink and paper up to 80° C.

The improved drying obtained by use of the invention may be exemplified by reference to the drying of paper, 36 inches wide and weighing about 52 grammes per square meter, printed with four colours simultaneously on one side.

If the drying were effected by means of infra-red heating alone, at 12 kw., the maximum permissible speed of the web through the heater would be less than 50 feet per minute. If the drying were by means of microwave energy alone, at 20 kw., the maximum permissible speed of the web through the microwave heater would be about 500 feet per minute. If the two heating means are combined according to the invention, however, so that the web is subjected first to a 20 kw. microwave heating and then immediately to a 12 kw. infra-red heater, a web speed through the heaters of as much as 1000 feet per minute is possible. It may be remarked, in this connection, that 20 kw. and 12 kw. approximate to 3:2, which is found in practice to be the optimum ratio of microwave power to infra-red power; though the optimum ratio may depend to some extent on the inks and papers used, and in particular on the water content of the paper.

It will be understood that, if the web is printed on both surfaces, extra infra-red heaters **23**, shown in broken lines in FIG. 1, are provided for heating the ink on the second surface.

Furthermore a similar graph to that shown in FIG. 4 can be obtained for coatings other than ink on dielectrics other than paper, and for the surface and inner portions of a dielectric. In the latter case, the curve for the temperature of the surface would be similar to that shown for the ink in FIG. 4 and the curve for the temperature of the inner portion of the dielectric similar to that for the paper in FIG. 4.

Hence the term "surface" is used in the following claims to mean both the surface proper of a dielectric or a coating thereon, when provided.

What we claim is:

1. Apparatus for heating a dielectric member having liquid absorbed therein comprising a conductive walled vessel for receiving the member, a microwave generator connected to the vessel for supplying microwaves thereto to heat the member, and a device for producing infra-red radiation, the vessel and the device being arranged to define a path along which the member can move and being disposed, with respect to the path, such that the member is heated sequentially by microwaves and infra-red radiation, and means for moving said member along said path at a speed such that said microwaves heat inner and outer zones to said member substantially uniformly up to a temperature at which said absorbed liquid may begin substantial vaporization and said infra-red radiation heats outer zones of said member beyond said temperature.

2. A method of heating a dielectric member having liquid absorbed therein comprising subjecting the member to microwave energy for a period sufficient to heat the member substantially uniformly in inner zones and surface zones to a temperature in the region of that at which substantial vaporization of said liquid may occur, thereupon discontinuing the subjecting of the member to said microwave energy and thereafter subjecting the member to infra-red radiation to continue the heating of the surface zones of said member beyond said temperature.

3. A method of drying a liquid coating provided on a dielectric member having moisture absorbed therein, comprising subjecting the member with the coating thereon to microwave energy for a time sufficient to heat the member and the coating to a temperature in the region of that at which substantial evaporation of said moisture may begin and thereafter subjecting said member to infra-red radiation to continue the heating of said coating to a higher temperature.

4. A method of drying a coating printed upon a web of dielectric material containing moisture absorbed therein, said coating having a drying temperature higher than the temperature at which said moisture evaporates, said method comprising subjecting the web with the coating thereon to microwave energy to heat the web and the coating to a temperature in the region of that at which substantial evaporation of said moisture from said web may begin to occur, thereupon terminating the subjecting of said web with the coating thereon to said microwave energy and thereafter subjecting said web with said coating thereon to infra-red radiation to continue the heating of said coating to said drying temperature.

5. A method according to claim **4**, wherein said coating is printing ink.

6. A method according to claim **5**, wherein said web is paper.

7. A method according to claim **4**, wherein the temperature of said coating increases at substantially the same rate during the subjecting of the web to the microwave radiation and to the infra-red radiation, and wherein said rate of increase is substantially uniform until the coating reaches said drying temperature.

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CHARLES SUKALO, Primary Examiner