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Ziemek

(54) METHOD OF OPERATING AN ELECTRICAL HEATING ARRANGEMENT

(75) Inventor: **Gerhard Ziemek**, Langenhagen (DE)

Correspondence Address:
WARE FRESSOLA VAN DER SLUYS & ADOLPHSON, LLP
BRADFORD GREEN, BUILDING 5, 755 MAIN STREET, P O BOX 224
MONROE, CT 06468 (US)

(73) Assignee: **Ziemek Cable Technology GmbH**

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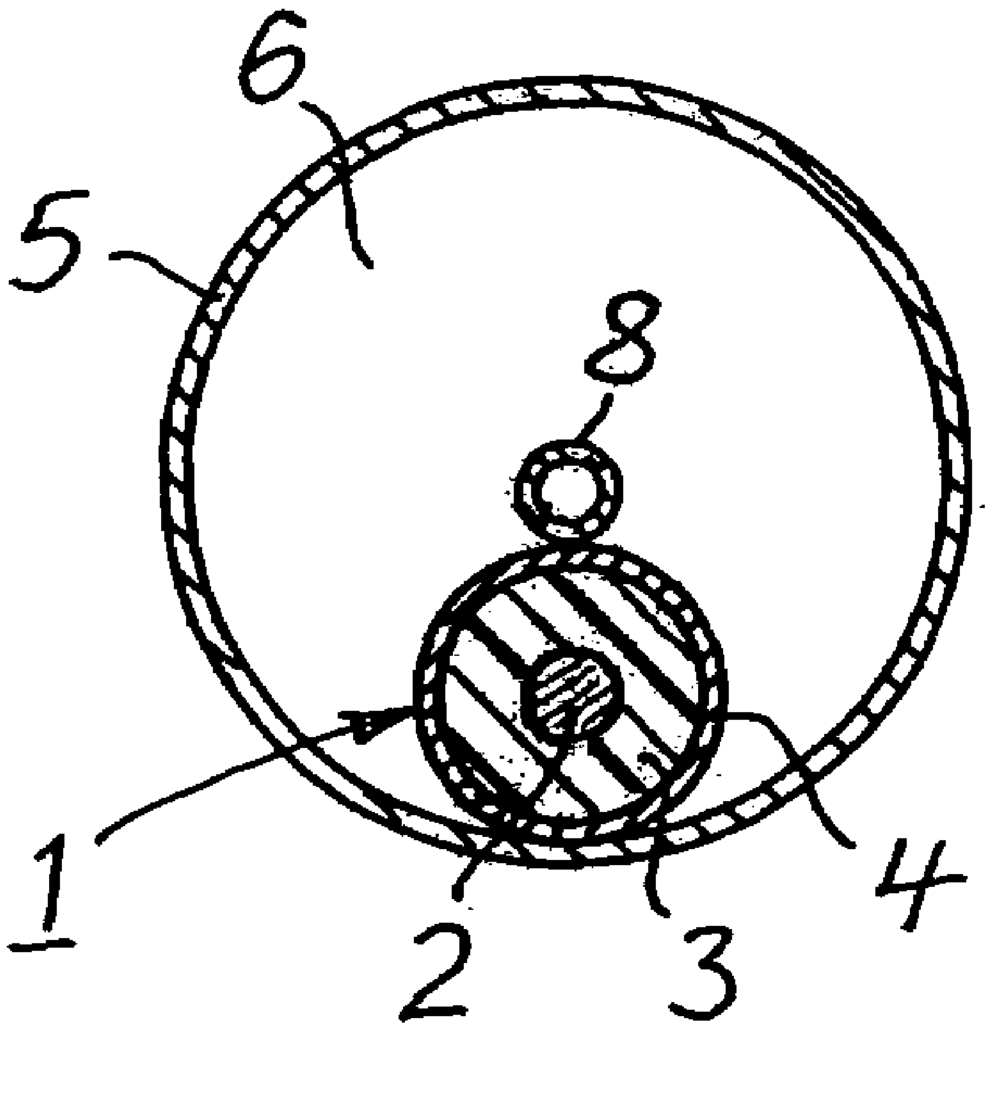
(57) **ABSTRACT**

A method of operating an electrical heating arrangement of considerable length using a heating line having at least one heating conductor surrounded by an insulation resistant to high temperatures. A metal tube (**4**) abutting against the insulation (**3**) is formed around the heating line (**1**) and the heating line (**1**), which is equipped with the metal tube (**4**) is inserted into a metallic tube (**5**) which has a diameter larger than the metal tube (**4**) and encloses, in addition to the heating line (**1**), an axially continuous clearance space (**6**). A non-combustible gas having a lower kinematic viscosity compared with air is inserted into the clearance space (**6**), the gas completely filling the latter and being kept permanently under pressure.



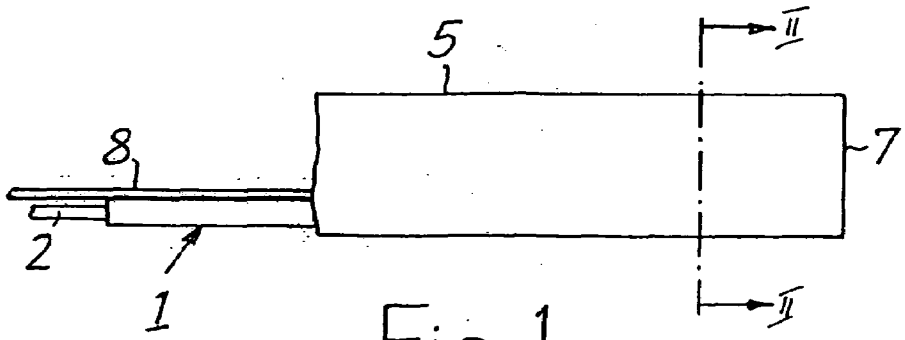



Fig. 1

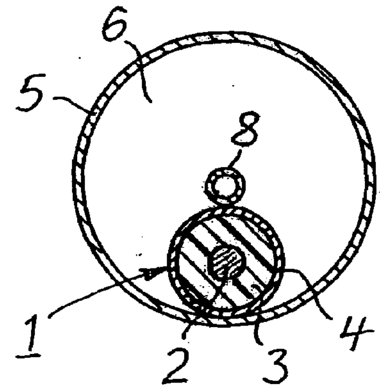



Fig. 2

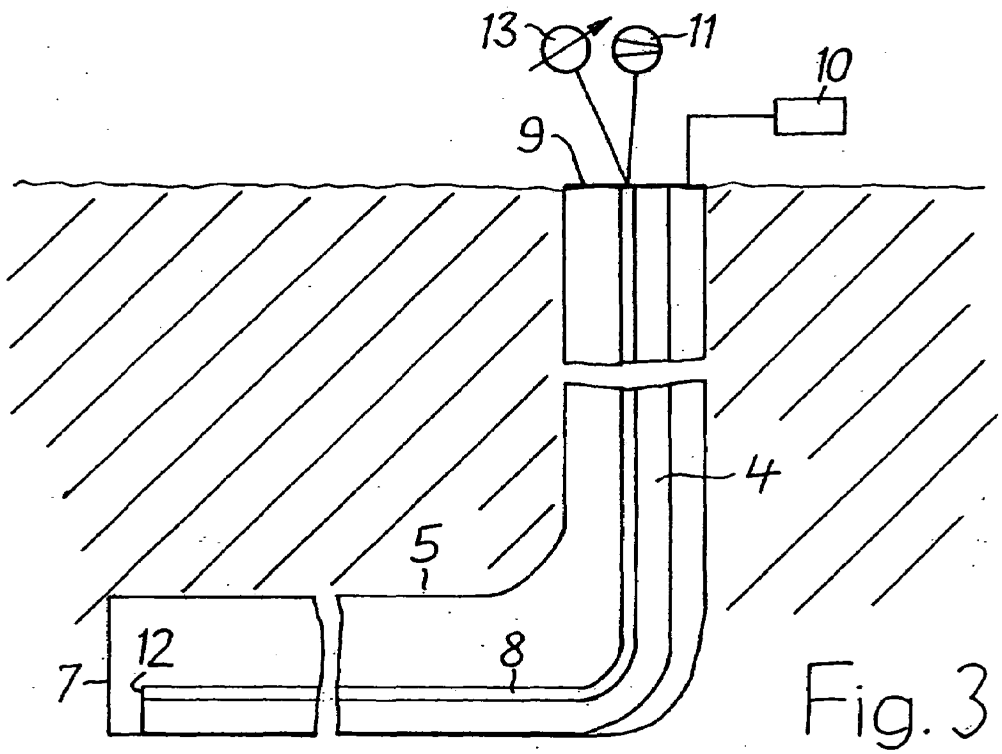



Fig. 3

# METHOD OF OPERATING AN ELECTRICAL HEATING ARRANGEMENT

**[0001]** The invention relates to a method of operating an electrical heating arrangement of considerable length using a heating line having at least one heating conductor surrounded by an insulation resistant to high temperatures.

**[0002]** Such heating lines are known and are obtainable on the market. Their heating conductors are encased, for example, with mineral or ceramic materials which are resistant at high temperatures. Such heating lines are used in principle where heating at high temperatures of, for example, up to 500° C. is to be effected.

**[0003]** A special field of use of heating lines for very high temperatures is crude oil exploration from oil reserves in which the crude oil is bound, for example, in porous rock, in sand or in shale. Such oil reserves are located in the ground at a depth of approximately 300 m. They extend over a large area at this depth. To deliver the crude oil, therefore, not only are vertically running bores placed, but said bores are continued in the ground over large distances of, for example, 600 m. In order to be able to pump the crude oil out of these reserves as completely as possible with a conventional technique, it must be brought to a sufficiently light-bodied state by heating the surrounding earth or rock.

**[0004]** The object of the invention is to specify a method of operating an electrical heating arrangement with which it is possible to also heat deeper regions of the earth's surface with high efficiency.

**[0005]** This object is achieved according to the invention in a method of the type mentioned at the beginning in that

- **[0006]** a metal tube bearing against the insulation is formed around the heating line,
- **[0007]** the heating line equipped with the metal tube is introduced into a metallic tube which has a diameter larger than the metal tube and encloses, in addition to the heating line, an axially continuous clearance space, and
- **[0008]** in the operating case, a non-combustible gas having a lower kinematic viscosity compared with air is introduced into the clearance space, said gas completely filling the latter and being kept constantly under pressure.

**[0009]** The expression "air" in this case refers to the gas mixture present at the earth's surface, with 77% nitrogen, about 21% oxygen and about 2% residual quantities.

**[0010]** The outer metallic tube serves to protect the heating line against the oil to be delivered and other aggressive media which could lead to corrosion of the metal tube of the heating line. The heat of up to 1000° C. generated by the heating line is to be transferred as completely as possible to the outer metallic tube so that the desired heating of the oil to be delivered is achieved.

**[0011]** With this method, the heat generated by the heating line is transferred at high efficiency by optimum heat transfer to the outer metallic tube, which in the fitted position is in direct contact with the earth or rock to be heated. This essential advantage is achieved by the gas located in the clearance space and having a low kinematic viscosity, by means of which gas the heat transfer by convection between the metal tube of the heating line and the outer metallic tube is substantially increased. As a result, the metallic tube and thus also its surroundings are heated to a correspondingly more intense degree. Crude oil located in the region of the metallic tube is thereby heated in such a way that it becomes light-bodied and can be pumped out more easily.

**[0012]** The radiation as a further proportion of the heat transfer between the metal tube of the heating line and the outer metallic tube can be increased by roughening the outer surface of the metal tube by the latter being subjected, for example, to sand blasting. This measures leads to further improved transfer of the heat generated by the heating line to the outer metallic tube.

**[0013]** The gas used is preferably an inert gas, such as argon. This results in the further advantage that corrosion cannot occur in the space enclosed by the metallic tube, and therefore the material selection for the metal tube of the heating line is not critical.

**[0014]** The method according to the invention will be explained with reference to the drawings as exemplary embodiment.

**[0015]** In the drawings:

**[0016]** FIG. **1** shows a schematic illustration of a heating arrangement which can be used for the method according to the invention and with layers removed in sections.

**[0017]** FIG. **2** shows a section through FIG. **1** along line II-II in an enlarged illustration.

**[0018]** FIG. **3** likewise schematically shows a heating arrangement laid in the ground.

**[0019]** Shown in FIGS. **1** and **2** is a heating arrangement with a heating line **1** which has an insulated heating conductor **2** which is surrounded by a high-temperature insulation **3**. Suitable materials for the insulation **3** are mineral and ceramic substances. The heating line **1** may also have more than one insulated heating conductor. It may advantageously consist of three intertwined, mineral-insulated heating conductors.

**[0020]** A metal tube **4** is placed over the insulation **3** of the heating conductor **2** and bears against the insulation. It is advantageously made of a material that is a good conductor of heat. To improve the transverse stability and the flexibility of the metal tube **4**, the same may be corrugated transversely to its longitudinal direction.

**[0021]** The heating line **1** is arranged in an outer metallic tube **5**, which has a diameter larger than the diameter of the metal tube **4** and additionally encloses a clearance space **6** relative to the heating line **1**. The areas of the outer surface of the metal tube **4** and of the inner surface of the outer metallic tube **5** are preferably to have a ratio of 1:4. The clearance space **6** is large enough so that a sufficient quantity of gas under pressure can be introduced into said clearance space **6** and held therein. The pressure with which the gas is introduced into the clearance space **6** is to be at least 1 bar. The outer metallic tube **5** is tightly closed hermetically at its end **7**. It has a wall thickness of preferably 2 to 4 mm and is preferably made of high-grade steel so that rusting can be ruled out in the long run.

**[0022]** The heating arrangement also includes a small metallic tube **8**, through which gas can be forced into the clearance space **6**. The small tube **8** is fastened to the metal tube **4**. It can run rectilinearly, but can also be placed helically around the metal tube **4**. To increase its transverse stability and its flexibility, the small tube **8** is advantageously corrugated transversely to its longitudinal direction.

**[0023]** For heating a region located deep in the earth **9**, first of all the outer metallic tube **5** is installed in a borehole, through which oil is to be pumped out of an oil reserve located in the ground. The borehole comprises a vertical bore having an approximately horizontally extension of considerable length. The metallic tube is installed as indicated in FIG. **3**. After that, the heating line **1** with small tube **8** fastened thereto is pushed into the outer metallic tube **5** to such an extent that its end lies approximately at the level of the closed end **7**. After that, the metallic tube **5** is also tightly closed at its proximate end **9**. The heating line **1** is then connected to a voltage source **10**, such that, after switch-on, it generates heat preferably up to 1000° C. The small tube **8** is at the same time connected to a supply of non-combustible gas provided with a pump **11**. The gas is forced into the small tube **8** by the pump **11**. It discharges at its remote end **12** and thus passes into the clearance space **6**, which it gradually fills from the remote end. Air located beforehand in the clearance space **6** is forced out of the same by the gas. To this end, a closable valve is advantageously provided in that closure of the metallic tube **5** which lies at the top.

**[0024]** As already mentioned, the pressure with which the gas is to be introduced into the small tube **8** and thus into the clearance space **6** is to be at least 1 bar. This pressure is monitored, for example by means of a pressure gauge **13**, while the method is being carried out. It is preferably kept constant through the use of a corresponding controller.

**[0025]** The gas forced into the clearance space **6** has a lower kinematic viscosity than air, which is $96.7\times10^{-6}$ $m^2$/sec at **500**C. The gas used is preferably to have a kinematic viscosity of $90\times10^{-6}$ $m^2$/sec at 500° C.

**[0026]** In an especially advantageous manner, the gas used is an inert gas, such as, for example, and preferably, argon, having a kinematic viscosity of $72.62\times10^{-6}$ $m^2$/sec. With argon as the gas located in the clearance space **6**, the heat transfer by convection between metal tube **4** and outer metallic tube **5** is increased by about 15%. In addition, an inert gas in the clearance space **6** prevents any corrosion at the metal tube **4** and at the inner surface of the metallic tube **5**. Therefore any desired metal, such as steel for example, can be used for the metal tube **4**.

**[0027]** The heat transfer between the metal tube **4** and the outer metallic tube **5** by radiation can be additionally improved by the outer surface of the metal tube **4** being roughened. This can be advantageously achieved by sand blasting. By means of such a measure, the heat transfer from the metal tube **4** to the outer metallic tube **5** by radiation can be increased by about 25%, which leads to an additional improvement in the efficiency of this method.

**1**. A method of operating an electrical heating arrangement of considerable length using a heating line having at least one heating conductor surrounded by an insulation resistant to high temperatures, characterized in that

a metal tube bearing against the insulation is formed around the heating line,

the heating line equipped with the metal tube is introduced into a metallic tube which has a diameter larger than the metal tube and encloses, in addition to the heating line, an axially continuous clearance space, and

a non-combustible gas having a lower kinematic viscosity compared with air is introduced into the clearance space, said gas completely filling the latter and being kept constantly under pressure.

**2**. The method according to claim **1**, characterized in that a gas having a kinematic viscosity of at most $90\times10^{-6}$ $m^2$/sec at 500° C. is used.

**3**. The method according to claim **2**, characterized in that an inert gas is forced into the clearance space.

**4**. The method according to claim **3**, characterized in that argon is forced into the clearance space.

**5**. The method according to claim **4**, characterized in that the gas pressure is monitored.

**6**. The method according to claim **5**, characterized in that the gas pressure is regulated to a constant value.

**7**. The method according to claim **6**, characterized in that the gas is fed from the remote end via a small tube which is fastened to the metal tube of the heating line.

**8**. The method according to claim **7**, characterized in that the outer surface of the metal tube of the heating line is roughened, preferably by sand blasting.

**9**. The method according to claim **1**, characterized in that the gas pressure is monitored.

**10**. The method according to claim **9**, characterized in that the gas pressure is regulated to a constant value.

**11**. The method according to claim **10**, characterized in that the gas is fed from the remote end via a small tube which is fastened to the metal tube of the heating line.

**12**. The method according to claim **1**, characterized in that the outer surface of the metal tube of the heating line is roughened, preferably by sand blasting.

**13**. An apparatus comprising:

a heating line having at least one heating conductor surrounded by an insulation resistant to high temperatures,

a metal tube bearing against the insulation and formed around the heating line,

wherein the heating line with the metal tube is positioned in a metallic tube which has a diameter larger than the metal tube and encloses, in addition to the heating line, an axially continuous clearance space, and

a non-combustible gas having a lower kinematic viscosity compared with air completely filling the clearance space, said gas having a constant pressure.

**14**. The apparatus according to claim **13**, wherein the gas has a kinematic viscosity of at most $90\times10^{-6}$ $m^2$/sec at 500° C.

**15**. The apparatus according to claim **13**, wherein said non-combustible gas is an inert gas.

**16**. The apparatus according to claim **15**, wherein said inert gas is argon.

**17**. The apparatus according to claim **13**, further comprising means to monitor the pressure of said non-combustible gas.

**18**. The apparatus according to claim **17**, further comprising means for regulating the pressure of said non-combustible gas so as to maintain the pressure of said non-combustible gas at said constant pressure.

**19**. The apparatus according to claim **13**, further comprising means for feeding said non-combustible gas from a remote end of said clearance space via a small tube which is fastened to the metal tube of the heating line.

**20**. The apparatus according to claim **19**, wherein an outer surface of the metal tube of the heating line is roughened.

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