

May 26, 1936.

W. A. DARRAH

2,042,145

PROCESS OF EVAPORATING AND EQUIPMENT THEREFOR

Filed March 5, 1931

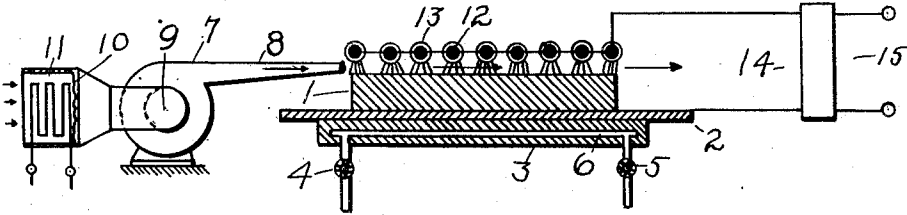


FIGURE I

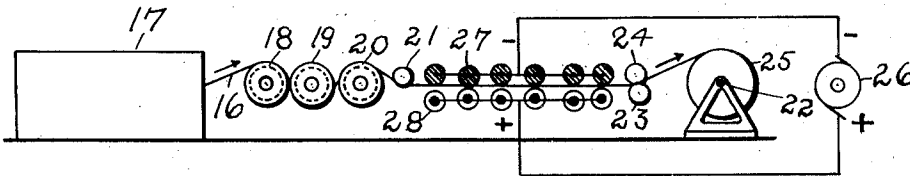


FIGURE II

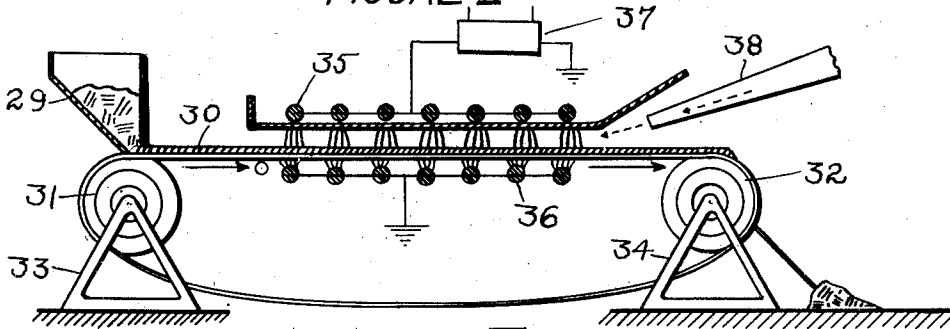


FIGURE III

William A. Darrah,
INVENTOR.

UNITED STATES PATENT OFFICE

2,042,145

PROCESS OF EVAPORATING AND EQUIPMENT THEREFOR

William A. Darrah, Chicago, Ill.

Application March 5, 1931, Serial No. 520,321

4 Claims. (Cl. 34-24)

This invention relates to a process of evaporating and equipment for carrying out the process. The invention may be employed in connection with the removal of water or other solvents as for example the drying of paper, paint, board, food products or practically any materials having an excess of solvent or material which may be evaporated or removed.

Some of the objects of my invention are to provide a process and apparatus for rapidly and efficiently removing materials which may be evaporated. My invention permits a speed of drying which is frequently considerably in excess of any now obtainable. My invention also permits the removal of liquids or vapors at lower temperatures than are now common.

Some further objects of my invention are to provide means for removing moisture from certain fluids such as gases or liquids. One application of this process would be the so-called drying of air, although obviously the equipment and method disclosed may be applied to other gases or liquids by making certain obvious changes.

Other objects of my invention may be apparent from the drawing, description and claims attached hereto.

In the drawing, Figure 1 shows diagrammatically an arrangement of one form of my equipment applied to drying of a stationary material.

Figure 2 shows a modification of my invention applied to the drying of a strip or sheet, as for example paper, cloth, fabrics, etc.

Figure 3 shows a further modification with some additional details of the process and equipment as applied to a moving conveyor carrying the material to be treated.

Referring to the drawing, and particularly Figure 1, 1 indicates the material to be dried which is shown resting on a table 2, preferably made of conducting material. A steam jacket 3 or other source of heat may be applied in contact with table 2. In the diagram jacket 3 is provided with inlet 4 and outlet 5 for condensate, with an interior chamber 6, in which the steam gives up its heat. Valves may be employed to control the flow of steam in the usual manner. A source of air such as a blower, fan, etc. is indicated at 7 provided with a nozzle 8 arranged to deliver the air in a constant stream above the surface of material 1, which is being dried. The inlet 9 of air moving member 7 is shown connected to air heating device 10 provided with coils or other heat source 11. The arrows indicate the direction of the flow of air. A series of conducting members 12 are located adjacent

to material 1, which is being dried. Members 12 may be of many shapes and sizes as for example bars, rods, sheets or screen cloth or gauze. For purposes of convenience I have shown them illustrated as rods surrounded with an insulating shell 13, which may or may not be used as desired. Members 12 are connected together as indicated diagrammatically and to one terminal of a source of relatively high potential. The other terminal of the source is connected to table or supporting member 2. For purposes of illustration, I have indicated a transformer 14 as a source of potential. The primary of the transformer is indicated by 15. It will be noted that the arrangement shown produces a strong electric field between the material being dried and the conducting members 12 and that a stream of moving air is directed across the field.

In the case of Figure 2, 16 indicates the material being treated as for example a sheet of paper, cloth or fabric. This may be drawn from any source, but is shown diagrammatically coming from a paper machine 17, passing over rolls 18, 19, 20 and 21 to the equipment which forms a part of this invention. It will be understood that the source of the strip or sheet and the construction and process of treating it prior to its arrival at the equipment, which constitutes no part of the applicant's invention is of no essential consequence, although in some cases it is an advantage to have the strip or sheet previously heated in which cases rollers 18, 19 and 20 may be considered to be hollowed and provided with steam or other means for heating them. The strip or sheet is shown for purposes of convenience as being rolled on reel 22. A series of rollers 23, 24, 21 and 25 are provided to align and control the strip or sheet while being treated. In this case I have indicated a generator of direct current, preferably of high potential by 26. One terminal as for example, the negative is connected to the sheet or strip 16 by a series of rods or rollers 27 which are intended to contact with the sheet. The other terminal as for example the positive of generator 26, is connected to another series of conductors indicated by 28, which are placed opposite conductors 27 and spaced therefrom. The sheet being caused to pass between the positive and negative conductors and thus through a strong electric field. It will be noted that in this case no supply of air is shown as the rapid travel of the sheet or strip through the air is substantially equal in many cases to the movement of air over a stationary strip or sheet. It

should be understood however that I do not care to limit my invention to any particular construction as one of the important features is a relative motion of the surrounding atmosphere and the article being treated.

In Figure 3 I have indicated a conveyor mechanism consisting of a means for loading the conveyor 29, a conveyor member 30, a pair of sprockets or other means for supporting and driving the conveyor as 31 and 32, the sprockets being mounted on bearing supports 33 and 34. The travel of the conveyor is as indicated by the solid arrows.

The conveyor member consists of a sheet or strip of insulating material as for example a rubber belt or in some cases a metallic conveyor may be employed, making obvious changes in the construction. The conveyor may carry sheets or strips of a fabric being dried or treated or it may carry powders, and granulated materials, etc. the various factors of design being modified to compensate for the individual characteristics of the material being treated.

A pair of conducting members 35 and 36 are placed adjacent to each other and in such a position that the conveyor passes between them. Conducting members 35 and 36 are connected to a source of high potential electric current which is shown diagrammatically as coming from transformer 27. A nozzle 38 is used to deliver a stream of moving air or gas through the field. It will be understood that the air or gas delivered to nozzle 38 may be heated if desired in any commercial manner and that the material being treated may also be heated as for example by a series of steam heated rolls 39 adjacent to conveyor 30.

Figures 1, 2 and 3 described above show diagrammatically various arrangements of treating certain classes of solid materials by my process and equipment.

Having now described some typical forms of constructing my equipment, I will outline certain specific applications and some methods of operation.

It will be apparent that the art of removing liquids from solid or fluid materials is of great importance and has been highly developed in certain lines. The removal of water or moisture is of course known as drying and constitutes an important portion of my invention, though I do not wish to be limited to this field only as obviously the removal of other vapors or liquids such as various kinds of solvents, etc. is of great importance. I will, however for purposes of clearness confine the description of the operation of my invention to the removal of moisture with the understanding that obvious changes will make the method and equipment applicable for many materials. In the case of the removal of moisture from materials as for example, from a sheet of paper or board, it is customary at present to supply both heat and some circulating medium such as a moving stream of air. Present dryers therefore largely operate by heating the material to be dried and then removing the moisture either by means of a vacuum or by a stream of air over the surface. In most commercial operations the rate of the removal of moisture is of great importance. Obviously on doubling the rate of removal of moisture, the size and therefore the cost of the equipment is substantially cut in half. Losses are reduced and operating costs are therefore materially reduced by an increase in the possible rate of drying. However

the present state of the art as far as I am aware has now progressed, so that it is quite difficult with usual means if not impossible, to further increase the rate of removal of moisture or drying. Higher temperatures have been used, but these in many cases tend to injure the material being dried. Even in case the material will permit the application of higher temperatures, a definite time is required for the heat to penetrate the material being treated and this in itself forms a limit to the possible rate of drying. My invention is designed to overcome some of these limitations and permit a more rapid rate of drying. This I have found can be accomplished by creating a relatively strong electric field in or around the material being dried and adjacent to its surface. Various methods of creating the electric field have been shown and described in the figures and in the drawing. The exact mechanism by which the electric field increases the rate of removal of vapors is not clearly known to me, although many tests have definitely proven the effect. As a theory which may or may not be correct, I am of the opinion that the electric field can assist the removal of moisture or other vapors or liquids in several ways. It would appear that there is a relatively dense, strongly adhering layer of liquid, adhering to the surface of all materials. This condition has apparently been established by many workers and this layer sometimes gives results which are known as the "skin effect". Studies of the transference of heat have definitely shown the presence of a strongly adhering layer upon the surface of many materials. It is quite probable that the formation of an electric field on or about the surface of the material being dried or heated has a tendency to disrupt or remove considerable portions of this layer. Since my tests have indicated that a rapidly varying current as for example an alternating current or a high frequency current is more effective than a slowly pulsating or alternating current, it seems quite probable that a disruption or partial removal of the surface layer is an important factor.

On the other hand, since the application of the high potential field produces striking results in connection with the drying of a relatively thick piece, I am of the opinion that the strong field produces a change in the vapor pressure in and immediately surrounding the article being dried. The change in vapor pressure naturally causes a flow of vapor particles from the points of high concentration to those of lower concentration. In other words, the electric field appears to disturb the equilibrium previously established. As soon as the flow of vapor brings the particles into contact with the surrounding air, they are of course carried away and this removal of vapor naturally facilitates drying.

Another factor which probably contributes to some extent to drying by my process, is the production of heat as a result of the flow of currents or electric bombardments which are caused by the electric field.

As stated above, it should be understood that the theories advanced are merely an effort to explain the results which I have found take place when carrying out my invention.

In general, I prefer to use an electric field which is concentrated in certain points in preference to a uniform field. I have also found that better results are in general obtained when the field changes its strength quite frequently. Several hundred thousand oscillations per second

give me very good results, although I have in many cases operated with a great acceleration of the drying rate, using frequencies as low as 60 cycles. Voltages ranging from a few hundred volts to as much as 50,000 volts applied at the terminals of the field give good results. For many practical conditions, 15,000 or 20,000 volts seem to be ample.

When the field is produced by connecting to it a power circuit of commercial frequency, some means for insulating terminals to prevent arcs are desirable unless a condenser or a similar device is interposed in the circuit to raise the impedance sufficiently to prevent the formation of an arc.

Referring now to Figure 1, it will be evident that I utilize blower 7 to deliver a stream of air or other circulating medium above the top surface of material 1, which is being treated. I produce a relatively strong electric field between material 1 and the conducting members 12, the field being in general transverse to the flow of air or other fluid. Apparently the electric field causes a flow of vapor particles of sufficient amplitude to allow vapor particles to become carried away by the air stream. Apparently also the un-uniform field assists in causing a flow of moisture or other material being removed from the interior of substance 1 toward its surface. As a matter of illustration with an arrangement similar to that shown in Figure 1, I have been able to reduce the drying time substantially in half when a strong field of 50,000 volts is applied. Undoubtedly the effect of the electric field and the resultant discharge is to disrupt and partially destroy the surface layer which separates substance 1 from the moving air stream. In the case of Figure 1 the moving air stream can to advantage be heated by the means shown (coil 11). This will still further accelerate the rate of drying. Also if desired, heat may be delivered to substance 1 as for example by means of the hot plate 3, thus further accelerating the rate of drying.

It will therefore be understood that my process does not necessarily eliminate the application of heat, but supplements the drying condition obtained whether heating means are employed or not. Where the articles being subjected to the evaporation process will permit the application of heat, it is desirable in addition to the electric field which I have developed. In those numerous cases however in which an appreciable elevation of the temperature will cause serious trouble, my process is particularly applicable. For example in the drying of food products, many chemicals and various organic materials, a temperature in excess of 100° is frequently impractical and in the case of practically all organic material a temperature in excess of 200° can rarely be employed.

In the case of the arrangement shown in Figure 2, the treatment of a continuous sheet or strip is illustrated. For purposes of discussion this may be considered the drying of a sheet of paper and 17 may be taken as representing the machinery for forming the sheet. Substantially the same arrangement may be used as for example in drying ink, paint or pigment as applied to sheets. The rapid drying of rotogravure, color plates, etc., represent some specific applications of my invention. As pointed out and it is occasionally desirable and practical to heat the strip or sheet prior to drying or to give it an initial or preliminary drying and this may be done

in many ways as for example by the steam heated rollers 18, 19 and 20.

Figure 2 shows diagrammatically the application of direct current from the generator as distinguished from alternating current. In case direct current is used I prefer to make the article being dried the negative terminal as in the case of the removal of water vapor there appears to be a definite condensation of water particles about the negative ions, as they leave the negatively charged sheet and travel toward the positive terminal of the field. In this case the moisture diffuses into the surrounding medium (air) and is carried away. Obviously a stream of air may be blown on the sheet or strip as in the other cases illustrated if desired.

Figure 3 illustrates an application of the principles shown above to the drying of powdered, granulated or lump material or sheets, blocks, etc. Figure 3 indicates continuous means for carrying out the process.

The disclosure here made may be modified in many details without departing from the scope of my invention. As for example I may employ either a direct current, an alternating current or a pulsating current. In the case of an alternating or pulsating current, I prefer to have the maximum number of alternations per second. Preferably several hundred thousand per second will give desirable results.

It would be obvious that the gas used to pass over the surface and wash away the vapor or drops which are released may either be at room temperature or heated. More rapid drying is obtained with heated circulating gases, but in the case of many articles this is impractical without causing damage.

Similarly the gas used to pass over the surface may have any desired degree of saturation or may be dried. I have found that even saturated gases or vapors will effectively remove the liquids in the article being dried, the action apparently being to an appreciable degree mechanical. However if the air or circulating gas used is not saturated, but relatively dry, the desired results are of course obtained more quickly.

Some of the results I have obtained lead me to believe that a portion of the "drying" effect results from the mechanical separation of small drops of the liquid as well as merely evaporation. This would perhaps account for the fact that in some cases the reduction in temperature which accompanies the removal of the liquid, does not seem to correspond with the normal heat absorption due to the conversion of the liquid to vapor.

Obviously the circulating gas which removes the liquid at the surface of the article being dried may be air or any desired gas, such as nitrogen, carbon dioxide, hydrogen or various vapors. Obviously, where possible air is the practical, inexpensive and desirable material to use.

In the same way as outlined above, my process is not confined to the removal of water, but may be applied in the case of many other liquids. I have found that water and the various liquids having a high specific inductive capacity are very markedly affected by my process. It would appear therefore that the electric field causes a greater motion in the case of those liquids having a high specific inductive capacity.

It will be apparent that the circulating gas which removes the liquids or vapor may travel the full length of the surface subjected to the electric field or it may escape at intervals as

between the various conductors 12 in the case of Figure 1.

In carrying out my invention it will be apparent that while I have disclosed both continuous and intermittent processes, I do not wish to be restricted to either one type exclusively. For example in drying materials I may operate for an interval and then stop either the flow of air or the electric field or both, or I may keep the air or gas flowing and intermittently apply the electric field. In the same way in the case of the removal of condensible material from gaseous fluids, I may pass the gas from which the condensible material is to be removed for a period, then apply the electric field to the absorbing surface for a period, removing the condensed material and then again circulate the air, etc. I prefer to operate the equipment continuously, but do not wish to restrict my invention to any particular method of operation.

In the claims and description, I have also referred to an electric field, but it will be understood that the electric field of the intensity which I ordinarily employ causes a measurable electrical discharge. I therefore intend to cover all of the associated phenomena by the term "electric field".

In the claims, I have used the term "condensible material" to refer to the substance which is to be removed. As pointed out in most cases, this will be water or similar liquids and the common application will be the removal of water, which in some respects may be considered the equivalent of evaporation or drying, although as pointed out a portion of the liquid may be removed in the form of a large number of fine drops, so that strictly speaking the term "removal of condensible material" is probably more correct than the term "evaporation" which normally in-

dicates a change from the liquid state to the vapor state. I do not wish to be restricted however to any particular form of liquid removal.

Having now fully described my invention what I claim as new and wish to secure by Letters Patent in the United States, is as follows:

1. The process of removing liquid in vapor form from the surface of solid material being dried which consists in electrically removing the surface layer of saturated gases by creating an electrical potential difference between said surface and an adjacent point spaced away from said surface and passing a stream of gas over said surface.

2. The process of removing liquid from an article which consists in passing said article through an electric field which originates from a point spaced away from said article and simultaneously causing a stream of gas to move relative to said article in contact with the surface thereof and through said electric field.

3. The process of removing liquid in vapor form from the surface of solid material being dried which consists in electrically removing the surface layer of saturated gases by creating an electrical potential difference between said surface and an adjacent point spaced away from said surface and passing a stream of heated air over said surface.

4. The process of removing liquid in vapor form from the surface of solid material being dried which consists in electrically removing the surface layer of saturated gases by creating a rapidly varying electrical potential difference between said surface and an adjacent point spaced away from said surface and passing a stream of gas over said surface.

WILLIAM A. DARRAH.