Dec. 15, 1953 J. B. CUNNINGHAM ET AL 2,662,302

METHOD AND APPARATUS FOR DRYING FILM BY DIELECTRIC HEATING

Filed Feb. 7, 1950

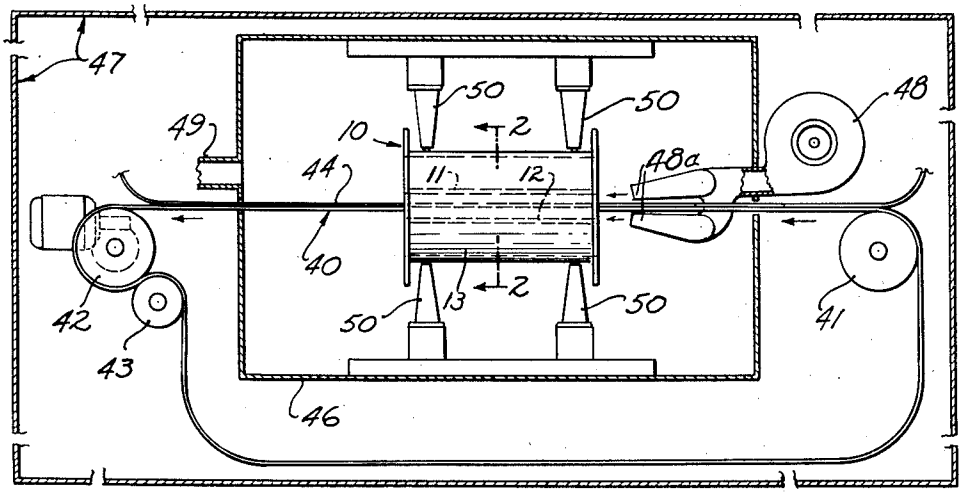



Fig. 1.

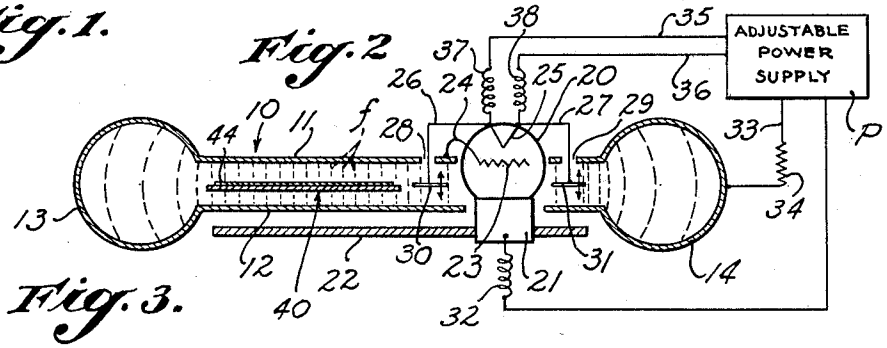



Fig. 3.

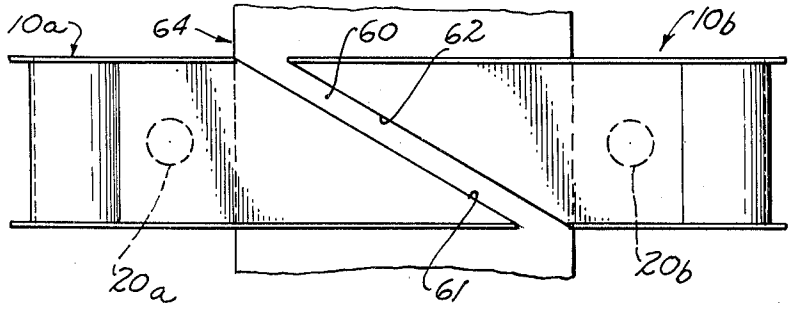
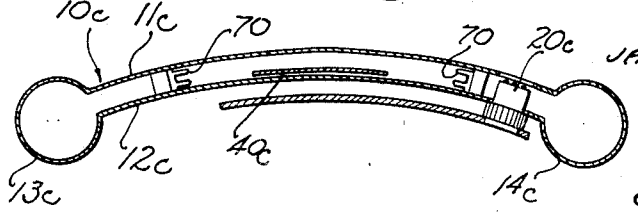



Fig. 4.




JACK B. CUNNINGHAM
FRANK WILBURN
INVENTORS

BY Forrest J. Lilly

ATTORNEY.

Patented Dec. 15, 1953

2,662,302

# UNITED STATES PATENT OFFICE

2,662,302

## METHOD AND APPARATUS FOR DRYING FILM BY DIELECTRIC HEATING

Jack B. Cunningham, North Hollywood, and Frank Wilburn, Burbank, Calif.; said Wilburn assignor to said Cunningham

Application February 7, 1950, Serial No. 142,774

2 Claims. (Cl. 34—1)

1

This invention relates generally to methods and apparatus for drying photographic film, or other substances or articles which can take advantage of the heating and drying conditions provided by the invention; and it relates more particularly to a drying process and apparatus for film and the like using uniform, high-intensity ultra high frequency dielectric fields created by novel cavity resonator apparatus.

In the art of dielectric heating it is generally recognized that the amount of heat generated in the load (the substance to be heated or dried) increases with the frequency. We have found that ultra high frequency energy, of the order of 90 megacycles, is especially useful, when properly applied, in the heating and drying of thin films, such as photographic film consisting of a photographic emulsion on the usual base, e. g., cellulose acetate, cellulose nitrate, or paper.

The proper application of this high frequency energy involves the factors of high energy or field intensity, and uniformity of field. We have found that a special type of ultra high frequency cavity resonator can be adapted for this purpose by opening two sides thereof and making provision for continuous travel of the film stock through the resonator on a continuous conveyor belt which passes through the two side openings of the resonator.

It is known in the art dealing with cavity resonators that openings in the sides thereof are sources of energy radiation, and therefore represent substantial energy dissipation, and it is also known that the efficiency and effectiveness of a cavity resonator depends upon minimization of such energy dissipation.

It is accordingly one major object of the invention to provide a cavity resonator having open sides for entrance and exit of the material to be heated, which will nevertheless have good oscillation characteristics and sufficient energy in the dielectric field to assure the availability of the high heat that is wanted.

A further object is the provision of a new and improved manner of coupling a high frequency generator to the resonator cavity.

The present invention, insofar as film drying is concerned, is directed more particularly to the drying of the emulsion during the original manufacture thereof, though, of course, it may also be employed in film processing as well. In the manufacture of photographic film, the emulsion is spread by conventional methods in a thin layer on the usual base, which may be a cellulose acetate or cellulose nitrate film, or paper. The present invention may be employed with advantage with any size film stock, but is especially useful for particularly wide stock, as for example up to 42" in width.

2

We have found that a superior film product, one of greater silver grain sensitivity, more uniform grain distribution, greater grain concentration, and flatter and more perfect final physical form, results from our process of drying by passing the film through the cavity resonator of the invention, with temperatures controlled as presently to be set forth. We find, for example, that the high uniform heat produced by the resonator flows and smooths out the emulsion, and functions to distribute the silver granules more uniformly in the emulsion. This permits the use of an increased concentration of silver granules, and hence results in an emulsion not only of increased uniformity, but of increased sensitivity.

A feature of the invention is that the emulsion substance, which may be of any conventional type, is applied to the film base at a room temperature preferably slightly above freezing. The film is then run through the cavity resonator in an air conditioned room, maintained at a predetermined low humidity level, and the speed of the conveyor belt carrying the film through the resonator, and the power on the resonator, are so regulated as to increase the temperature of the film rapidly from around 32° to 165° F. The belt speed is preferably about 120 feet per minute, though this is of course subject to wide modification. The suddenly applied high heat, of uniform concentration, drives off the moisture and other volatile constituents at a rapid rate, and the deep, "through" penetration of the heat produced by the high frequency dielectric field assures that the inside regions of the film will be heated and dried as effectively as the outside surfaces. Thus we avoid the surface drying and "case hardening" characteristic of conventional drying processes, which, as is well known, tend to cause surface shrinkage, and consequent curling and warping of the film. The film product of our drying process comes out with substantially perfect flatness.

It is actually desirable, in practice, to leave from two percent to fifteen percent by weight of moisture in the film, since if dried out to a greater degree, it will re-absorb moisture from the atmosphere to that extent. Accordingly, in practice, the power on the resonator and the speed of film travel are so regulated that the volatiles and moisture will be sufficiently driven off, but with from two percent to fifteen percent of moisture allowed to remain.

As mentioned above, the heat and speed of film travel are so regulated as to rapidly carry the film from near freezing up to 165° F. Any higher temperature has a deleterious effect on the emulsion, materially reducing its sensitivity. Accordingly, a temperature of about 165° F. being the maximum, the drying process in accordance with the invention contemplates a reduced starting temperature, so that a long temperature range will be obtained. With the emulsion applied to the film base at around freezing, it holds only a relatively small proportion of moisture at the outset. By then starting it through the drying process while continuing to hold the room atmosphere at the same reduced temperature, the emulsion can be carried through the expanded temperature range of from 32° to 165°, giving a maximum opportunity to drive off volatiles and moisture.

The invention will be more fully understood by referring now to the following detailed description of a preferred embodiment thereof, reference for this purpose being had to the accompanying drawings, in which:

Figure 1 is a diagrammatic side elevational view of a film dryer in accordance with the invention;

Figure 2 is a diagrammatic section taken on line 2—2 of Figure 1, showing only the cavity resonator portion of the apparatus, together with external electric circuiting therefor;

Figure 3 is a plan view of a modified cavity resonator; and

Figure 4 is a side elevational view of another alternative form of cavity resonator in accordance with the invention.

Referring first to Figures 1 and 2, numeral **10** designates generally a modified re-entrant type of cavity resonator, or a medial section of a doughnut type of cavity resonator, having relatively close spaced condenser plates or plate portions **11** and **12**, and inductor loops in the form of open-ended end lobes or boxes **13** and **14**, preferably hollow cylinders whose interior diameter is about three times the spacing distance between plates **11** and **12**. The lobes **13** and **14** are integrally joined to the plates **11** and **12**, and while conveniently in the form of cylinders, they might consist of rectangular boxes, or have other forms. Also, while the lobes **13** and **14** are here shown with open ends, this is not to be regarded as essential though it is necessary that the resonator be open at each side between the plates **11** and **12** in order to provide for passage of the film. Without intention of limiting the invention, we have found that, for a film width of 9½", the resonator **10** may be of about 48" in length, and about 12" in width, and that the plates **11** and **12** may be spaced 1½", and the cylinders **13** and **14** have an inside diameter of 9". Such a resonator will oscillate, when loaded, at around 90 megacycles.

A novel form of high frequency generator is employed for driving the oscillator, comprising a high frequency oscillator tube **20** (Machlett ML 5530), whose anode **21** is seated in capacity plate **22** positioned parallel to and close spaced below resonator plate **12**, and whose anode and bulb are accommodated by suitable apertures in the plates **11** and **12**, as clearly shown in Figure 2. The grid **23** of tube **20** is connected by short lead **24** to resonator plate **11**, and the two terminals of filament **25** by short leads **26** and **27** passing through small apertures **28** and **29** in plate **11** to reach small condenser plates **30** and **31**, respectively, positioned parallel to and about half way between the plates **11** and **12** on opposite sides of tube **20**. These condenser plates **30** and **31** are to be understood as arranged through any suitable means, not shown, for adjustment movement between the plates **11** and **12**, as indicated by the arrows.



The letter P designates conventionally any suitable adjustable power supply unit, adapted to supply a suitable high voltage through RF choke **32** to anode **21**, a suitable grid bias voltage through lead **33** and grid bias resistor **34** to lobe **14**, and filament heating current through leads **35** and **36** containing filter chokes **37** and **38** to the terminals of filament **25**.

The circuit as thus described is basically the old ultra audion circuit in which plate-to-filament capacity is the inter-electrode plate-to-filament capacity of the tube. In order to increase the plate-to-filament capacity to allow sufficient grid coupling to maintain oscillations, additional capacity is introduced externally of the tube, which in this instance comprises the novel use of the adjustable condenser plates **30** and **31** placed in the electric field between the plates **11** and **12**, and therefore coupled to the capacity plate **22** connected to the anode and placed at close spacing to the plate **12**. It will be seen that the grid bias voltage is applied to the grid by way of the lead **33**, lobe **14**, plate **11** and lead **24**, while suitable anode coupling and filament-grid phasing is obtained by the adjustable condensers **30** and **31** within the electric field of the resonator to establish oscillations at the desired frequency.

In operation, a concentrated high intensity uniform field is established in the center section of the resonator between the plates **11** and **12** owing to the oscillatory system, the field being at right angles to and extending between the plates **11** and **12** as indicated by the dashed lines *f*.

Any dielectric article to be rapidly dried or heated can be placed in this field, or passed continuously therethrough. As here shown, an endless conveyor belt **40** is arranged to pass through the electric field between the plates **11** and **12** of resonator **10**, this belt passing first over an idler roll **41** located at one side of the resonator, thence through the resonator to a motor driven roll **42**, being then passed around idler roll **43** which holds it in proper engagement against the periphery of roll **42**. Returning from roll **43** to roll **41**, the belt loops down and hangs below the apparatus as clearly indicated in the drawings. Any type of belt capable of withstanding the high heat within the resonator may be employed, though we prefer to use a silicone rubber belt, which is well able to stand up under the high heat conditions imposed. The film, designated generally by numeral **44**, is carried through the resonator on this belt **40**, as clearly indicated in Figures 1 and 2. As shown best in Figure 2, the belt **40** and film **44** occupy a medial plane between the resonator plates **11** and **12**, and pass through that portion of the center section of the resonator between the condenser plate **30** and the lobe **13**. As it is important to be able to regulate the speed of travel of the film in passing through the resonator, a variable speed drive motor is employed, or alternatively, a variable speed drive may of course be employed between a constant speed motor and the drive roller.

Figure 1 indicates diagrammatically at **46**, the outlines of an exterior housing which may be employed to enclose the resonator **10**, and as will be seen, this housing is located between the infeed

and takeout rolls 41 and 42, suitable apertures for the belt being of course provided. In the event that a refrigerated atmosphere is desired, and it is not feasible to refrigerate the entire room, indicated in Figure 1 by the numeral 47, merely the interior of this housing 46 need be refrigerated. Any suitable refrigerating apparatus, not shown, may of course be employed. Also, either the entire room 47, or alternatively merely the housing 46, may be air or gas conditioned—that is to say, maintained at some predetermined low humidity level. Thus, the room 47 might contain either air at a predetermined degree of dryness, or some inert gas, as helium. As shown in Figure 1, a blower 48 circulates and directs gas from the conditioned room 47 through one end of housing 46, to be discharged towards the open space between the plates 11 and 12 by flattened or fan-like nozzles 48*a*, so as to direct the gas through the electric field of the resonator, and this gas is then discharged at the opposite end of the housing by way of the outlet 49. Thus a continuous circulation of drying atmosphere is maintained through the housing 46, and in particular through the electric field of the resonator where the film is undergoing drying, carrying away volatiles and moisture exaporated from the film. Any suitable means may of course be employed for these purposes, and may readily be supplied by those skilled in the art.

The return stretch of belt is indicated as passing below the housing 46. Any suitable supporting means for the housing may of course be employed, and since such features form no part of the present invention, they may be omitted from the present disclosure. Also, the resonator will be understood as mounted in any convenient or suitable fashion inside the housing 46, and while the details of such mounting means are also optional and well within the skill of the art, such details are omitted from the present disclosure. Figure 1 of the drawings does diagrammatically indicate, however, the use of insulator 50 for the support of the resonator at its lobes.

In some cases, with film of great width, as of the order of 42'' or greater, it becomes difficult to maintain the oscillation of the resonator at the large scale which is called for, and for such cases, a resonator of the type as disclosed in Figures 1 and 2 may be made to large scale, but severed into two individual resonators 10*a* and 10*b* which will oscillate readily by simply cutting the center section along a vertical diagonal plane, and moving the two halves a few inches apart (Figure 3). Thus, with reference to Figure 3, which is a plan view of such a resonator as has been described in connection with Figures 1 and 2, the center plate portions are formed with a diagonal gap 60, typically of a few inches of width, and it being understood that the gap extends in a vertical diagonal plane, so that the upper and lower center plates of resonator 10*a* terminate along a vertical diagonal plane 61, while the center plates of resonator 10*b* terminate along a vertical diagonal plane 62, said planes being parallel to and spaced from one another by a matter of a few inches. In this instance, the two halves of the original resonators resulting from severing along the diagonal plane become two individual resonators, which must be individually driven. Each, therefore, has its own high frequency generator, which may be of the same type as illustrated in Figure 2. The plan view of Figure 3 accordingly shows the two high frequency generator tubes, indicated at 20*a* and 20*b*, and it is to be understood that each of said tubes is mounted in its corresponding resonator, and provided with circuit connections to the resonator and to a power supply unit according to the method illustrated in Figure 2. The conveyor belt and film are shown in Figure 3 in dot-dash lines at 34, and will be seen to pass through the center section of the resonator between the generator tubes 20*a* and 20*b*.



Each of the two resonators 10*a* and 10*b* of Figure 3 will resonate individually, forming the same type of transverse electric field between their two center plates. It should be clear that any point on the film passing through the resonator will be outside the electric field while it passes through the gap 60, but that all points on the film will be within the gap region for the same distance of travel, and hence for the same period of time, and that uniform heating is therefore accomplished for the full width of the film. The divided or dual resonator embodiment of Figure 3 thus accommodates wider lengths of film than can readily be handled by the simple embodiment of Figures 1 and 2, the embodiment of Figure 3 differing from that of Figures 1 and 2 only in that the center section is divided by a diagonal gap, and in that the two halves so formed require to be separately driven.

According to our film drying process utilizing the above described resonators, the emulsion is first applied by conventional methods to the film base, in a room maintained at a reduced temperature, preferably just above freezing. The film is then run through the resonator, with surrounding atmospheric temperatures maintained at 32° F., or thereabouts. This can either be accomplished by reducing the room temperature, or reducing merely the temperature of the atmosphere within the resonator housing. In any case, the film at a temperature of around 32° F. is, after application of the emulsion, run at the reduced temperature into the resonator. The speed of travel of the film through the resonator, and the power on the resonator, are so controlled and correlated that the film is raised to a temperature approximating 165° F., or at least not substantially in excess of that temperature, by the time the film leaves the resonator. This treatment rapidly drives off the volatiles, reduces the moisture to the necessary degree, further distributes the silver grains in the emulsion, and uniformly dries the film base as well as the emulsion layer so that the usual curl and warping does not occur. A flatter film product, of greater uniformity and improved sensitivity, is obtained by this process. The process has one very important result, in that the application of the high frequency electric energy is found to thoroughly sterilize the film, effectively and completely killing all fungi in the emulsion. It is a known fact that fungi in the emulsion attacks and destroys the emulsion, particularly in tropical climates. The present drying process eliminates this source of film deterioration.

Figure 4 is a further alternative embodiment, wherein the resonator 10*c* has the usual lobes 13*c* and 14*c*, but wherein the center section is made up of plates 11*c* and 12*c* which are curved to accommodate a curved article to be heated. In this instance, the illustrative articles to be heated and dried are plastic coat hangers carried by a curved conveyor belt 40*c*, and guided at the ends by ceramic guides 70. Aside from these innovations to adapt the device to a curved article to be heated and dried, the resonator may conform to

the teachings of Figures 1 and 2, and no further discussion is believed necessary.

We have now disclosed the invention in a typical preferred form, but it will be understood that many variations and modifications are possible, and the invention is accordingly to be limited only in accordance with a fair interpretation of the following claims.

We claim:

1. The method of film drying that includes: initially reducing the film to be dried to substantially a temperature of 32° F., and continuously passing said film through the electric field of a high frequency cavity resonator at a rate of speed to increase the temperature of said film while passing through said resonator to a final value which is substantially in excess of normal atmospheric temperature but below the temperature at which the film is adversely affected.

2. The method of film drying that includes: initially reducing the film to be dried to substantially a temperature of 32° F., continuously passing said film through the electric field of a high frequency cavity resonator at a rate of speed to increase the temperature of said film while passing through said resonator to a final value substantially in excess of normal atmospheric temperature but below the temperature at which the film is adversely affected, and passing a gas of predetermined low humidity through said high frequency electric field while said film is passing therethrough.

JACK B. CUNNINGHAM.
FRANK WILBURN.

**References Cited** in the file of this patent

UNITED STATES PATENTS

| Number | Name | Date |
|---|---|---|
| 1,699,349 | Dailey | Jan. 15, 1929 |
| 2,364,526 | Hansell | Dec. 5, 1944 |
| 2,480,954 | Palmer | Sept. 6, 1949 |
| 2,490,938 | Wiergerink | Dec. 13, 1949 |
| 2,492,187 | Rusca | Dec. 27, 1949 |
| 2,503,779 | Story | Apr. 11, 1950 |
| 2,512,311 | Davis | June 20, 1950 |
| 2,513,991 | Bradbury | July 4, 1950 |
| 2,521,993 | Parker | Sept. 12, 1950 |
| 2,549,511 | Nelson | Apr. 17, 1951 |
| 2,588,218 | Dippel et al. | Mar. 4, 1952 |
| 2,588,811 | Dippel et al. | Mar. 11, 1952 |