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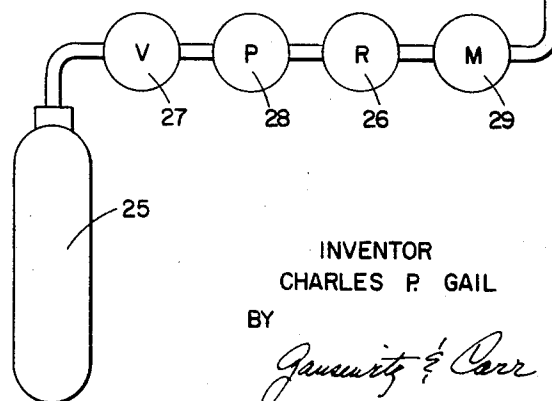
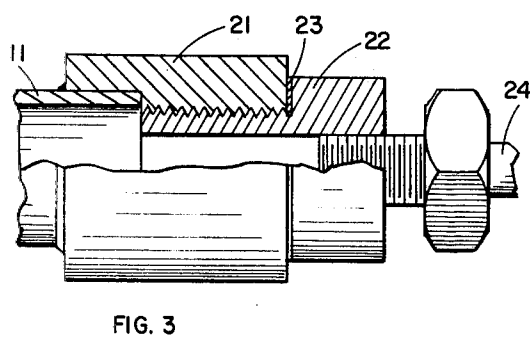
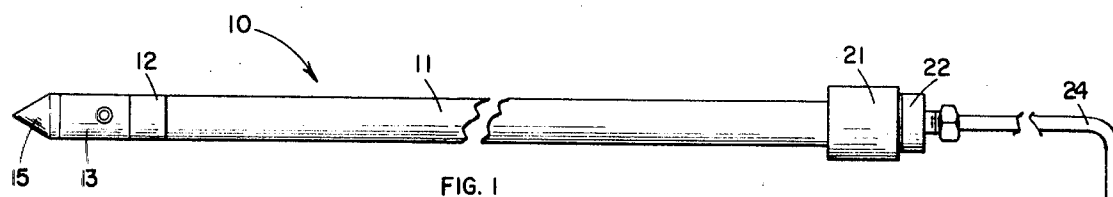
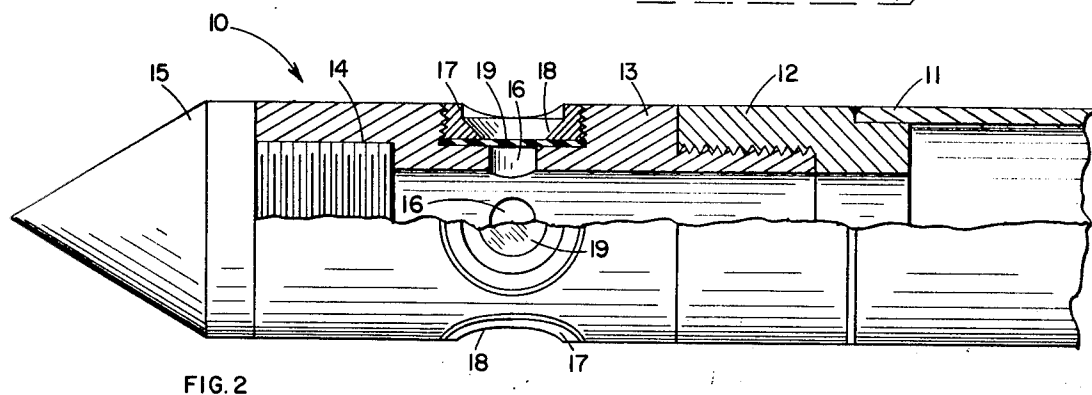
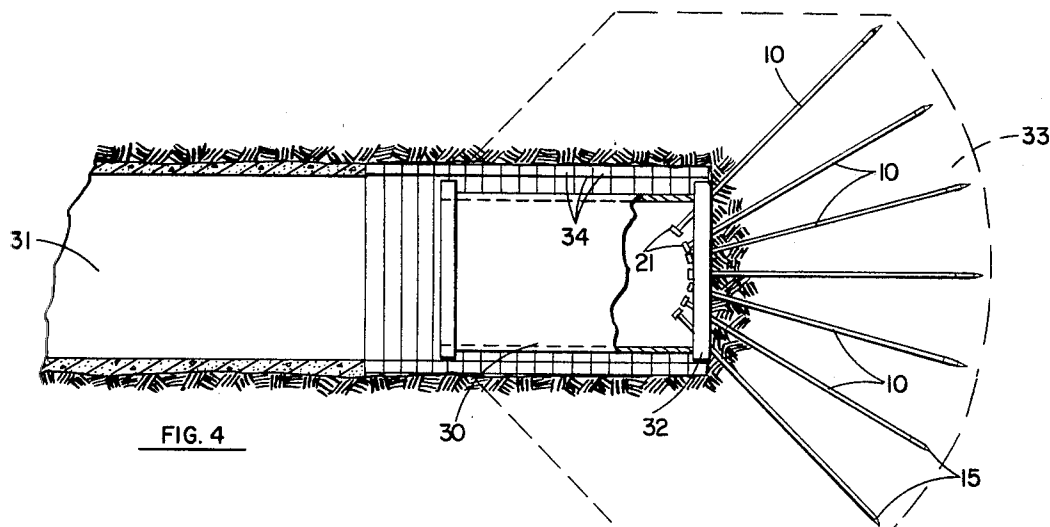
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ARRANGEMENT FOR SOLIDIFICATION OF EARTH FORMATIONS

Filed Jan. 29, 1968

3 Sheets-Sheet 1



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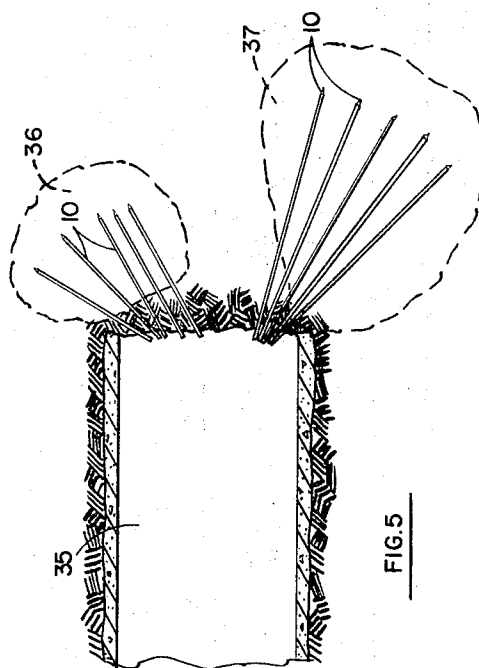
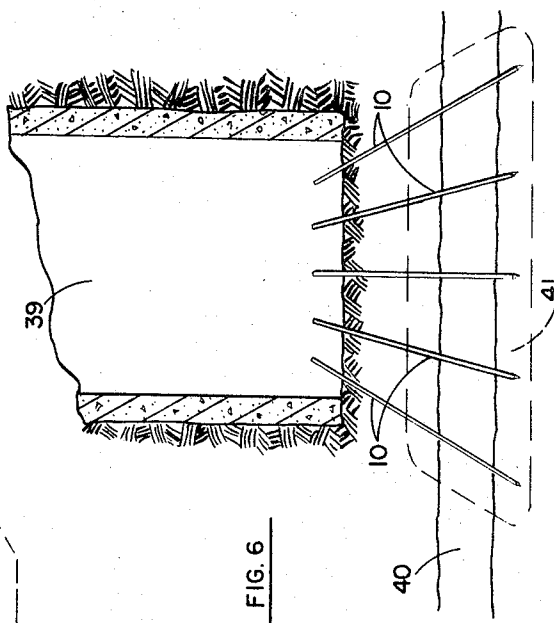
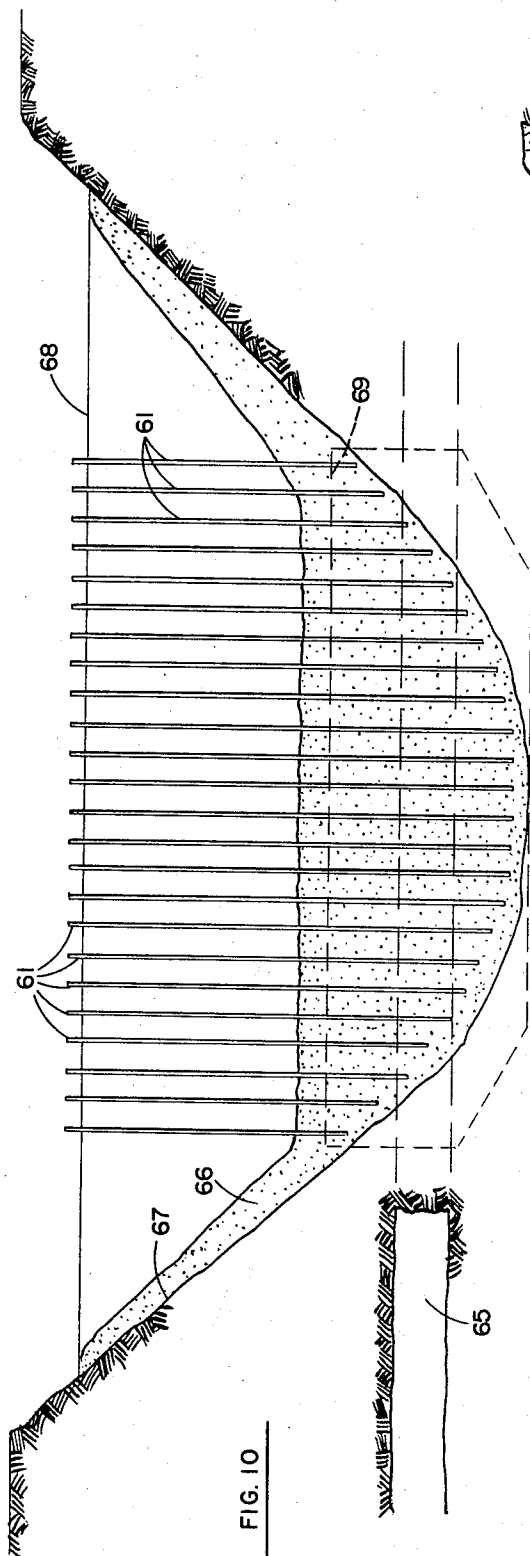
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ARRANGEMENT FOR SOLIDIFICATION OF EARTH FORMATIONS

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3 Sheets-Sheet 3



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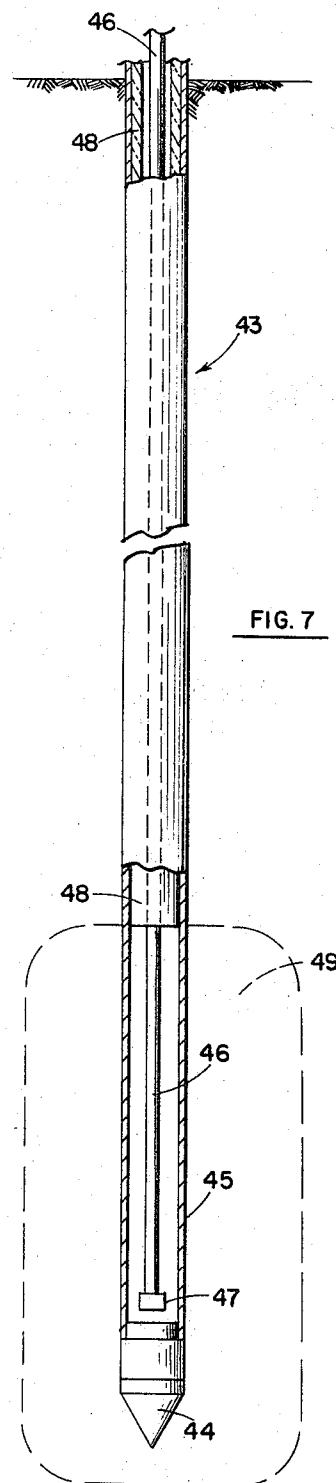
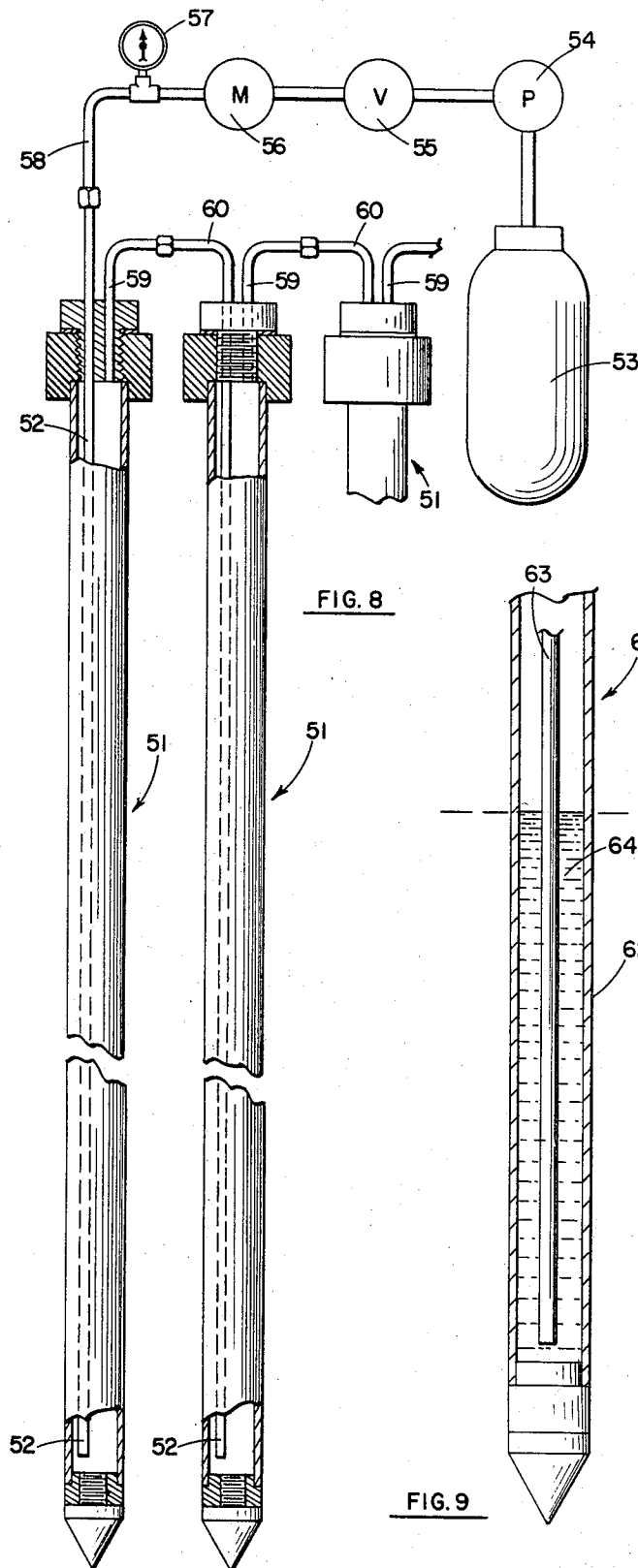
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ARRANGEMENT FOR SOLIDIFICATION OF EARTH FORMATIONS

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3 Sheets-Sheet 3



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3,528,252 ARRANGEMENT FOR SOLIDIFICATIONS OF EARTH FORMATIONS

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4 Claims

ABSTRACT OF THE DISCLOSURE

An arrangement for freezing an earth formation in which liquefied gas is allowed to evaporate for withdrawing heat from such a formation.

BACKGROUND OF THE INVENTION

The field of the invention

This invention relates to the freezing of earth formations.

The prior art

It has been known that unstable ground formations, such as those bearing water, may be excavated if first they are frozen so that they are solidified. This may be necessary, for example, during mining or other excavation work when an incompetent formation may be encountered that will not permit cutting through it in the conventional manner. In order to combat such situations, it has been the practice to sink pipes into the earth to the unstable area. Brine is then circulated through these pipes so that ultimately the unstable portion becomes frozen and solidified, thereby allowing it to be cut through to complete the excavation. There are certain disadvantages attendant to this procedure. In particular, it is very time-consuming, as months may be required to effect adequate freezing in the area in question. Moreover, this has necessitated the freezing of a large zone all the way from the surface to the unstable portion, often at considerable depth, as the brine must be conducted the full distance even where there is a relatively small part where freezing is needed. Thus, the process inherently is inefficient. Furthermore, it has not been practical as a means for freezing where the drilling is in the horizontal direction, such as in the formation of tunnels. This has limited the use of ground freezing as a technique in excavation work.

In addition to the circulation of brine, it has been suggested to blast cold air into pilot portions of a tunnel or other excavation to be formed. This has failed to freeze the formations effectively and is impractical and has not enjoyed commercial usage.

SUMMARY OF THE INVENTION

According to the provisions of this invention, liquefied gas is evaporated at the earth formation to be frozen to effect the heat transfer necessary to accomplish freezing. This utilizes the latent heat of vaporization of the gas and causes the earth formation to be subjected to a very low temperature. This may be accomplished by inserting a member in the form of an elongated tubular spear into the formation to be frozen and introducing the liquefied gas into this member, where it is allowed to evaporate. The member may include openings allowing the gas to escape from the inner end portion of the member into the formation for direct contact with the formation and increased heat transfer. Several of the members are utilized in freezing larger areas. In some instances, where the members are directed downwardly, the liquefied gas is introduced into them up to a predetermined level, after

which it is permitted to boil off to effect freezing of material into which the members have been sunk. Also, several of the members may be connected in series for conducting the gas from one to the other for maximum utilization of the gas and efficiency of operation. Insulation may be provided for portions of the members that are inserted into the formation, so that the freezing may be accomplished at selected areas rather than throughout the lengths of the members inserted.

An object of this invention is to provide rapid, efficient and economical cooling of earth formations to effect solidification thereof.

Another object of this invention is to provide an arrangement permitting the freezing of selected portions of a formation.

An additional object of this invention is to provide an arrangement permitting freezing for excavation at any attitude.

These and other objects will become apparent from the following detailed description taken in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a side elevational view of an arrangement by which liquefied gas is introduced into a formation through a spear;

FIG. 2 is an enlarged fragmentary elevational view, partially broken away, illustrating the distal end portion of the spear;

FIG. 3 is an enlarged elevational view, partially broken away, showing the inner end of the spear;

FIG. 4 is a longitudinal sectional view showing the use of the spears in freezing formations in digging a tunnel;

FIG. 5 is a fragmentary sectional view illustrating the manner in which the spears can effect selected freezing of particular zones;

FIG. 6 is a fragmentary sectional view illustrating the manner in which freezing is accomplished in sinking a vertical shaft;

FIG. 7 is a longitudinal sectional view, partially in elevation, of a modified spear;

FIG. 8 is an elevational view, partially broken away, illustrating the manner in which the freezing spears may be connected in series;

FIG. 9 is a fragmentary sectional view of the end portion of a spear, illustrating how liquefied gas may be introduced into it to a predetermined level; and

FIG. 10 is a sectional view illustrating how freezing may be accomplished by allowing the liquefied gas to evaporate in a plurality of members extending downwardly into an incompetent formation.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

According to the provisions of this invention, liquified gas is introduced into the unstable area to be frozen and allowed to expand, which thereby accomplishes the freezing. A probe or spear 10, such as seen in FIG. 1 and the detail views of FIGS. 2 and 3, may be used as the means to introduce the liquefied gas into the area to be frozen. The probe 10 includes an elongated tube 11 of alloy steel defining an inner passageway or chamber, adjacent one end of which is welded a collar 12 of copper, bronze or other material capable of withstanding very low temperatures without deterioration. The end of the collar 12 is interiorly threaded and receives a threaded end portion of a sleeve 13. The latter member also is of copper, bronze or other material that will withstand low temperatures. At the other end, the sleeve 13 is internally threaded and receives the shank 14 of an end member

15 that is conical in shape. The member 15 is made of hardened steel.

In the circumferential wall of the sleeve 13 are radially directed openings 16. These openings include outer enlarged portions which are threaded and receive nuts 17. These nuts are annular, so that the openings 18 through them provide, in effect, continuations of the openings 16. However, a diaphragm 19 is positioned beneath each nut 17, closing off communication between the openings 18 and the inner portions of the openings 16. Thus, the diaphragms 19 seal the bore of the spear 10 from the exterior.

At the opposite end of the spear is an enlarged collar 21 welded onto the end of the tube 11. This is used in the installation and removal of the spear, providing a means for driving the spear into a formation or for gripping the spear for pulling it free. When the spear is to be used, a fitting 22 is threaded into the collar 21, the connection being sealed by a gasket 23. The fitting 22 receives the end of a line 24 that supplies liquefied gas to the spear. This gas flows from a suitable supply tank 25. Included in the line 24 is a regulator 26 for controlling the flow of liquefied gas to the spear and a metering device 29 for measuring the amount of liquid gas injected. Also in the line 24 is a control valve 27. The gas is forced into the spear by means of a pump 28.

In FIG. 4, the use of the spear 10 may be seen in conjunction with the driving of a tunnel in a generally horizontal direction. Some or all of the formation through which the tunnel is to be driven may be unstable, preventing the cutting of the tunnel in the conventional manner. However, this material is solidified by inserting the spears 10 into it and discharging liquefied gas through the ends of the spears directly into the formation. This produces the cooling effect, which will very rapidly cause the formations to freeze, permitting the tunnel then to be cut.

As shown in FIG. 4, a tunnel-driving shield 30 is positioned at the inner end of the tunnel 31. A plurality of the spears 10 is inserted into the formation ahead of the end of the tunnel, being passed through the breast board 32. The spears either may be driven into the earth by impact or they may be introduced into openings drilled into the formation to receive them. The pointed end members 15 facilitate the movement of the spears into the earth. Preferably, the spears are arranged to diverge outwardly so that an area somewhat larger than the diameter of the tunnel will be frozen.

After the spears 10 have been positioned, each is hooked up to a supply of liquefied gas in the manner indicated in FIG. 1. When the valve 27 is opened up for each spear, the liquefied gas travels through the bore of the spear to the openings 16 at the spear's outer end, with the liquefied gas flow and pressure being governed by the regulator 26. By being under pressure, the liquefied gas will easily rupture the diaphragms 19, allowing the gas to escape through the openings 16. However, prior to that time, the diaphragms 19 serve to seal off the end of the spear, preventing the entry of water or other foreign matter into the spear while it is being positioned in the incompetent formation.

As the liquefied gas escapes through the openings 16, it returns to its gaseous form. As this vaporization takes place, the gas is in direct contact with the formation into which the spear has been inserted. Therefore, there is an efficient cooling effect as the vaporization of the liquefied gas draws heat from the surrounding media. As a result, the formation becomes frozen in a relatively short time. The liquefied gas not only directly contacts the formation, but also is at a much lower temperature than is brine as conventionally used. Satisfactory solidification will be achieved in a matter of days, contrasted with the months required for freezing by the use of brine. Moreover, as illustrated in FIG. 4, the freezing in accordance with the present invention is adapted for horizontal tunnel drilling, which is not suitable for brine freezing. The

freezing takes place directly at the area to be excavated, and not through other formations where freezing is not required.

The perimeter of the area frozen by the discharge of the liquefied gas is indicated by the dotted line 33 in FIG. 4. This line extends to a portion to the left of the spears, this representing a zone previously frozen and still unthawed where the excavation already has taken place. Once solidified, the formation easily is cut in a conventional manner and the sections of the tunnel liner 34 are fitted in place. Thus, the driving of the tunnel proceeds incrementally as the space ahead of it is progressively frozen.

The use of liquefied gas as the refrigeration medium is particularly effective, both because of its low temperature and the absorption of heat required in converting it to a vaporized state. Thus, the latent heat of vaporization is utilized and the gas is at a very low temperature. Liquid nitrogen, which is suitable for use in conjunction with this invention, boils at -320.4° F. Adequate ventilation is needed in the working area when nitrogen is used to avoid an accumulation of excess nitrogen in the atmosphere. Liquid air, which has a boiling point of -317.6° F., also may be used. Generally, it is preferred to use a nontoxic liquefied gas, such as nitrogen or air, to avoid danger to personnel. If liquid air is allowed to boil off at atmospheric pressure, the oxygen and nitrogen in it evaporate at different rates. This can cause the surroundings to become oxygen rich, thus creating a health hazard. However, if the pressure around liquid air is maintained at around 85 p.s.i., the oxygen and nitrogen come out at a balance rate and produce a proper air mixture. Therefore, when using liquefied air, the hazard may be avoided by maintaining the surroundings at around 85 p.s.i.

After the freezing has been completed, the spears are removed by pulling outwardly on the collars 21 within the tunnel area. In some instances, the spears may need to be heated to free them for removal. With the spears being hollow elements, it is a simple matter to heat them sufficiently to cause localized thawing around and allow them to be withdrawn easily.

The freezing may take place in selected locations in the manner illustrated in FIG. 5. Here, there are isolated pockets of incompetent material which must be solidified rather than an entire zone ahead of the tunnel 35 as in the arrangement of FIG. 4. In such an instance, the spears 10 may be inserted into the selected areas to freeze specific localities designated by the lines 36 and 37. Moreover, as shown in FIG. 5, the spears 10 may be made of different lengths to adapt them for particular situations which may be encountered.

The spears are equally applicable for sinking vertical shafts, as shown in FIG. 6. Here, a plurality of the spears is inserted into the earth beneath the shaft 39, in this instance to solidify a portion of the water-bearing or incompetent formation 40 that extends beneath the part of the shaft 39 which previously has been dug. The line 41 indicates how the spears will accomplish freezing of the zone beneath the shaft to permit the shaft to be sunk deeper. This efficiently solidifies only the localized incompetent formation and does not require freezing to the surface as where brine is employed. Moreover, the freezing may be accomplished for any attitude of excavation, whether vertical, horizontal or sloping.

Rather than being discharged exteriorly of the spear into the surrounding formation, the liquefied gas may be allowed to vaporize within the spear. Such an arrangement is seen in FIG. 7, where the spear 43 includes a driving point 44 attached to the lower end of the tubular portion 45. There are no openings in the end of the spear for discharging the gas into the surrounding media. Within the bore of the spear at its axis is a tube 46, which extends to a location adjacent the point 44. At the end of the tube 46 is a relief valve 47. Upwardly of the bottom end

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of the spear is an additional inner tubular jacket 48 of insulating material.

In use of the spear 43, the liquefied gas is introduced through the smaller tube 46 and discharged through the relief valve 47 adjacent the bottom of the spear. It thereupon vaporizes within the spear and rises upwardly through the bore of the spear around the tube 46. Above the bottom portion of the spear, the gases enter the insulating jacket 48. By this construction, therefore, there is a freezing effect at the lower portion of the spear, as indicated by the zone 49, above which there is either no freezing or a minimum amount of freezing. This is because the insulating sleeve 48 reduces the heat transfer above the bottom end of the spear. This provides for selective freezing at the zone around the bottom end of the spear.

The spears may be connected in series, with the gas being conducted from one spear to the next when arranged as indicated in FIG. 8. Here, the spears 51 do not discharge into the surrounding media, and the vaporization takes place within the spears. Each spear includes an elongated tube 52 for receiving the gas. The first spear receives the liquefied gas from the storage tank 53, from which it is moved by the pump 54 through a control valve 55 and a regulator 56. A pressure gauge 57 may be included in the inlet line 58. After passing outwardly through the open bottom end of the tube 52 into the first spear, the gas is conducted from the spear by an outlet 59 that joins an inlet 60 to the next spear that extends to the discharge tube 52 within it. Each of the spears in series includes the outlet 59 for connecting to the inlet 60 of the adjacent spear. This provides a maximum conservation in use of the expanding gas in accomplishing cooling in a series of spears and not merely one.

In some instances, it is preferred to merely fill up the bottom portion of the spear with liquefied gas and allow it to boil off, with the vapor passing upwardly through the bore of the spear. Such an arrangement is seen in FIG. 9, where the spear 61 includes a tubular member 62, within which is an inlet line 63 through which the liquefied gas is introduced. The gas is caused to fill the bore of the tube 62 to a predetermined level, after which the inlet supply is closed off. The liquefied gas 64 then vaporizes, passing upwardly through the bore of the tube 62 and causing freezing at the lower portion of the spear where the vaporization takes place.

A typical use of the arrangement of FIG. 9 is seen in FIG. 10. Here, a tunnel 65 is to be drilled through a river bed that includes a portion 66 of silt, sand and gravel above the rock line 67. The spears 61 are sunk vertically into the material 66 in a series across the river channel, as indicated. The spears 61 may be of different lengths, and all have their upper ends above the surface 68 of the water flowing in the river. Liquid gas then is introduced into the spears 61. Different quantities of liquefied gas are introduced into the spears, depending upon their depths of penetration, bringing the upper level of the liquefied gas in all of the spears to a common position which is spaced a predetermined distance above the path of the tunnel. This may be at the horizontal line 69. The gas then is allowed to evaporate, passing out through the upper ends of the elements 61. This produces a frozen zone generally as indicated by the dotted lines in FIG. 10. With the freezing complete, the tunnel 65 may be continued along a straight horizontal path through the river bed.

The foregoing detailed description is to be clearly understood as given by way of illustration and example only, the spirit and scope of this invention being limited solely by the appended claims.

I claim:

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1. The method of freezing an earth formation comprising the steps of:

inserting into a formation to be frozen a member having an interior chamber therein, introducing liquefied air into said chamber, allowing said liquefied air to evaporate for thereby withdrawing heat from said formation, and maintaining the zone where said liquefied air is allowed to evaporate at a pressure sufficient to cause the constituents of said air to evaporate at a balanced rate to produce a balanced gaseous mixture upon said evaporation.

2. The method of freezing an earth formation comprising the steps of:

providing a member with an interior chamber and an opening therethrough in one end portion of said member,

said opening providing communication between said chamber and the exterior of said member.

inserting said one end portion of said member into a formation to be frozen with said opening adjacent said formation, and with the opposite end portion of said member protruding from a surface of said formation, then introducing a liquefied gas into said chamber, and allowing said liquefied gas to escape from said opening to engage said formation remote from said surface, and to evaporate for thereby withdrawing heat from said formation.

3. A device for effecting freezing of an earth formation comprising:

a member having a chamber therein,

a source of liquefied gas connected to said chamber for introducing said gas into said chamber,

said member having opening means therethrough for allowing said gas to escape from said chamber for direct contact with a medium into which said member is inserted,

whereby said liquefied gas upon evaporation thereof withdraws heat from said medium, and a closure means in said opening means for sealing said opening means during the introduction of said member into a medium to be frozen,

said closure means being openable in response to the pressure of said gas for thereby allowing the discharge of said gas through said opening means.

4. A device as recited in claim 3 in which said closure means includes an elastomeric diaphragm extending across said opening means.

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U.S. Cl. X.R.

61—63; 62—293