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Morarau

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[54] **METHODS AND ELECTRODES FOR THE DRYING OF DAMP BUILDINGS**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 744,162, July 11, 1968, abandoned.

[30] **Foreign Application Priority Data**

Sept. 19, 1967 Romania 54724

[52] **U.S. Cl.** ..... **204/180 R**

[51] **Int. Cl.** **B01d 13/02**

[58] **Field of Search** ..... 204/180 R, 130

[56] **References Cited**

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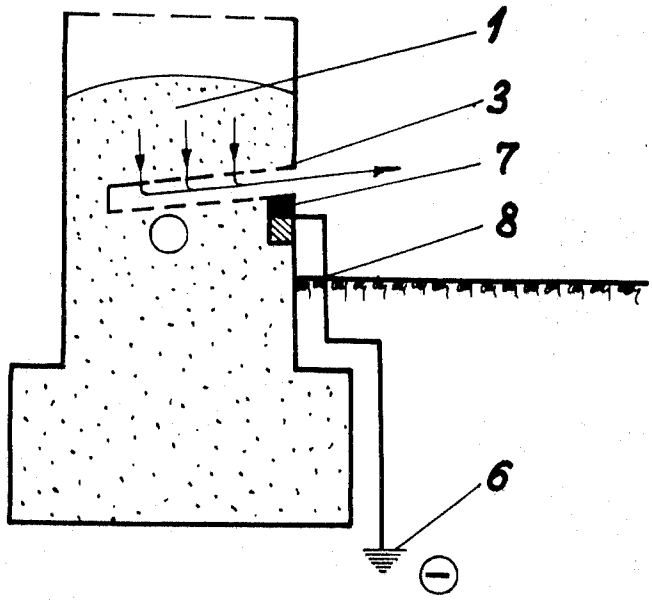
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Primary Examiner—John H. Mack
Assistant Examiner—A. C. Prescott
Attorney, Agent, or Firm—Waters, Roditi, Schwartz & Nissen

[57] **ABSTRACT**

Active and passive methods for the electro-dehumidification of damp structures in which moisture is collected in hollow tubular electrodes and is discharged externally of the structure into the ambient atmosphere. In the active method, positive and negative electrodes are connected to a D.C. voltage source, and the moisture migrates to the negative electrodes from which the water is discharged. In the passive method, the electrodes are connected to ground and a natural current is generated between the electrodes and ground which is negative. This causes the moisture to migrate to ground. After dehumidification by the active method, the electrodes can be disconnected from the voltage source and connected to ground so that operation is then carried out by the passive method, thereby preventing any subsequent increase in the moisture content in the structure. The electrodes themselves incorporate a depolarizing material which prevents corrosion or deterioration of the electrode material.

23 Claims, 7 Drawing Figures



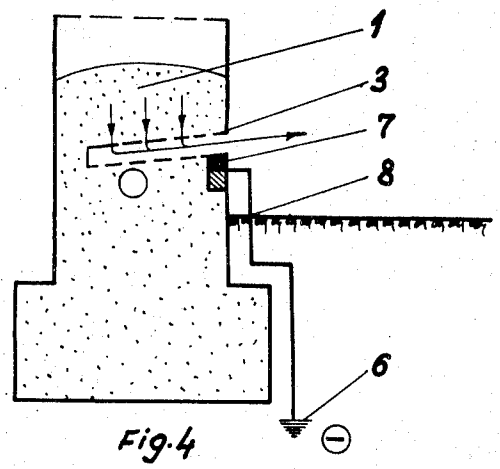


Fig. 4

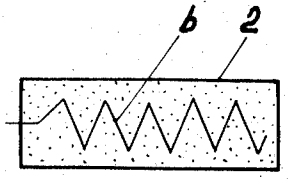


Fig. 5

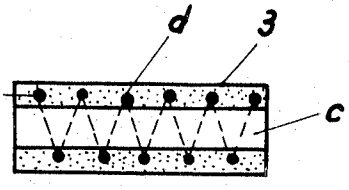


Fig. 6

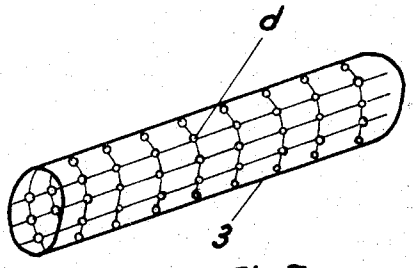


Fig. 7

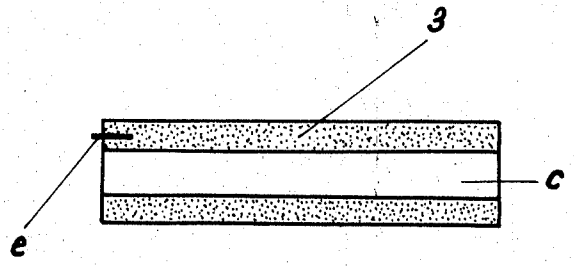


Fig. 8

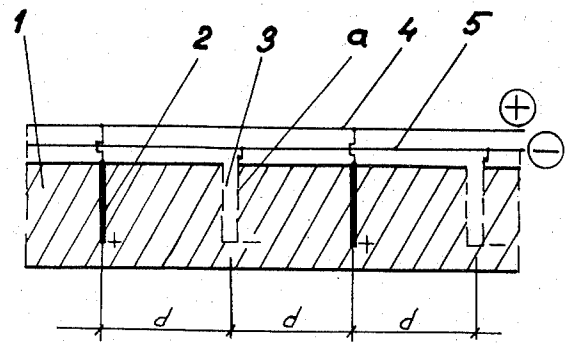


Fig. 1

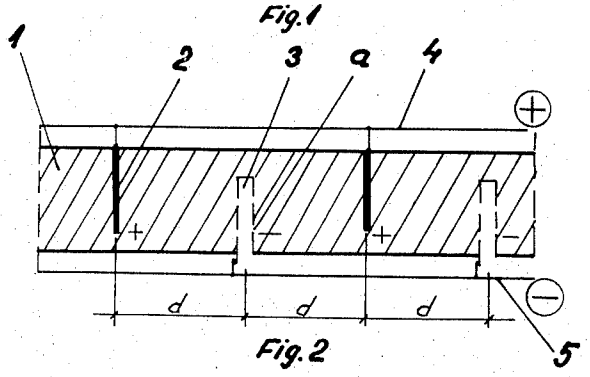


Fig. 2

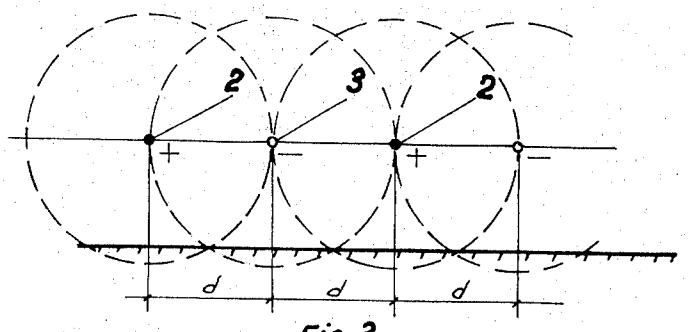


Fig. 3

METHODS AND ELECTRODES FOR THE DRYING OF DAMP BUILDINGS

CROSS RELATED APPLICATION

This Application is a continuation-in-part of my eariler application Ser. No. 744,162, filed July 11, 1968 now aboandoned.

BACKGROUND

1. a. Field of the Invention

The invention relates to electro-dehumidification methods for drying damp buildings and to the construction of electrodes for drying damp buildings and to the construction of electrodes which are used in these methods. Such methods fall into three categories:

a. a method which employs a continuous supply of electrical current, and hereafter termed, the active method,

b. a method which does not employ any voltage source, and hereafter termed, the passive method, and

c. a method which is a combination of the active and passive methods.

2. Prior Art

A passive electro-dehumidification method is known in which a number of electrodes are fixed in a damp zone of a wall and are interconnected to one another and connected in groups to grounding electrodes, without any external source of current.

An active method is also known in which the electrical circuit contains a source of direct current, the wall electrodes being connected to the positive pole, the grounding electrodes to the negative pole. In a variant of the passive method, superposed series of pairs of electrodes made of different metals are coupled together and then connected in groups to the grounding electrodes, the negative metal being in the lowest series. The disadvantage of the known/active methods is the requirement of special grounding electrodes. Another disadvantage is the removal of moisture only through electro-osmotic migration from the capillars of the building materials into the soil where the grounding electrodes (negative electrodes) are placed, and the moisture removal is less in the air.

The known active method also has the disadvantage of allowing salt efflorescence if the current and the voltage are not limited. If special precautions are not taken, both these methods allow the rapid corrosion/ and polarization of the electrodes.

SUMMARY OF THE INVENTION

In accordance with the invention there are provided hollow tubular negative electrodes which directly discharge the collected moisture to the ambient atmosphere. According to the active method, positive and negative electrodes are embedded in alternation in a wall of the structure in a damp region thereof which is to be dehumidified and positive and negative charges are applied to respective electrodes by connecting the same to respective poles of a voltage source. The moisture flows to the negative electrodes by electro-somotic action and the moisture is collected in the hollow water-permeable negative electrodes and discharged outside the wall directly to the ambient atmosphere.

According to the passive method of the invention, the electrodes are preferably all constituted as hollow tubular members and are connected to a grounding electrode, whereby a natural current flow is generated from the hollow/tubular members, to negative ground without the presence of an electrical source.

In further accordance with the invention, after the moisture has been removed from the structure by the active method, the electrical source may be disconnected and the electrodes in the wall connected to a grounding electrode, whereby the passive method now prevails. Thus, the active method may be utilized initially to accelerate the drying and thereafter the passive method insures a continued low humidity in the structure.

In further accordance with the invention, the electrodes incorporate depolarizing material in order to prevent corrosion of the electrodes as well as to achieve improved electrical contact. The depolarizing materials are applied both to the positive and negative electrodes for the active method.

The electro-draining system is founded on a new phenomenon discovered by me in electro-osmosis, and constituting the object of this invention. Specifically, an electro-osmotic flow is induced in the porous medium of the masonry wall, (assumed to be substantially homogeneous). This flow occurs from the neighboring positive and negative electrodes, as a result of the difference of direct electric potential, between these alternately mounted positive and negative electrodes.

In a first stage of this draining process, the water migrates from the positive to the negative electrode, gathers around the latter and is directly drained into the atmosphere because of its tubular shape and the porous structure of the electrode.

A lack of humidity is thus created around the positive electrode and a surplus around the negative one —both estimated by comparison with the quasi-constant moisture content in the remaining porous medium. This being the case, it is obvious that the thermodynamic and hydraulic moisture conditions in the porous medium are thrown out of balance. A suction or negative pressure state is created around the positive electrode and an overpressure occurs around the negative electrode.

In consequence, a migration of humidity occurs above the row of electrodes placed in the suction zone while the moisture conditions are being re-established around the positive electrodes to the detriment of the upper zones which are drying up. The moisture content which has recently migrated toward the positive electrodes, is again introduced into the electro-osmotic circuit and then released into the atmosphere through the negative electrodes.

Basically, this is the mechanism of conveying the moisture content according to the active method.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a horizontal section through a wall with positive and negative electrodes fixed at the same side of the wall;

FIG. 2 is a horizontal section through a wall with positive and negative electrodes fixed on opposite sides of the wall;

FIG. 3 diagrammatically illustrates in elevation the arrangement of the positive and negative electrodes in relation to the ground level, for the active electro-dehumidification method;

FIG. 4 is a vertical section through a wall showing an arrangement for passive electro-dehumidification;

FIG. 5 is a section through a solid cylindrical cartridge electrode containing a depolarizing mixture;

FIG. 6 is a section through a hollow tubular electrode;

FIG. 7 is a perspective view of a perforated tube which is usable as a hollow electrode; and

FIG. 8 is a section through a hollow tubular electrode with a graphite stick.

DETAILED DESCRIPTION

FIGS. 1 and 2 show two different arrangements for electro-dehumidification by the active method, and the same elements are designated with the same numerals. A masonry wall 1 from which moisture is to be removed contains a plurality of positive electrodes 2 and negative electrodes 3 interposed in alternation in a single row in the wall. Although the electrodes 2 and 3 are shown in a single row they can be offset in respective rows, but in such case it is necessary for the negative electrodes to be below the positive electrodes. In FIG. 1 the positive and negative electrodes are fixed on the same side of the wall, whereas in FIG. 2 they are fixed on opposite sides of the wall. The positive electrodes 2 are connected to conductor 4 and the negative electrodes 3 are connected to conductor 5, the conductors 4 and 5 being connected to respective poles of a source of direct current.

The positive electrodes 2 are constituted as cylindrical cartridges, as shown in FIG. 5, comprising an element of conductive material *b* embedded in a material of a depolarizing nature (as will be explained more fully hereinafter). The positive electrodes may also be constituted as soild metal bars.

The negative electrodes 3 are water permeable and are in the form of hollow tubular members to permit outflow of water directly to the ambient atmosphere. Thus, the interior of the hollow tubular members 3 are ventilated to atmosphere to remove the collected water. Obviously, the removal of the water can be effected in other ways and promoted by the use of fans, evaporators or the like. The tubular electrodes 3 may incorporate a depolarizing material as shown in FIG. 6. (to be explained more fully hereafter) and the active electrode material *d* may be in the form of a winding as shown in FIG. 6, or a perforated metallic tube as shown in FIG. 7, or a short graphite stick *e* as shown in FIG. 8. In all cases the electrode material is imbedded in the depolarizing material and the resulting assembly forms the electrode.

In the active method, the need for grounding electrodes is obviated and hence these are not used. The moisture migrates by electro-osmotic current to the negative tubular electrodes 3 wherefrom the moisture is discharged.

In order to achieve an optimum electro-dehumidification it has been found according to the invention that a precise positioning and spacing of the electrodes is necessary. Specifically, the electrodes are fixed in the wall 1, at a height from the ground level equal to 0.86 of the distance between the electrodes, and no lower than 5cm from the ground level.

The optimum spacing between the electrodes is given by the relation:

$$d = re^{(R_\pi l/\rho_z)} \qquad (1)$$

and the time needed for the thorough drying of the masonry or brickwork is given by the relation

$$t = c\,[Va\ ln\ (n/d)\ /k_e\ \pi U\ 1\ ] \qquad (2)$$

wherein:

R —the electrical resistance of the masonry, in ohms
ρz —the electrical resistivity of the wall, in ohm-cm
r—the radius of electrodes, in cm
e —the base of natural logarithms
l —the length of the electrodes, in cm
Ke —the electro-osmotic permeability coefficient of the masonry, in cm^2/sec. -Volt
Va —the volume of drained water, in cm^3
U —the voltage of the current source, in volts
c —is greater than 1 and is a safety coefficient for the operation of the installation.

The electrode spacing as given by equation (1) will result in most efficient drainage and minimum energy requirements.

In order to avoid salt efflorescence due to the operation of the active method, the density j of the current is limited to a value less than $2A/m^2$ and it preferably has a value between 0.1 to 1.0 $A/.m^2$. Corresponding to this current density is the voltage U given by the expression $U = j \cdot z \cdot d$

In the passive method, the need for a voltage source is eliminated and this cost of operation is obviated. In the passive method, as shown in FIG. 4, the electrodes 3 are fixed in wall 1 in the lower region of the zone where the humidity is to be reduced and the electrodes 3 are connected as seen in FIG. 4 to a grounding electrode 6 by a metallic belt 7 and a conductor 8. This arrangement permits the direct removal of moisture to the outside air withoutthe use of a voltage source.

The distance between the electrodes in the passive method is given by the relation:

$$d = (\ 1\ Ke\ \rho z)/(981\ k\ g\ l) \qquad (3)$$

and the number of electrodes for a single grounding electrode is given by the relation:

$$n_e = l/c \cdot (2\ h\ r\ H\ \rho z)\ /d\ R_p\ S_p) \qquad (4)$$

wherein:

$R\ p$ —is the electrical resistance of the grounding electrode, in ohms
h —is the height of the zone of humidity from the ground level, in cm
k —is the hydraulic filtration coefficient, in cm/sec.
Ke —is the electro-osmotic permeability coefficient in cm^2/sec. -volt
n —is the viscosity of the migrating water, in poise
g —is the specific gravity of the migrating water, gf/cm^3
ρz —is the electrical resistivity of the masonry, in ohm-cm.
r —is the radius of the electrodes, in cm
l—is the length of the electrode, in cm
Sp—is the area of the lateral surface of the grounding electrode, in cm^2
I —is the intensity in amps of the naturally induced current
c—is greater than 1 and is a safety coefficient for the operation of the installation.

In order to prevent a subsequent increase in the humidity of the dehumidified zone, the above-described active electrodehumidification installation can be converted, after the drying of the construction, to a passive electro-dehumidification installation by connecting the positive electrodes **2** and the negative electrodes **3** to the grounding electrodes **6.** In such case, water migrates to grounding electrodes **6.** As before in the passive method as described in FIG. **4,** the water is evaporated directly into the atmosphere in the course of such migration.

In order to avoid corrosion of the electrodes and achieve better electrical contact, the electrodes for these two methods are preferably constructed as cartridges containing a depolarizing mixture in relation to the nature of the electrode.

Thus, as shown in FIGS. **5–7,** if the conductive material is in the form of a copper winding, the depolarizing mixture is composed of powdered clay (approx. 50percent), powdered copper sulphate (approx. 20 percent), and Portland cement (approx. 30 percent).

If the conductive material is in the form of graphite rods, as shown in FIG. **8** the depolarizing mixture consists of pyrolusite, MnO_2 (approx. 20 percent), potassium permanganate, $KMnO_4$ (approx. 20 %), powdered graphite (approx. 40 percent), ammonium chlorate, NH_4Cl (approx. 0.5 percent) and Portland cement (approx. 20 percent).

If the conductive material is in the form of steel bars to be used for reinforced concrete, the depolarizing mixture consists of Portland cement (approx. 60 percent) and graphite powder (approx. 40 percent).

Each of these mixtures is prepared with water in order to obtain a plastic mastic for the cartridges, and the latter are constituted as follows:

the positive electrodes **2** (FIG. **5**) are cylindrical cartridges approximately 40 mm in diameter, including a winding *b* of copper, steel or aluminum wire, or a graphite rod *e*; the winding is approximately 3–4 mm in diameter; the spiral pitch of the turns of the winding is approximately 10 mm; the winding *b* is 25 mm in diameter; the grapthite stick is approx. 7 mm in diameter and approx. 7 cm in length; and the length of the carriage is two thirds of the depth of the wall **1.**

the negative electrodes **3** (FIG. **6**) are cylindrical tubular cartridges with a cylindrical interior bore approximately 15 mm in diameter and embedded in the wall is winding *d.* of copper, steel or aluminum or a graphite stick; the winding is 3 –4 mm in diameter, the pitch of the turns of the winding is approximately 10 mm; the winding is about 28 mm. in diameter; the length of the cartridge is two thirds of the depth of the wall **1.** In lieu of winding *d* a wire mesh of the same metal or a graphite stick *e* can be used. The winding *d* of negative electrode **3** can be replaced as shown in FIG. **7,** by a zinc-coated steel tube with perforations *a* therein, the area of the perforations being approximately 45percent of the entire surface area; the tube is embedded in the wall of the corresponding depolarizing mixture in the same manner as winding *d.*

The advantages of the methods for the electrodehumidification of buildings, according to this invention, are:

the active method excludes the need for grounding electrodes of difficult construction, as the humidity in the building is removed directly from the air through negative, tubular, ventilated electrodes;

the passive method accelerates the drying of buildings compared to the known passive methods, by means of ventilated, tubular electrodes, because in this way the time for removal of moisture is shortened;

the use of cartridge electrodes prevents corrosion of the electrodes and improves the electrical contact due to the shape of electrodes for the active as well as the passive methods;

the length of time of dehumidification is shortened, the operating costs are reduced by approximately **50%**, as well as the time of operation, because drying is achieved **5** times more quickly then by the known methods.

There are next given examples showing the use of the equations for establishing operative conditions for the active and passive methods of the invention.

EXAMPLE 1

Active method

To be calculated is the distance between the electrodes and the drying time of a ceramic brick masonry structure, 50 cm thick, the humidity upper level being 2 m. above the electrode line, by using a 24 V direct current source and 4 cm diameter electrodes.

The physical data of the masonry are as follows:

masonry humidity =**13%**, which is to be reduced to about **5%** i.e. a reduction of **8%**

$Ke = 10^{-5}$ cm²/sec. v

$\rho = 10^{-4}\Omega$cm

length of electrodes $l = 0.66$ $t = 0.66 \times 50$ **32** 33 cm

The volume of water that should be drained corresponding to 1 m of masonry length is:

$$Va = 100 \times 200 \times 0.08 = 80{,}000 \text{ cm}^3$$

The rate that can be ensured by the system having the electrodes placed at an optimum spacing distance of 50 cm, resulting from experience, is given by the relation:

$$Qe = K_e \pi U 1 \frac{1}{\ln\left(\frac{d}{r}\right)} = 10^{-5} \times 3.14 \times 24 \times \frac{100}{\ln \frac{50}{0.5}}$$

$$= 0.20 \text{ cm.}^3/\text{sec.} = 0.756 \text{ 1/h. 50 cm.}$$

The effective draining time is:

$t_{real} = c(Va/Qe) = 10\,(80.000/0.20) = 4{,}000{,}000$ sec

$= 1120\ h = 46$ days

$j = U/(pz.d) = 24/10^4 \times 50) = 48 \times 10^{-6}$A/cm²

$I = I.j. = 48 \times 10^{-6} \times 100 = 48 \times 10^{-4} A$

EXAMPLE 2

Passive method

To be calculated are the parameters for the passive electrodraining system for a 1 m thick brick masonry, with a dampness height of **1** m, and having the following parameters:

$\rho z = 2 \times 10^4\Omega$

$\rho p = 200\Omega$ cm $= 20\Omega$ m (measured resistivity of soil)

$\rho_1 = 500\Omega$ cm $= 5\ \Omega$ m (resistivity of earth filling)

$K_e = 0.5 \times 10^{-5}$ cm²/sec, V.

$K = 10^{-5}$ cm/sec

L = 200 cm (length of grounding bar)

dp = 3 in. = 7.62 cm (diameter of grounding bar)

The earthing resistance, calculated using Dwigt 's formula, is:

$$R_p = 32.55\ \Omega$$

Taking a 50 cm distance between electrodes, the number of electrodes corresponding to an earthing is given by the relation:

$$ne = \frac{2\pi r h \rho_z}{d \cdot R_p \cdot S_p} = \frac{2\times 3.14\times 4\times 100\times 2\times 10}{50\times 32.35\times 200\times 3.14\times 7.62}$$

$$= 65 \text{ electrodes/earth plate}$$

What is claimed is:

1. An active electro-dehumidification method for a damp structure, said method comprising embedding positive and negative electrodes in alternation in a wall of the structure in a damp region thereof which is to be dehumidified, forming the negative electrodes as hollow water-permeable members which can receive water externally thereof and convey the water for discharge outside said wall, and applying positive and negative charges to respective electrodes by connecting the electrodes to respective poles of a voltage source.

2. A method as claimed in claim **1**, wherein the distance between adjacent electrodes is given by the formula

$$d = re^{(R\pi l/\rho_z)}$$

wherein:

d —distance between adjacent electrodes
r —radius of the electrode
ρz —electrical resistivity of the wall
R —electrical resistance of the wall *l* —length of the electrode
e —base of natural logarithms;

and the electrodes are fixed at a distance from ground level equal to 0.86 of the distance between adjacent electrodes, and no lower than 5 cm from ground level.

3. A method as claimed in claim **2** comprising terminating dehumidification after full removal of the moisture in the wall after a minumum period of time as given by the following formula:

$$t = [Va\ in\ (d/r)\ ]/(\ Ke\ \pi U\ l)\ ps \text{ wherein:}$$

Va =is the volume of water to be removed
Ke =is the electro-osmotic permeability of the wall and
U =is the magnitude of voltage of the source.

4. A method as claimed in claim **3** comprising limiting the current density applied to the electrodes to a value of less than 2 ma/cm².

5. A method as claimed in claim **4**, wherein the current density is between 0.1 and 1.0 A/m².

6. A method as claimed in claim **5**, wherein the magnitude of the voltage of the source is given by the formula

$$U\ 32\ j\ \rho_z\ d$$

wherein:

j — is the current density and ρ_z and *d* are as defined above.

7. a method as claimed in claim **1** comprising disconnecting the electrodes from said voltage supply after dehumidification and connecting the electrodes to ground to cause migration of water from the electrodes to ground to prevent subsequent increase of humidity in the structure.

8. A method as claimed in claim **1**, wherein said electrodes incorporate depolarizing material to prevent corrosion of the electrodes.

9. A method as claimed in claim **8**, wherein each said electrode comprises an active material of copper, graphite or steel and the depolarizing material for the copper is 50% powdered clay, 20% powdered copper sulphate and 30% Portland cement; for the graphite is 20% pyrolusite (MnO_2), 20% potassium permanganate ($KMnO_4$), 40% powdered graphite, 0.5% ammonium chlorate, and 20% Portland cement; and for steel is 60% Portland cement and 40% powdered graphite.

10. A method as claimed in claim **9.** wherein the electrode inclusive of the depolarizing material contains a sufficient maount of water to form a moldable paste, and embedding the active material in dried form into the paste.

11. A method as claimed in claim **10,** including the step of covering the active electrode material with the mixture inclusive of depolarizing material, said active electrode material being a winding a copper, steel, or aluminum wire or a graphite rod, the diameter of the wire being between 3 and 4 mm, the pitch of the turns of the winding being 25 mm and the length of the electrode is two thirds of the depth of the wall.

12. A method as claimed in claim **10,** including the steps of forming the active material of the negative electrode in cylindrical form and covering the active material with said mixture inclusive of depolarizing material to form a tubular electrode with a hollow bore, said active material being open and water-permeable.

13. A method as claimed in claim **12,** wherein said active material of the negative electrode is selected from the group consisting of a perforated zinc-coated steel tube in which the perforations cover 45 percent of the surface area; an open meshwork of copper, steel or aluminum; and a spiral winding of copper, steel or aluminium wire of 3 -4 mm in diameter, the pitch of the turns of the winding being 10 mm, the diameter of the spiral being 28 mm; a graphite stick of approximately 7 mm in diameter and 7 cm in length and the length of the electrode is two thirds of the depth of the wall, the bore of the electrode being 15 mm in diameter.

14. A method as claimed in claim **1** wherein said electrodes are disposed in a single horizontal row.

15. A passive electro-dehumidification method for a damp structure, said method comprising embedding hollow, tubular, water-permeable electrodes into the lower portion of a wall of a structure which is to be dehumidified, connecting the electrodes to a grounding electrode whereby water migrates to said grounding electrodes by electro-dehumidification, discharging the water in the course of said migration externally of the structure, and spacing the electrodes at intervals given by the formula:

$$d = (J\ Ke\ N\ \rho z)/(981\ K\ g\ l)$$

wherein:

d = spacing of the electrodes
j= intensity of generated current flow
Ke = electro-osmotic permeability coefficient of the wall
n = viscosity of the migrating water ρ=electrical resistivity of the wall
g = specific gravity of the migrating water, and
l = length of the electrode,
K = hydraulic filtration coefficient and the maximum number of electrodes connected to the grounding electrode is given by the formula:

$$N_e = (2\ \pi\ r\ h\ \rho_z)/(d\ R_p\ S_p)$$

wherein:

N_e = number of electrodes for a grounding electrode
R_p = electrical resistance of the grounding electrode

S_p = lateral surface area of the grounding electrode
r = radius of the tubular electrodes
h = height of the moisture in the wall from ground level, and
d, and ρ_z are as defined hereinabove.

16. A method as claimed in claim **15,** wherein said tubular electrodes are formed with mixtures of depolarizing material to prevent corrosion of the tubular electrodes.

17. A method as claimed in claim **16,** wherein/each said tubular electrode comprises an active material of copper, graphite or steel and the depolarizing material for the copper is 50% powdered clay, 20% powdered copper sulphate and 30% Portland cement; for the graphite is 20% pyrolusite (MnO_2), 20% potassium permanganate ($KMnO_4$), 40% powdered graphite, 0.5% ammonium chlorate, and 20% Portland cement; and for steel is 60% Portland cement and 40% powdered graphite.

18. A method as claimed in claim **16,** wherein the depolarizing material contains a sufficient amount of water to form a moldable past which may embed the dried active material.

19. A method as claimed in claim **16,** including steps of forming the active material of the tubular electrodes in cylindrical form and covering the active material with said mixture of depolarizing material to form a tublar electrode with a hollow bore, said active material being open and water-permeable.

20. A method as claimed in claim **19,** wherein said active material of the tubular electrode is selected from the group consisting of a perforated zinc-coated steel tube in which the perforations cover 45percent of the surface area; an open meshwork of copper, steel or aluminum; and a spiral winding of copper, steel or aluminum wire of 3–4 mm in diameter, the pitch of the turns of the winding being 10 mm, the diameter of the spiral being 28 mm; a graphite stick of approximately 7 mm in diameter and 7 cm in length and the length of the electrode is two-thirds of the depth of the wall, the bore of the electrode being 15 mm in diameter.

21. A method for the electro-dehumidification of a damp structure, said method comprising embedding hollow, tubular, water-permeable electrodes into the structure to be dehumidified, establishing a negative electrical charge on said electrodes to cause migration of the moisture in the structure to said electrodes, and ventilating the hollow interior of the electrodes to atmosphere to remove the moisture collected therein.

22. A method as claimed in claim **21,** wherein said negative electrical charge is established by connecting the electrodes to the negative pole of a D.C. voltage source.

23. A method as claimed in claim **21,** wherein said electrodes are mounted in the structure such that their hollow interiors are open to the atmosphere whereby the collected moisture is directly evaporated into the atmosphere.

* * * * *