United States Patent [19]

Bergh et al.

[11] **3,878,312**

[45] **Apr. 15, 1975**

[54] **COMPOSITE INSULATING BARRIER**

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[73] Assignee: **General Electric Company**

[22] Filed: **Dec. 17, 1973**

[21] Appl. No.: **425,474**

[52] **U.S. Cl.** .... **174/9 F;** 138/145; 161/184; 161/189; 166/60; 166/242; 166/248; 174/209

[51] **Int. Cl.** **E21b 43/24;** H01b 17/60

[58] **Field of Search**.. 174/47, 68 C, 110 FC, 110 E, 174/137 R, 137 A, 137 B, 138 C, 209, 8, 9 F; 138/137, 140, 141, 144, 145, 146, DIG. 2, DIG. 3, DIG. 7; 161/184, 189; 166/57, 65 R, 242, 248, 302; 219/277, 278

[56] **References Cited**

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2,932,597	4/1960	St. John et al.	138/141 X
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2,991,808	7/1961	Siegmann et al.	138/141
3,030,253	4/1962	St. John et al.	138/DIG. 3 UX
3,213,254	10/1965	Strom	174/209 X
3,549,477	12/1970	Burgman	161/189 X
3,674,912	7/1972	Titus et al.	174/47 X

Primary Examiner—Laramie E. Askin
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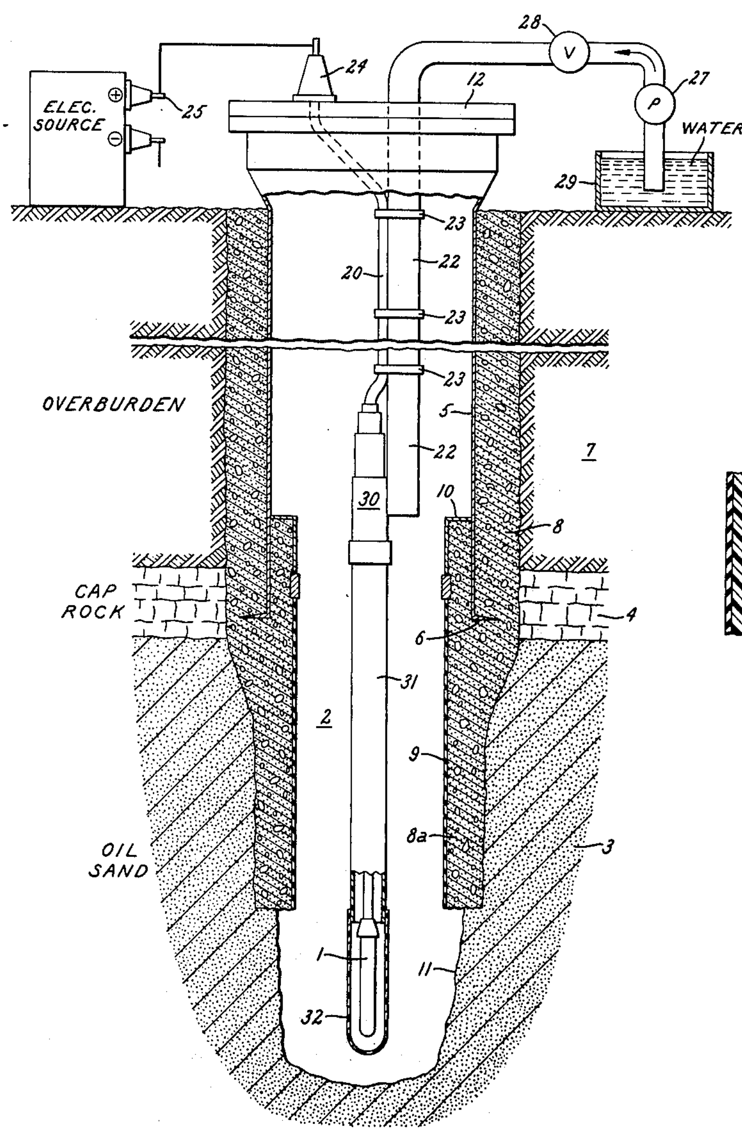
[57] **ABSTRACT**

A composite insulating barrier adapted for exposure to conductive fluid at high temperature and pressure with high unidirectional voltage stress across the barrier is formed of a rigid resinous insulating material such as glass filled epoxy, subject to wetting and ion migration. To prevent thermal degradation and electrical breakdown the epoxy is provided with at least one layer of fluid-impervious insulating material such as "Teflon," having a less negative or a positive temperature coefficient of resistance.

6 Claims, 6 Drawing Figures



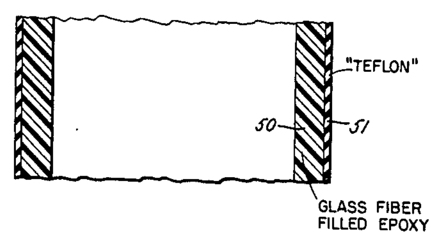


Fig. 1.

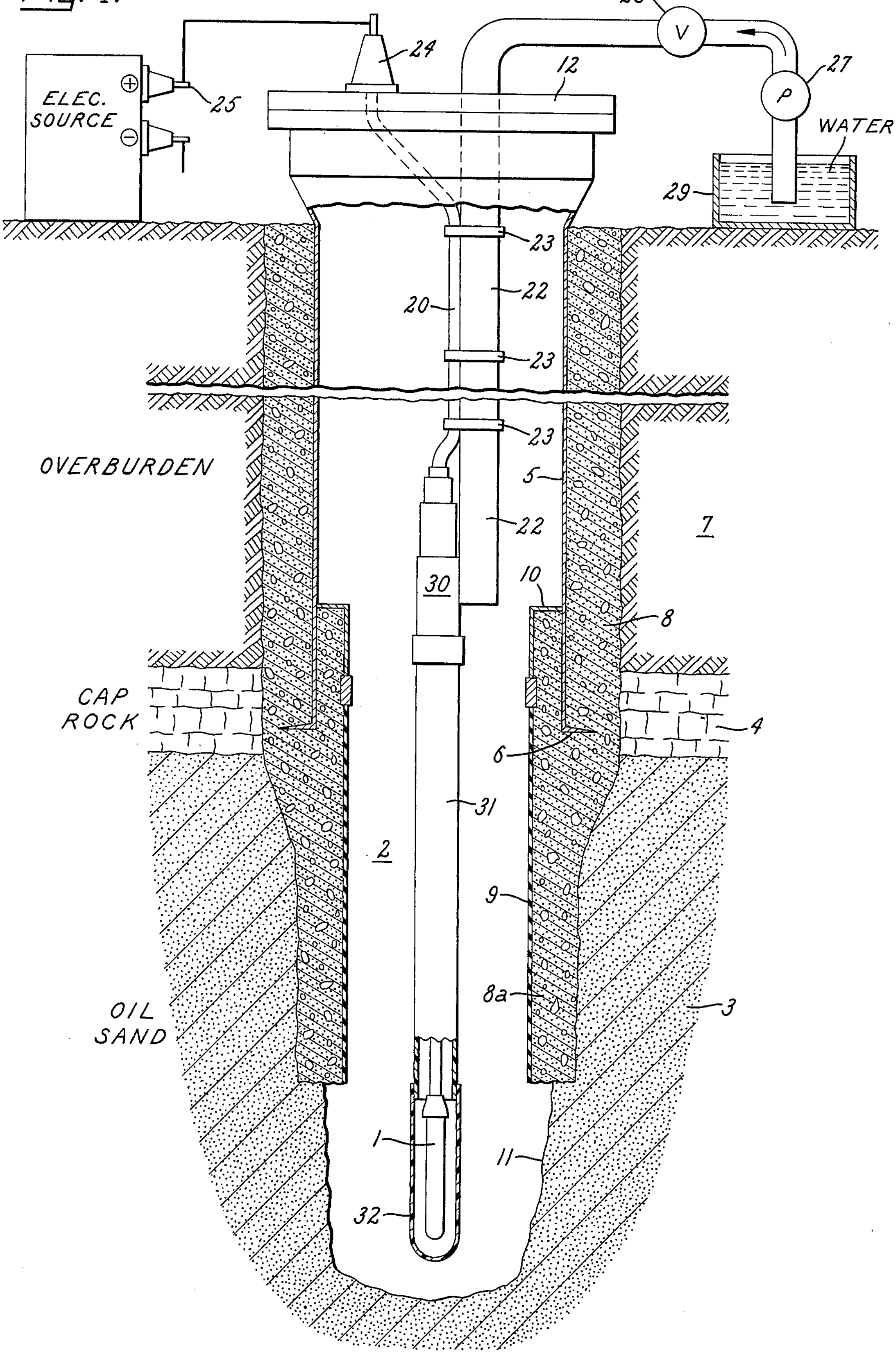

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Fig. 2.

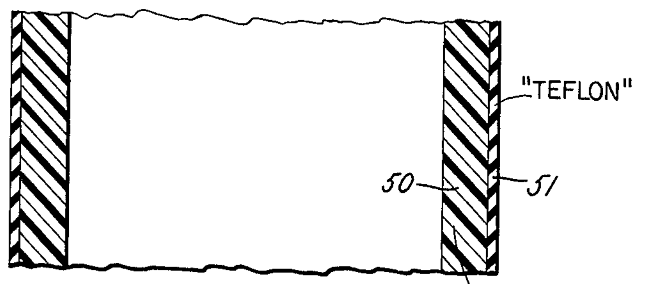


Fig. 4.

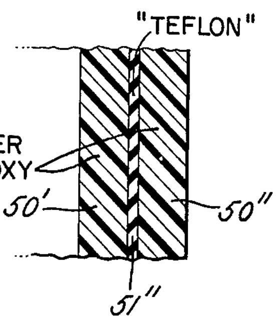


Fig. 3.

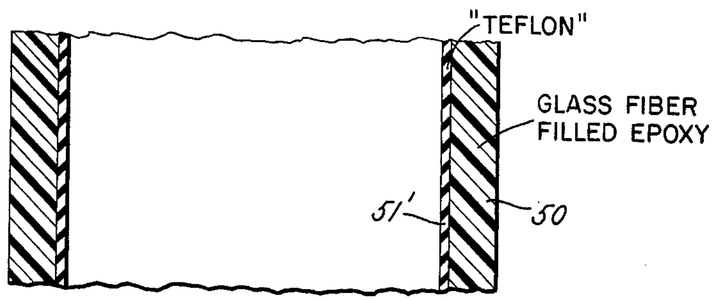


Fig. 5.

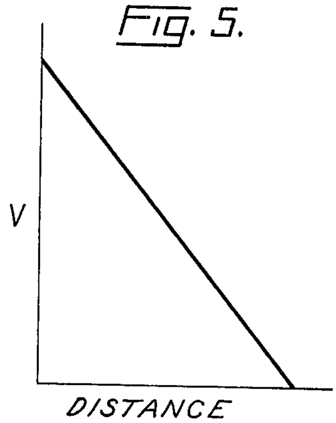
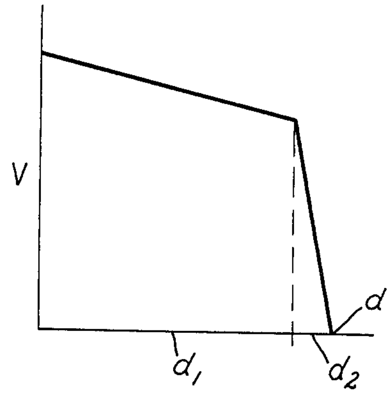


Fig. 6.



COMPOSITE INSULATING BARRIER

Our invention relates to composite insulating barriers especially adapted for use in high intensity unidirectional electric fields under high temperature conditions. The invention is particularly well adapted for use as a barrier between two bodies of conductive fluid at high temperature and pressure in a high voltage unidirectional electrostatic field. The following prior patents are representative of related art now known to applicants:

U.S. Pat. No. **3,206,537** — Steward
U.S. Pat. No. **3,531,236** — Braddick et al
U.S. Pat. No. **3,719,230** — Kemp et al

Most insulating materials are known to have a highly negative temperature coefficient of resistance, insulation resistance commonly decreasing in the order of several hundred to one as temperature is increased in the range of 20° to 120°C. In addition it is known that exposure to moisture severely reduces insulation resistance at any temperature. Some materials of course are less subject to permeation by moisture than are others. For use where exposed to moisture or to conductive fluids it is desirable to utilize high quality cast resinous materials such as glass fiber-filled epoxy resins and the like. Many such materials however are still subject to severe diminution of insulation resistance with increase in temperature.

In U.S. Pat. No. 3,674,912-Titus et al there is disclosed a high voltage underground electrode suitable for immersion in a moving stream of electrolytic fluid under high hydrostatic pressure and in an environment where the conductive fluid is maintained at a high temperature of the order of 250°F (120°C). To supply electrolytic fluid to the region of the anode there is disclosed in that patent a fluid supply conduit formed of insulating material such as an epoxy fiberglass tubing. We have discovered that even glass-filled cast epoxy resin is subject to disintegration in the extremely hostile environment constituted by simultaneous exposure to high pressures of the order of 1,000 to 3,000 pounds per square inch, high temperature of the order of 200° to 300°F, high voltage stress in the order of 200 to 2,000 volts d-c and direct exposure to conducting fluid on opposite sides of the insulating conduit.

Accordingly it is a general objective of our invention to provide an improved insulating plate or barrier of a design adapted to withstand high direct current voltage stress when exposed directly to high temperature conducting fluid.

It is a more particular object of our invention to provide new and novel means for relieving unidirectional voltage stress across an insulating plate or barrier having a highly negative temperature coefficient of resistance.

In carrying out our invention in a preferred embodiment we have constructed an insulating fluid conduit which comprises a composite structure having one layer of high dielectric strength material bonded to another layer of glass fiber-filled epoxy resin for mechanical strength.

Our invention will be more fully understood and its various objects and advantages further appreciated by referring now to the following detailed specification taken in conjunction with the accompanying drawing in which:

FIG. **1** is a foreshortened cross-sectional view of a bore hole through the earth showing a ground electrode assembly which includes an insulating fluid conduit in an environment where our invention is especially useful.

FIGS. **2, 3** and **4** are enlarged fragmentary cross-sectional views of a portion of the insulating conduit shown at FIG. **1** illustrating several embodiments of our invention; and

FIGS. **5** and **6** are graphical representations of electrical voltage stress characteristics in homogeneous and composite materials, respectively, to illustrate the effect and mode of operation of our invention.

Referring now to the drawing, we have shown a high voltage electrode **1** suspended in a deep bore hole **2** which penetrates an oil bearing formation **3** beneath the surface of the earth. Typically the formation **3** lies beneath a layer of cap rock **4.** The bore hole **2** may extend several hundreds or thousands of feet into the earth and is lined for most of its length with an elongate metal tube or casing **5** the lower end of which is terminated by a shoe **6** disposed at approximately the same elevation as cap rock **4.** In a manner well known to those skilled in the art the tubular casing **5** is sealed in the earth overburden **7** by an external annular layer **8** of concrete. Near the bottom of the bore hole **2** a tubular liner **9** of insulating material (e.g., an epoxy resin) extends from the tubular metal casing **5** for an appreciable distance into the oil bearing formation **3.** The insulating liner **9** is telescopically joined to the metallic casting **5** by means of an offset annular coupling **10.** The space between the exterior wall of the insulating liner **9** and the surrounding oil sand **3** is packed with high temperature concrete **8***a*. Although shown out of scale at FIG. **1** to simplify the drawing, it will be evident to those skilled in the art that the liner **9** may be of considerable length and a relatively small internal diameter. The electrode **1** is positioned in a cavity **11** formed in the oil sand immediately beneath the lower end of the insulating liner **9.** The bore hole **2** is closed at the top by a closure cap **12** sealed to the liner **5.**

The electrode **1** is suspended in the cavity **11** at the lower end of an insulated electric conductor or cable **20.** In the application illustrated at FIG. **1** the electrode **1** is preferably the anode in a high current circuit through the earth. Extending centrally through substantially the full length of the bore hole **2,** and in annular spaced relation with the casing **5** there is provided a tubing string **22** which constitutes a fluid conduit. As is well known to those skilled in the art the tubing string **22** is ordinarily formed of a plurality of metallic pipe sections coupled in end to end relation. The insulated cable **20** is fixed externally to the conduit **22** from a point below the cap **12** at ground level to a point slightly above the liner coupling **10** as by a plurality of clamps **23.** Both the cable **20** and the fluid conduit **22** emerge from the bore hole **2** through suitable sealed aperatures in the cap **12.** At its point of emergence the cable **20** is connected through an insulating bushing **24** on the cap **12** to the positive terminal **25** of a suitable source of high voltage unidirectional current supply. Above ground the fluid conduit **22** is connected through a shut off valve **28** to the outlet of a pump **27.** The inlet of pump **27** communicates with a source of fluid supply shown as a water reservoir **29.**

In the lower region of the bore hole **2,** and particularly in that section provided with the insulating liner

9, it is desirable that the fluid conduit be formed of insulating material and that the cable **20** be carried concentrically through the insulating section of fluid conduit in annular spaced relation with the conduit. For this purpose I provide immediately above the liner coupling **10** an offset or cross over conduit section **30** of a type described and claimed in U.S. Pat. No. **3,674,912**-Titus et al. Below the cross over conduit sections **30** there is coupled a tubular conduit section **31** formed of insulating material (e.g., fiberglass-filled epoxy tubing). The anode **1** at the lower end of cable **20** extends beyond the lower end of the insulating conduit **31** and is positioned within an insulating enclosure **32** fixed to the end of conduit **31.** The anode enclosure **32** is sufficiently permeable to permit egress of water but not sufficiently permeable to permit ingress of oil from the surrounding formation. The cable **20** is introduced axially into the cross over section **30** and passes axially through the insulating conduit section **31** in annular spaced relation therewith. Through the cross over conduit section **30** cooling fluid from the tubing string **22** is introduced into the insulating conduit section **31.** The conduit sections **30** and **31** thus serve as a combined fluid and electric conduit.

In the operation of the apparatus illustrated at FIG. **1** a conductive fluid electrolyte such as saline water is pumped downwardly through the conduits **22** and **31** to the bottom of the bore hole **2** and is maintained at a pressure greater than the ambient pressure in the surrounding formation **3.** The pressurized water is thus exceeded through the permeable enclosure **32** and fills the bottom of the bore hole from which it is gradually dissipated into the formation. The insulating fluid conduit section **31** is therefore exposed to pressurized conductive saline electrolyte on both its interior and exterior surfaces. The anode **1** is maintained at a unidirectional potential of the order of 200 to 2,000 volts above the potential of the surrounding ground formation and the insulating conduit **31** is subject to unidirectional voltage difference of this magnitude between its interior and exterior surfaces. In the conduction of large amounts of power through the anode **1** to heat the formation **3** and promote the flow of oil therefrom, the saline water filling the bottom of the bore hole may be heated to the order of 200° to 300°F but remains liquid due to the extremely high ambient hydrostatic pressure several thousand feet below the surface of the earth.

We have discovered that under the extremely hostile conditions described above an insulating conduit such as the conduit **31** formed of glass fiber-filled cast epoxy resin, even though free of voids is subject to electrical breakdown and thermal degradation. While the cause of such breakdown is not known with certainty, it is believed that the fibers of an epoxy-bound glass-fiber tube, being under high unidirectional electric stress and exposed to saline water under pressure of many hundreds of pounds per square inch, are wet by the saline water. This wetting effect may be the result of electroosmosis and sodium ion migration along the fibers. The wet fibers then provide a high resistance path in which leakage current generates sufficient heat to result in thermal degradation of the epoxy and dissolution of the glass. Under these conditions therefore glass-filled, cast epoxy as well as other organic polymers, will demonstrate a highly negative temperature coefficient of resistance.

At FIGS. **2, 3** and **4** we have illustrated composite structures of insulating tubing by means of which unidirectional voltage stress on the epoxy section may be sufficiently relieved to avoid degradation at high temperatures and pressures when exposed to conductive fluids and high potential difference on opposite sides of the insulating barrier. At FIG. **2** we have shown a section of glass filament wound epoxy tubing **50** coated on the outside with a relatively thin film **51** of polytetrafluoroethylene known commercially as Teflon. At FIG. **3** we have shown a similar section of epoxy glass tubing **50** having an internal coating **51'** of Teflon. In FIG. **4** we have shown a composite tubing structure comprising internal and external layers **50', 50''** of epoxy glass tubing with an intermediate layer **51''** of Teflon. If desired of course more than a single layer of Teflon may be utilized, as by coating the epoxy glass tube both internally and externally. We believe however that a single layer of a material such as Teflon, which blocks ion migration and thereby provides a substantially lower negative temperature coefficient of resistance than does epoxy, is sufficient to relieve the epoxy layer of voltage stress and avoid thermal degradation.

The tubing illustrated at FIGS. **2, 3** and **4** may be formed by filament winding of epoxy impregnated glass fiber in a manner well known to those skilled in the art. In the case of FIGS. **3** and **4** the Teflon layer may be laid down on a mandrel prior to winding the outer or final layer of glass filled epoxy and bonded thereto in the winding process. In the embodiment shown at FIG. **2** the Teflon may be applied to the outside of a filament wound epoxy glass tube in the form of tape or a heat shrunk sleeve of Teflon.

At FIGS. **5** and **6** we have shown voltage stress characteristics which illustrate the effect of our composite insulating structure. The curve shown at FIG. **5** represents the voltage stress characteristic across a homogeneous insulating barrier of epoxy glass fiber alone, the abscissa of the curve representing distance transversely through the insulating barrier from a first wall exposed to high voltage V to the opposite wall exposed to zero voltage. The ordinant represents electrostatic voltage at various points progressively through the thickness of the barrier. It will be observed that a substantially linear distribution is characteristic of a uniform or homogeneous material. At high temperature the linear characteristic of FIG. **5** would have considerably reduced slope, as apparent at FIG. **6.**

At FIG. **6** we have illustrated a similar distance-voltage characteristic under high temperature conditions for a composite material having a total thickness d consisting of an epoxy layer having a thickness d_1 and a Teflon layer having a thickness d_2. In this case voltage drop through the barrier is distributed in the several layers inversely in proportion to their insulating resistance. At very high temperature when the insulation resistance of the epoxy layer is severely diminished because of its negative temperature characteristic of resistance, the greater portion of the voltage drop takes place in the Teflon layer in which insulating resistance is not severely reduced at high temperature. Thus only a small portion of the voltage drop occurs in the epoxy layer thereby significantly to relieve the voltage stress on the layers having a highly negative temperature coefficient of resistance.

While we have illustrated our invention in particular reference to a composite insultating barrier formed of glass fiber-filled cast epoxy and the polytetrafluoroethylene composition known as Teflon, it will be appreciated by those skilled in the art that any rigid insulating material having an undesirably high negative temperature coefficient of resistance may be combined with a less negative or positive material with like results. In this way we are able to construct an insulating barrier for use in a high temperature, high pressure fluid environment which provides high mechanical strength with good insulating properties under adverse conditions. In such a barrier it is, in general, desired that the combined structure have low water absorption, (desirably less than 0.01%/day), a low dissipation factor at 60 cycles (i.e., of the order of 0.0003) and high resistivity.

While we have shown and described by way of illustration certain preferred embodiments of our invention, many modifications will occur to those skilled in the art and we therefore wish to have it understood that we intend in the appended claims to cover all such modifications as fall within the true spirit and scope of our invention.

What we claim as new and desire to secure by letters Patent of the United States is:

1. In combination with two bodies of electrically conductive fluid having a high unidirectional potential difference therebetween, said fluids being exposed to high temperature and high differential pressure conditions, a composite insulating barrier interposed between and in contact with said fluids, said barrier comprising a first layer of insulating material having a highly negative resistance-temperature coefficient and a second layer of insulating material having a substantially less

negative resistance-temperature coefficient, at least one said insulating layer having sufficient mechanical strength to withstand said differential pressure, whereby increasing temperature progressively reduces the voltage stress imposed across said first layer of insulating material.

2. The combination of claim **1** wherein said first layer is formed of a rigid insulating material.

3. The combination of claim **1** wherein said first layer comprises a glass fiber-filled cast organic resin.

4. The combination of claim **1** wherein said first layer comprises cast epoxy and said second layer is formed of polytetrafluoroethylene.

5. The combination of claim **4** wherein said first layer comprises a cast body of glass fiber-filled epoxy.

6. In combination, a composite insulating conduit interposed between two bodies of electrically conductive fluid at different pressures, means maintaining said bodies of fluid at different unidirectional potentials sufficient to impose a high intensity electrostatic field between inner and outer surfaces of said conduit, said conduit comprising a first layer of rigid insulating material having a predetermined temperature coefficient of resistance, said first insulating layer being sufficiently rigid to withstand the pressure differential between said fluid bodies, and a second layer of insulating material having a significantly different temperature coefficient of resistance, at least one of said materials having a negative temperature coefficient of resistance and the material having the most negative coefficient being subject to electrical breakdown under the ambient conditions of temperature, pressure and electrical stress.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,878,312

DATED : April 15, 1975

INVENTOR(S) : Dustin D. Bergh, Charles H. Titus & J. Kenneth Wittle

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading of the patent, line 6 -

Change Assignee: General Electric Company

To Assignee: Electro-Petroleum, Inc., Bryn Mawr, Pa.

Signed and sealed this 1st day of July 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks

UNITED STATES PATENT OFFICE
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C. MARSHALL DANN
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