

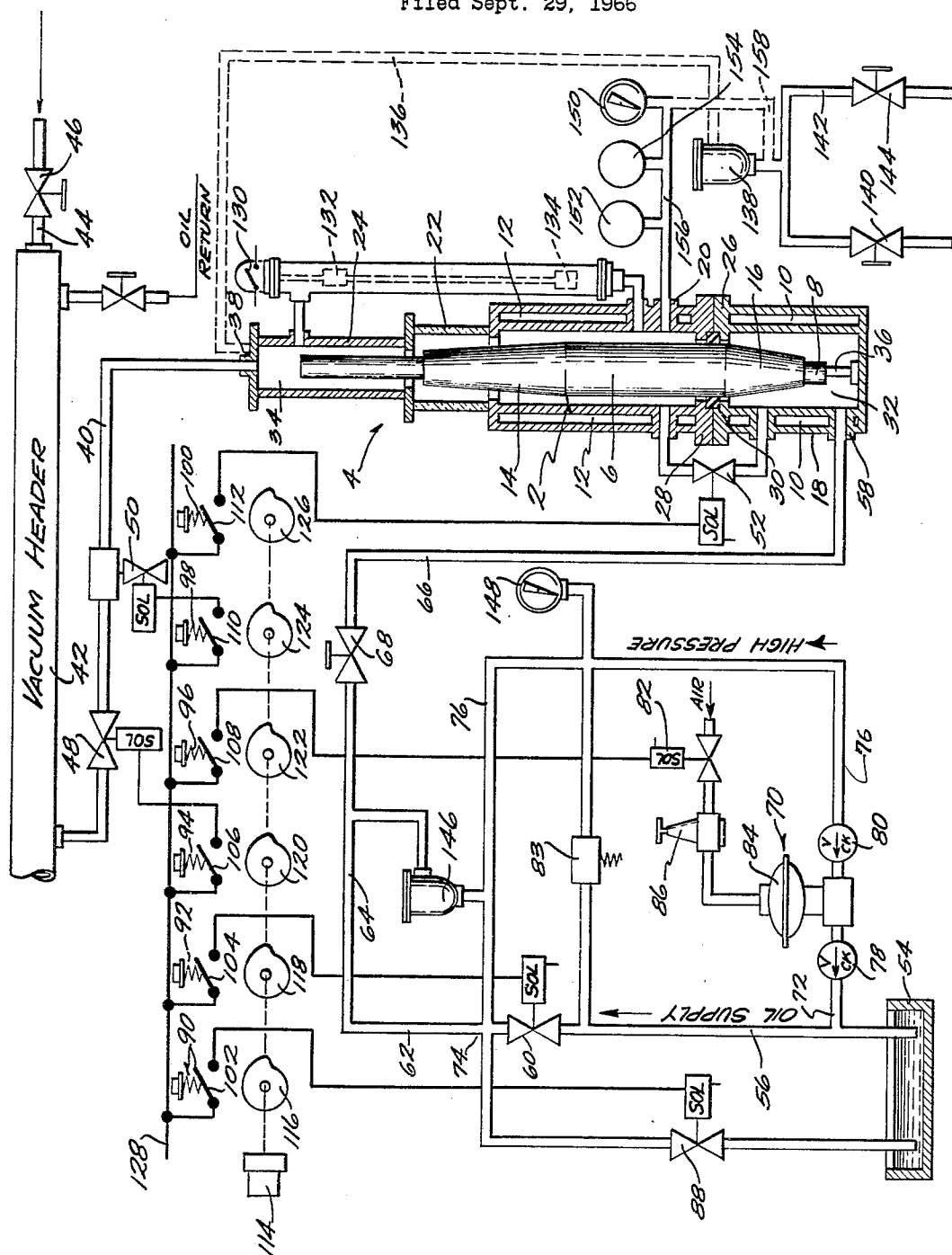
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IMPREGNATION PROCESS

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IMPREGNATION PROCESS

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ABSTRACT OF THE DISCLOSURE

A bushing core is positioned in an impregnation tower with the opposite ends of the core exposed in isolated chambers. A vacuum is drawn in one chamber and oil under high positive pressure is introduced into the other chamber. Periodically, both the vacuum and high pressure conditions are removed from the chambers and subsequently both are reapplied in sequence, the vacuum first and the positive pressure later. In another aspect, the core end normally exposed to the vacuum may be temporarily exposed to a positive pressure between the time of removal and reapplication of the vacuum and high positive pressure.

This invention relates to impregnation processes wherein air is evacuated from a generally porous article and a fluid, such as oil, is introduced into the article to replace the air. More particularly, this invention relates to the oil impregnation of electrical insulation used in various electrical apparatus such as bushing cores. This invention will be specifically discussed in connection with a method of impregnating bushing cores with oil but it is to be understood that the method may have wider utility to impregnation processes in general.

Bushing cores are generally made up of a conductive stud and kraft paper wound on the stud with interleaved layers of aluminum or copper foil. The kraft paper provides part of the overall bushing insulation and also provides insulation between adjacent layers of foil. Such cores are commonly used in oil filled housings and preferably the paper is completely impregnated with oil and all air is removed. This is generally accomplished in an impregnation tower where the core ends are isolated one from the other, one end being exposed to a vacuum with the other end being exposed to a relatively higher positive pressure. Impregnating oil is made to flow from the high pressure side through the core to the low pressure or vacuum side by reason of the difference in pressure across the core ends. The induced flow of oil moves oil into the spaces vacated by the air. This results in an impregnated core but heretofore conventional accepted impregnation processes have required relatively long cycling time to achieve satisfactory impregnation. Various attempts have been made to speed up the impregnation time, one of these has been to interrupt the impregnation process at a selected point during the cycle and to temporarily replace the vacuum at one end of the core with a positive pressure. These prior attempts, including temporarily replacing the vacuum with a positive pressure, have under some conditions achieved a reduction in impregnation time, but the overall times still required remain unduly long.

An object of this invention is to shorten the time required to achieve adequate impregnation of articles of this type.

A more specific object of this invention is to provide a method of impregnating bushing cores or the like with oil, which method requires a relatively short process time and achieves more complete impregnation as compared to heretofore accepted processes.

It is known that this type of impregnation proceeds by the air which is contained in the wound core moving

toward the low pressure area by virtue of the pressure drop across the core in the impregnation tower. Eventually the entrapped air leaves the low pressure end of the core in the form of bubbles. The bubbles provide a visual indication of the progress of the impregnation process and, moreover, complete cessation of bubbles provides an indication that impregnation is complete. The oil is forced from the high pressure chamber through the core to fill the areas vacated by the air and thereby achieve the desired oil impregnation.

It is believed that the delay in thorough and complete impregnation is caused by oil being forced through the core along the paths of least resistance. In many places this forced oil flow is believed to surround pockets of air and, in effect, subject the air pockets to equal pressure on all sides. This compresses the air in the pockets and creates a relatively static condition preventing immediate air movement. Because of the pressure drop across the core ends, a small gradual pressure differential will occur across the compressed air and the air will move toward the low pressure area. Thus the static condition does not prevent the removal of air but it does retard the impregnation process.

It has been discovered that the time required for complete impregnation can be substantially reduced by periodically interrupting the vacuum on one end of the core and also removing the high pressure condition on the other end of the core. Subsequent to this interruption of the vacuum and removal of the high pressure, the vacuum is reapplied to one end of the core and after a preselected time period the high pressure is again applied to the opposite end of the core. When the vacuum and high pressure are removed, the entrapped air is permitted to expand and tends to move from the position it had maintained during the static condition. Reapplication of the vacuum influences that movement toward the low pressure or vacuum chamber and then by re-exerting the high pressure on the oil at the opposite end of the core, oil is forced into the core to replace the evacuated air. Eventually the static condition of entrapped compressed air explained above is reached again and the interruption of the vacuum and high pressure and the reapplication of both is repeated as often as necessary to achieve complete impregnation. At the start of the impregnation process violent bubbling occurs at the low pressure end of the core and soon subsides to a slow expulsion of bubbles from the core thereby indicating the establishment of the static condition. It has been observed that violent bubbling similar to that encountered at the initiation of the impregnation process occurs each time the vacuum and high pressure are interrupted and reapplied. In some cycles it may be desirable to apply a slight positive pressure in place of the vacuum for a temporary interval for, in some instances, this appears to further stimulate the impregnation process.

Other objects and advantages will be pointed out in, or be apparent from, the specification and claims, as will obvious modifications of the embodiments as shown in the drawing. The drawing consists of a single generally schematic illustration of an impregnation tower and an example of a pipe system and control for carrying out this process.

With particular reference to the drawing, a bushing core 2 of conventional construction is arranged in an impregnating tower 4. For example, the core can be made of kraft paper 6, or the like, wound on conductive stud 8 with periodically interleaved conductive sheets of, for example, aluminum or copper (not shown). The kraft paper is generally continuous with a gradually reduced width, or axial dimension, to form tapered ends 14 and 16 on the wound core. In this respect the axial length of the conductive sheets varies as the axial width of the core

paper is reduced to conform to the taper shape. Generally the reduction in axial length of the conductive sheets is correlated with the increase in diameter which results as the winding proceeds further and further from the core center to thereby maintain virtually consistent electrical characteristics through the core cross section.

Structurally the tower is made up of a base 18, intermediate portion 20, sight glass portion 22, and a top 24. The top of base 18 and the bottom of intermediate portion 20 are provided with flanges 26 and 28 to facilitate connecting these two members and a sealing ring 30 is clamped between the flanges. The sealing ring engages the outer periphery of the bushing core dividing the interior of the tower into a high pressure chamber 32 and a low pressure or vacuum chamber 34. The walls of base 18 and intermediate portion 20 are hollow to provide jackets 10 and 12 for a purpose to be explained hereinafter.

Core 2 is supported from base 18 on a suitable support pedestal 36 which engages the core stud. The bushing core is arranged so that sealing ring 30 engages the core just above tapered end 16. The ring has a sealing engagement with the core to provide the two separate and distinct chambers 32 and 34 within the impregnation tower as mentioned above.

Top 24 of the impregnation tower includes a coupling 38. A vacuum hose 40 is connected to the coupling 38 and is also connected to a high vacuum header 42. The high vacuum header is only partially illustrated in the drawing since this is a conventional construction and has a conventional connection through conduit 44 and manually operable valve 46 to a vacuum tank. The header can be connected to one or more impregnation towers as desired, however, hose 40, and a valve system which will be described hereafter, control the vacuum in impregnation tower 4. More particularly, two solenoid valves 48 and 50 are connected in hose 40 between the header 42 and coupling 38. Valve 48 is operative to open and close the impregnation tower, or specifically vacuum chamber 34, to the vacuum header and solenoid valve 50 is effective to selectively open and close the vacuum chamber to the atmosphere. With valve 50 closed and valve 48 open, a vacuum is drawn in the chamber 34, and with valve 48 closed and valve 50 open the vacuum is removed from chamber 34 and the chamber assumes atmospheric pressure.

Although chambers 32 and 34 are isolated except through core 2, a bypass valve 52 is provided to permit selective connection of the two chambers. Preferably valve 52 is also solenoid operated.

Oil for the impregnation process is supplied from a suitable reservoir 54. Oil supply line 56 extends from the reservoir to deliver oil to chamber 32 through an inlet coupling 58 in base 18. More particularly, supply of oil to the high pressure chamber is controlled by a solenoid valve 60 which is connected in supply line 56 and through conduit sections 62, 64 and 66 to inlet 58. A manual valve 68 is also connected in conduit 66 to provide manual control over the input to the high pressure chamber.

After the bushing core has been inserted in the impregnation tower, the tower is filled with low pressure oil. More particularly, valve 48 is opened and valve 50 closed to draw a vacuum in chamber 34. By pass valve 52 is opened to connect the vacuum and high pressure chambers and valves 60 and 68 are opened to admit oil from reservoir 54 into chamber 32. The oil introduced into chamber 32 proceeds through valve 52 into the vacuum chamber. The oil is allowed to fill the high pressure chamber and then to rise in the vacuum chamber until it becomes visible through the sight glass. At this point bypass valve 52 is closed isolating the high pressure and vacuum chambers. Steam can be circulated through jackets 10 and 12 to heat the oil and reduce its viscosity.

A high pressure is now applied to the oil in chamber 32 to provide a force urging the oil to flow through the core towards the vacuum chamber. This high pressure is pref-

erably achieved by activating a pump 70 which is connected to conduit 56 through conduit 72 and is also connected to junction 74 in conduit 62 by a high pressure oil line 76. Activation of the pump increases the pressure of the oil in chamber 32 to enhance the flow of oil into the core to replace air which is evacuated from the core into the vacuum chamber. Pump 70 can be of any conventional type, for example, it can be an air-over-oil pump with suitable check valves 78 and 80 being provided to prevent flow through the high pressure line when the pump is not activated. Activation of the pump is controlled by solenoid valve 82 which is connected to air chamber 84 of the pump through an air regulator 86. In order to activate the pump the valve 82 is opened and the pump then increases the pressure of the oil in chamber 32. A pressure relief valve 83 is connected between the high pressure and oil supply lines.

Initially when the filling process has been completed, the vacuum and high pressure chambers isolated, and the high pressure applied to chamber 32, violent bubbling will be observed at tapered end 14 of the bushing core indicating that the evacuation of air and impregnation with oil is proceeding at the desired rate. However, after this initial violent bubbling, a static condition occurs within the bushing core and the rate of bubbling, which indicates the rate of air evacuation, diminishes substantially. After this condition has been reached evacuation proceeds slowly but continually as indicated by a slow expulsion of bubbles. It is believed that the reason for the retardation of the air evacuation is that the high pressure in chamber 32, which is desirable to insure forced flow of oil through the core to replace the evacuated air, also causes oil flow through the bushing core in such a manner that the oil surrounds pockets of air within the core. The air within these pockets is compressed and is surrounded by equal pressure on all sides thereby creating a static condition tending to hold the entrapped air stationary. By virtue of the pressure drop between chambers 32 and 34 the entrapped air is eventually subjected to a pressure differential and moves toward core end 14 but this is a relatively slow occurring condition. Accordingly, after the initial rapid evacuation of air the impregnation process proceeds at a relatively slow rate.

In accordance with this invention it is proposed that after the rapid removal of air from the core indicated by the violent bubbling ceases, the vacuum in chamber 34 is interrupted. This interruption of the vacuum is achieved by closing valve 48 and opening valve 50, this exposes chamber 34 to atmospheric pressure and removes the vacuum. Bypass valve 52 is then opened and pump 70 deactivated so that not only is chamber 34 returned to atmospheric pressure but the high pressure in chamber 32 is also removed and both chambers assume substantially atmospheric pressure. This condition is maintained for a preselected time whereupon valve 50 is closed and valve 48 opened with valve 52 being simultaneously closed thereby reestablishing the vacuum in chamber 34. Subsequently pump 70 is again reactivated, in the preferred embodiment, by opening valve 82, and the high pressure again applied in chamber 32. At this point violent bubbling will again be observed through sight glass 22 at core end 14 indicating that rapid evacuation of entrapped air has again been achieved.

It is believed that the reason for this increase in evacuation of gas lies in the fact that by removing the vacuum and high pressure in chambers 32 and 34 and allowing the pressures in those chambers to relatively equalize the compressed air pockets mentioned above are permitted to expand which also produces some movement of the air pockets. By then isolating the two chambers and reapplying a vacuum in chamber 34 this movement of the air pockets is directed toward the vacuum chamber. Subsequent reapplication of the high pressure in chamber 32 insures adequate oil flow into the bushing core to replace the air which is now being evacuated. This interruption and reapplication of both the vacuum and high pressure is re-

peated periodically until the impregnation process is completed.

This recycling by periodically interrupting and reestablishing the vacuum and high pressure conditions can, if desired, be achieved manually through manipulation of suitable conventional push buttons 90, 92, 94, 96, 98 and 100 which open and close switches 102, 104, 106, 108, 110 and 112 to control their respective solenoid valves. However, it is preferred that the recycling occur automatically under the control of a suitable timer so that recycling occurs without requiring continuous attention by an operator. The timer is illustrated schematically as including a timer motor 114 and cams 116, 118, 120, 122, 124 and 126 associated with each switch as shown. The use of the solenoid valves at the various control points in the recycling system facilitates the use of an electrical timer for control purposes. The push button control of the switches permits manual control over the fill and initial impregnation stage whereas the timer provides automatic control over the subsequent stages of repeated removal and reapplication of the vacuum and high pressure. Since such timer and switch arrangements are well known in the electrical art and since the specific construction of such timers is not an essential element in this invention, the timers, switches, cams and electrical connections from the switches to the solenoids have only been illustrated schematically. It will be readily apparent to those skilled in the art how the actual connections are to be made. For example, one side of each switch is connected to one side of each solenoid, the opposite sides of the solenoids are connected to one side of an electrical source (not shown) while the other side of each switch is connected to the other side of the electrical source 128.

To summarize the automatic recycling process and correlate the process with timer operation, the process will now be described with typical times which have given satisfactory results in connection with the impregnation of one type of bushing core. The impregnation tower is filled by opening valve 48, bypass valve 52 and inlet valve 60, and closing valve 50, control valve 68 remaining open. After the tower is filled to the desired height, a vacuum is present in chamber 34 (for example 30 inches of mercury), valve 52 is closed and valve 82 is opened to activate pump 70 to increase the pressure in chamber 32 (for example to 200-250 p.s.i.). At this point the timer is activated and after a predetermined time, for example two hours (which can be established by observation as to the time necessary for the initial violent bubbling to diminish for a given core and given vacuum and pressure condition), the timer manipulates the necessary switches to close valves 48 and 82 and open valves 50 and 52 and expose chambers 32 and 34 to atmospheric pressure. This first stage condition is allowed to exist for a predetermined relatively short time (e.g. 5 minutes) after which the timer again manipulates the switches to close valves 52 and 50 and open valve 48 to re-establish the vacuum in chamber 34. This second stage condition is allowed to persist for a longer duration than the first stage (e.g. 1 hour). At the termination of the second stage the timer opens valve 82 and increases the pressure in chamber 32. This third stage is allowed to continue for a predetermined time (e.g. ½ hour). At the end of the third stage the timer again opens the tower to atmospheric pressure by repeating stage one. The three stages are repeated in sequence so long as necessary to complete impregnation, the number of repeated cycles can be determined by experience for a given type of bushing core or, periodically, the bushing can be visually checked for bubbles and when the bubbles have stopped the impregnation process is terminated. At this point cold water is run through jackets 10 and 12 to cool the oil, whereupon oil can be drained by opening valves 50 and 52 and a return valve 88. When the oil is completely drained, the bushing is removed from the tower and is ready for the next assembly step.

It will be appreciated that, although a single timer has been shown to control all three repeated cycles, a separate timer can be provided for each stage.

During the impregnation process oil forced through the bushing core will gradually fill vacuum chamber 34. It has also been found, that the head of oil in the chamber above tapered end 14 actually works against the vacuum provided in that chamber and tends to retard air evacuation. Thus, the amount of oil in the chamber may reach an undesirable level and it is desirable to reduce the amount of oil in the impregnation tower periodically. This can be accomplished by interrupting the impregnation process at various points, depending on the oil level in a tower 4, and draining oil from the tower to reduce the level of oil in the vacuum chamber. As illustrated this is accomplished by providing a control switch 130 and high and low level floats 132 and 134. Switch 130 has two levels of operation, or can be two separate switches, controlled by floats 132 and 134. When the level in tower 4 reaches float 132 the float is moved upwardly operating switch 130. Switch 130 effects closure of valves 48, 60 and 82 and opens valves 50 and 52 and opens return valve 88. Oil then drains from the tower through the conduits and valve 88 back to reservoir 54. As the level of oil diminishes and reaches the level of float 134, the float moves downwardly and operates switch 130 to close valves 50, 52 and 88 and open valves 48 and 82, if necessary, together with valve 60 to continue the recycling process. During this draining operation the timer will also be interrupted to preserve the desired process time intervals. Again, since the actual electrical connections necessary to achieve this function and the actual valve opening and closing will be well known to those skilled in the art they have not been illustrated.

As stated above, the recycling can be controlled manually by push button manipulation of the the switches to activate the various solenoid valves. An additional alternative embodiment is shown in the drawing. In accordance with this alternative, coupling 38 can also be connected to a source of low vacuum (not shown) through removable conduit 136, float switch 138 and manual valve 140. With this arrangement the high vacuum can be interrupted and the vacuum chamber connected to a source of flow vacuum by manual manipulation of the high vacuum valve and valve 140. This variation also includes a branch 142 which is connected to a suitable pressure source, such as a source of nitrogen, through valve 144 so that, if desired, a slight positive pressure can be introduced into the vacuum chamber during the recycling process at the point where the vacuum is normally removed. It will also be noted at this point that valve 50 could be connected to the nitrogen source of low positive pressure so that, if desired, a slight positive pressure can be introduced into the vacuum chamber in the basic process. This alternative provides a wider selection of conditions in the low pressure chamber 34 to provide adequate stimulation of the process as desired.

A drain float switch 146 is in the oil line to close valve 88 and stop oil flow after the drain down is complete.

Preferably a high pressure gauge 148 is connected to the high pressure line to give a visual means of monitoring the condition in chamber 32. Similarly, a vacuum gauge 150 is connected to the vacuum chamber to monitor the vacuum and suitable safety switches 152 and 154 are connected in conduit 156 which communicate with the vacuum chamber, one being responsive to vacuum and the other to pressure and the other to assure a vacuum seal before oil filling commences. When the low vacuum and nitrogen source are used gauge 150 can be connected to monitor the pressure in both sources by removable conduit 158.

Impregnation with the basic process of this invention has achieved a 25% to 30% reduction in overall impregnation time as compared to heretofore accepted conventional impregnation processes. Moreover, this reduction

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in impregnation time has been achieved together with an actual improvement in the impregnation of the bushing core.

I claim:

1. The process of impregnating an elongated generally porous member with oil, said process comprising the steps of

isolating the opposite ends of said elongated member, subjecting one end of said article to a vacuum and exposing the opposite end of said article to oil under a relatively high positive pressure so that a pressure differential occurs across the ends of said elongated member, and

during the time interval from initiating said impregnation process to complete impregnation, periodically removing both said vacuum and positive pressure and after a predetermined time delay reestablishing both said vacuum and positive pressure at said opposite ends of elongated member, said removal and reestablishment of said vacuum and positive pressure being repeated throughout said interval until said member is impregnated.

2. The process of claim 1 wherein said vacuum and positive pressure are reestablished in sequence, said positive pressure being reestablished with a preselected interval after said vacuum is reestablished.

3. The process of claim 1 wherein said elongated member comprises a wound core and said process includes the steps of

arranging said core in an enclosure with said one end disposed in a first chamber, said other end disposed in a second chamber, and said first and second chambers isolated one from the other,

filling said second chamber with oil and said first chamber to a predetermined level, and establishing said vacuum in said first chamber and said positive pressure in said second chamber, and

subjecting said first and second chambers to said periodic removal and reestablishment of both said vacuum and positive pressure, respectively.

4. The process of claim 3 including the steps of maintaining the head of oil above said one end of said article below a predetermined head by draining oil from said first chamber to a predetermined minimum level whenever the oil level in said first chamber reaches a predetermined level.

5. The process of claim 3 wherein said core is a wound bushing core and including the steps of heating said oil in said enclosure.

6. The process of claim 1 including the step of applying a positive pressure to said one article end after said vacuum and positive pressure have been removed and before re-applying said vacuum and said positive pressure.

7. The process of impregnating a generally porous article with a liquid comprising the steps of

placing said article in an enclosure having first and second chambers with portions of said article disposed in each chamber and said chambers being isolated one from the other except through said article,

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filling at least said second chamber with said liquid, establishing a vacuum in said first chamber and a relatively high positive pressure in said second chamber whereby a pressure differential occurs across said article and gaseous media in said article moves through said article into said first chamber and said liquid is directed into said article to replace said gaseous media, and

periodically removing both said vacuum and positive pressure from said chambers, returning said first chamber to atmospheric pressure, and thereafter reestablishing both said vacuum and said positive pressure in said first and second chamber respectively.

8. The process of claim 7 wherein the progress of said impregnation process is indicated by the emission of bubbles from the portion of said article in said first chamber,

the initial condition of said vacuum and relatively high positive pressure in said first and second chambers is maintained for a duration sufficient to permit the emission of bubbles to subside,

after said duration both said vacuum and high pressure are removed and said first chamber is exposed to atmospheric pressure for a first interval of time.

at the end of said first time interval a vacuum is reestablished in said first chamber and maintained for a second interval of time,

at the end of said second time interval said relatively high positive pressure is reestablished in said second chamber and said vacuum and relative high positive pressure are maintained simultaneously for a third interval of time, and

removal of both said vacuum and high positive pressure with sequential reapplication thereof is periodically repeated with said first, second and third time intervals until said impregnation process is completed.

9. The process of claim 8 including the step of maintaining the head of fluid above said portion in said first chamber below a predetermined head by draining fluid from said first chamber to a predetermined minimum level whenever the fluid level in said first chamber reaches a predetermined level.

10. The process of claim 8 wherein said intervals are automatically repeated under timer control.

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