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Lefever et al.

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[54] **METHOD AND APPARATUS FOR TRANSPORTING PETROLEUM PRODUCTS THROUGH A FROZEN MEDIUM**

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[63] Continuation-in-part of Ser. No. 124,065, March 15, 1971.

[52] **U.S. Cl.** ..... **137/340,** 62/55, 62/512, 62/518, 62/519, 137/375, 138/114, 138/148, 174/15 C

[51] **Int. Cl.** **F16l 53/00**

[58] **Field of Search** 302/64, 14, 15, 16; 137/236, 340, 13, 375; 62/55, 518, 524, 525, 526, 512, 519

[56] **References Cited**

UNITED STATES PATENTS

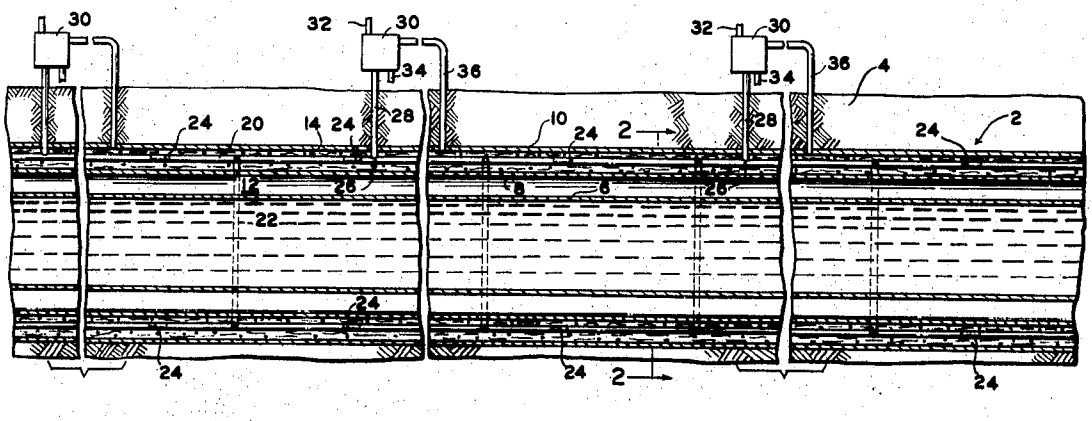
3,407,835	10/1968	Rolfes	137/340
1,994,037	3/1935	Gay	62/512 X
3,360,947	2/1968	Fretwell et al.	62/55 X
3,433,028	3/1969	Klee	62/55 X

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[57] **ABSTRACT**

A method and apparatus for transmitting petroleum products through a frozen medium, in which the petroleum is pumped at an elevated temperature through an inner conduit, the inner conduit being surrounded by an outer coaxially-disposed annular conduit spaced from the inner conduit and containing a refrigerant medium. The refrigerant medium takes up heat from the petroleum products to protect the frozen medium, and a heat pipe and heat exchanger are connected with the annular conduit to maintain the stability of the refrigerant medium as it takes up heat. The system associated with the refrigerant medium is also useful to effectively transport cryogenic materials.

18 Claims, 7 Drawing Figures



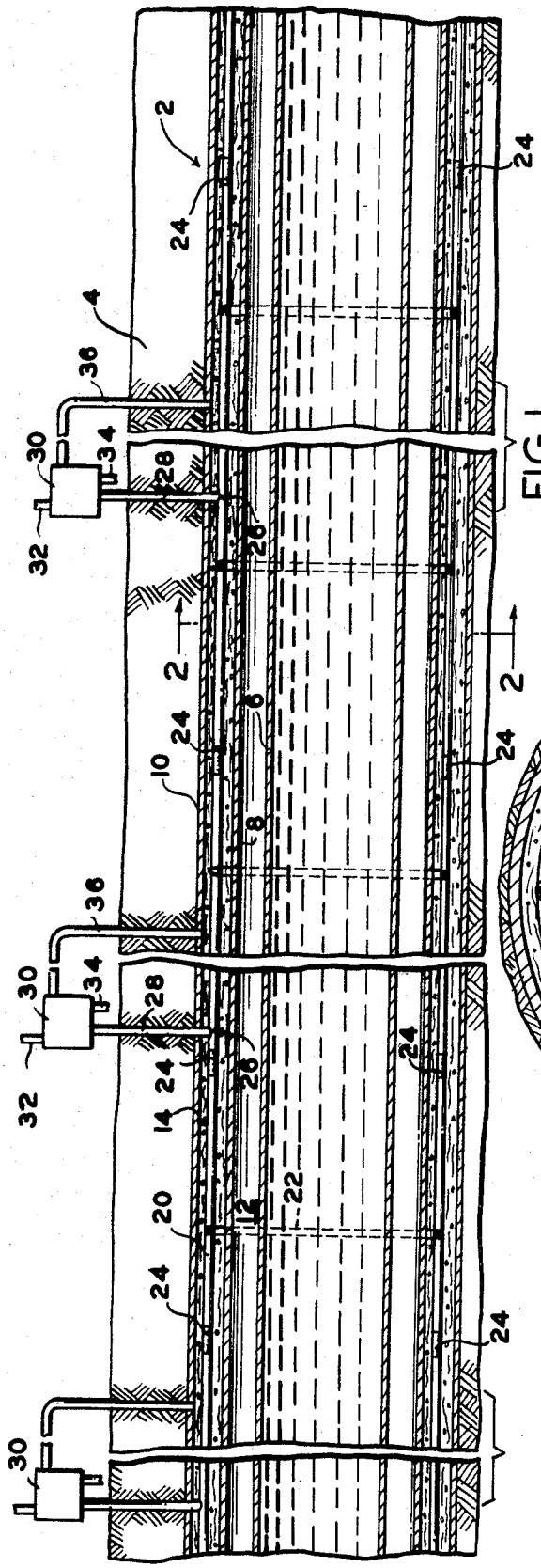


FIG. 1.

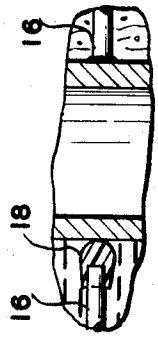
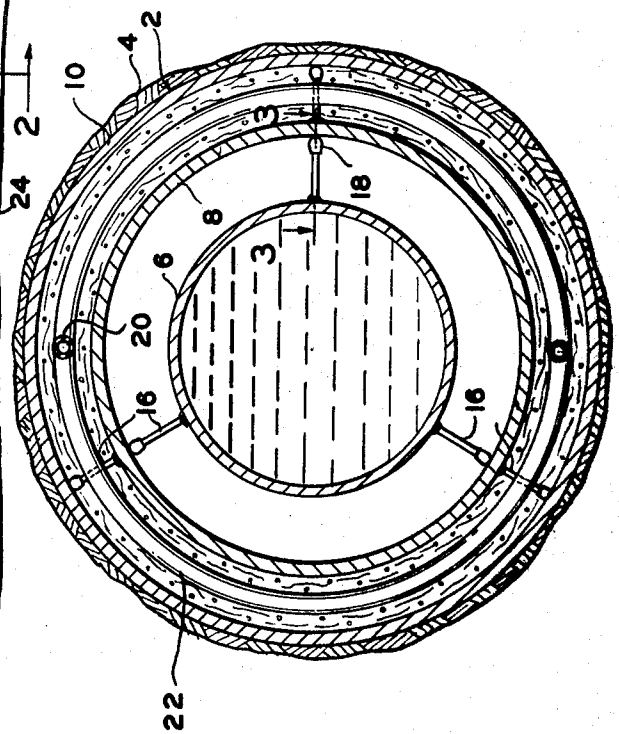


FIG. 3.

FIG. 2.



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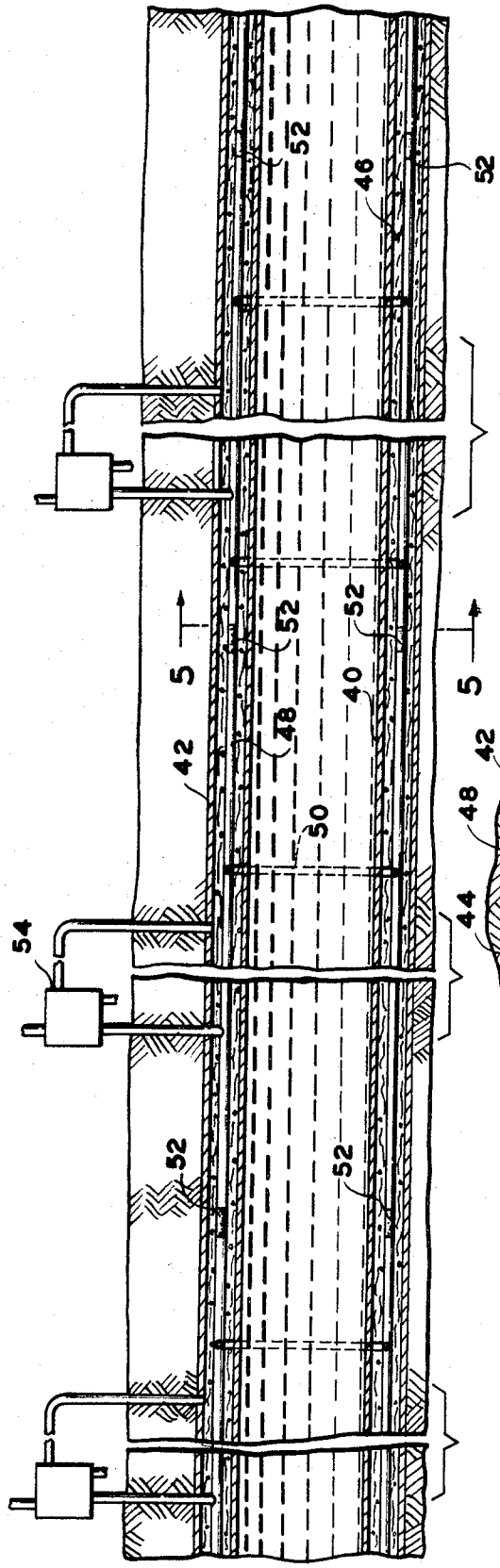


FIG. 4.

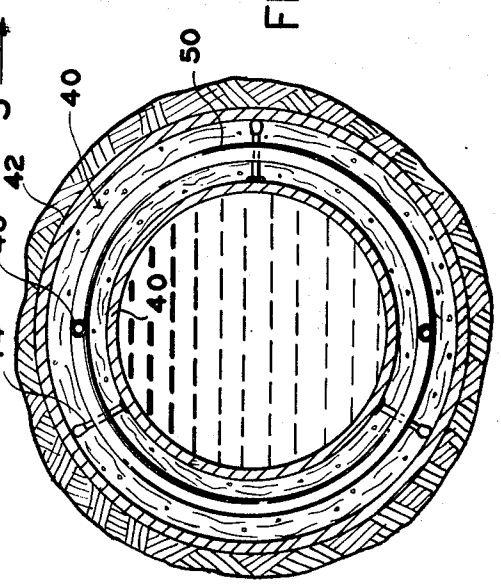


FIG. 5.

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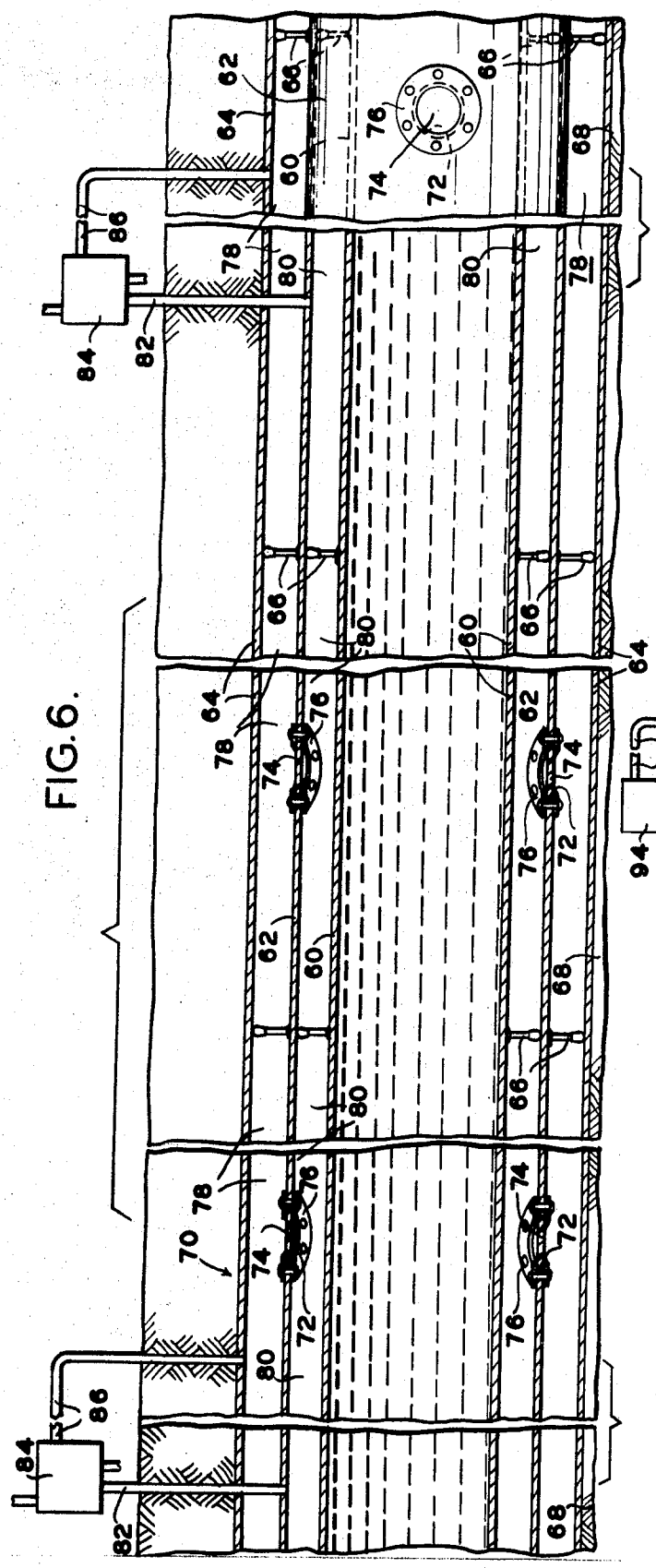


FIG. 6.

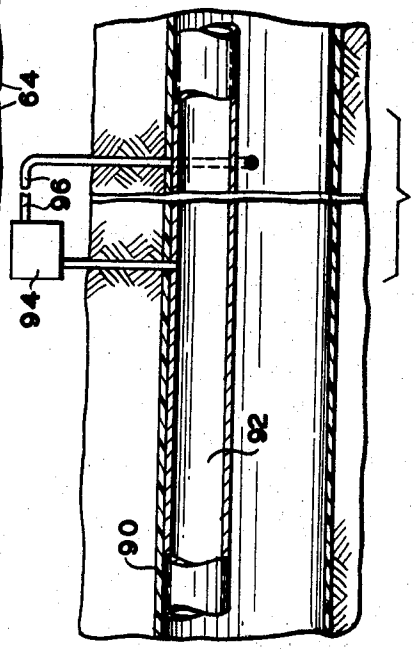


FIG. 7.

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METHOD AND APPARATUS FOR TRANSPORTING PETROLEUM PRODUCTS THROUGH A FROZEN MEDIUM

This application is a continuation in-part of application Ser. No. 124,065, filed Mar. 15, 1971, and entitled "Transmission of Petroleum Products Through a Frozen Medium"

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to the transportation of materials by pipeline. More particularly, it relates to a method and apparatus for transporting heated materials by pipeline through a frozen medium such as the permafrost layer found in the Arctic, without effecting a thawing action on the frozen medium.

2. Description of the Prior Art

With the discovery of oil deposits on the North Arctic Slopes, attention has been directed to the transmission of petroleum across Alaska by pipeline. Concern for the protection of the environment and difficulties peculiar to the Arctic region have posed unique problems in connection with such an Arctic pipeline, problems that must be solved if construction of a practical and useful pipeline that does not adversely affect the environment is to be a reality.

A principal problem encountered in any construction in or through the Arctic permafrost layer is the instability of the layer itself. Permafrost is a ground layer prevalent in arctic and antarctic regions, and is a mixture of earth and frozen water resulting from the prevailing ambient temperatures. During the arctic summer the permafrost in some areas thaws to some degree for depths varying from 6 inches to 2 feet. These areas become quite unstable, and incapable of supporting normal structures.

In the transmission of oil by pipeline from the oil fields on the North Arctic Slopes, the oil would be extracted from the ground at about 140°F, and this temperature would be maintained during transmission by energy imparted by the pumping stations along the line. Pre-cooling of the oil is not accomplished because the viscosity thereof would be increased thereby, rendering transmission more difficult. An ordinary pipeline therefore becomes a heat source and itself becomes a destabilizing factor on the permafrost layer if placed therein.

Various means have been proposed for overcoming the above problems, one of which is elevation of the pipeline above the permafrost on platforms. This method, although avoiding direct thawing of the permafrost, has several disadvantages, not least of which is the widespread opposition by the public to the bisection of large areas of the Northland by such a physical barrier, with the attendant effect on the environment. Other disadvantages are that the exposed pipeline is vulnerable to damage by natural or man-made forces, thereby providing an ever-present threat to the environment. Furthermore, within the state of the art, it is difficult to prevent transmission of heat from the pipeline through the supports, such heat transmission rendering the permafrost liable to instability through thawing.

In patent application Ser. No. 124,065, of which this application is a continuation-in-part, there is disclosed a novel pipeline concept that enables construction of a buried pipeline in the arctic region for the transmission of petroleum products, whereby the permafrost layer is maintained in a frozen condition notwithstanding the passage of heated petroleum therethrough. Thus, the advantages of buried construction are obtained, while protection of the environment is assured. Among the advantages of buried construction as opposed to an elevated pipeline are that the erection of a physical barrier is eliminated, along with possible damage to the exposed pipeline from unusually strong winds and other like causes.

The pipeline of the prior application Ser. No. 124,065, consists of an inner pipe through which the heated petroleum is transmitted, and which is surrounded by concentrically disposed intermediate and outer conduits. The space between the intermediate and outer conduits contains a refrigerant medium that takes up heat given off by the inner conduit, and which maintains the permafrost layer in a frozen condition. The annular space between the intermediate conduit and the inner conduit constitutes an interface region between the heated and the cold pipes.

In the system of said prior application the refrigerant medium undergoes physical change as it takes up heat, which changes must be accomodated in the system. For example, where liquified natural or propane gas is used as a refrigerant medium, portions of the material will change from a liquid to a gaseous state as heat is taken up. This can cause a pressure buildup in the outer conduit, and in some instances can require the establishment of heat exchanger servicing stations periodically along the pipeline to treat the refrigerant medium and return it to its liquid state.

The present invention is directed to an extension and further development of the inventive concept of the said prior application, and provides a unique arrangement for handling and treating the refrigerant medium to accomodate changes therein brought about by heat transfers.

SUMMARY OF THE INVENTION

In the present invention three concentrically arranged conduits form the pipeline, the inner conduit being utilized to transmit the heated material, and the outer conduit containing a refrigerant medium, as in the invention described in said prior application Ser. No. 124,065. Heat is taken up from the inner conduit by the refrigerant medium, the system being designed to maintain the permafrost layer in which the pipeline is buried at the desired temperature, while also maintaining adequate viscosity for the heated material being pumped through the pipeline.

The refrigerant medium can be any one of several substances, including liquified propane gas or liquified natural gas. When such a refrigerant medium in the liquid state takes up heat, the heat tends to vaporize some of the liquid, which generates a refrigerating effect. If the resultant gases are not taken off, then the pressure within the outer conduit will continue to build.

In the present invention the annular space containing the refrigerant medium is connected with a heat pipe, through a membrane that is impervious to the passage of the liquid medium, but porous to the medium in a gaseous state, Thus, as the transfer of heat to the refrigerant medium generates gases therein, such gases enter the heat pipe.

The term "heat pipe" as used herein refers to a pipe containing only the vaporized form of the refrigerant, such that these vapors can travel very quickly to a treatment point where they are recondensed. The term "semi-permeable" or "porous only to vapor", refers to a porous material with pores of such dimensions that only vapors of the liquid will be transported through the material. This will require that pumps be used at each treatment point to maintain a lower pressure in the heat pipe than is present on the liquid side of the porous material, such that the vapors will not condense between treatment points. These pumps, requiring an external energy source for operation, distinguish this system from conventional heat pipe designs using capillary action to transfer the working fluid. Hereafter, use of the terms heat pipe, semi-permeable, and porous only to vapor will be used to imply systems of this design, which include pumps at each treatment point.

The generated gases are of course warm, and are quickly and effectively transmitted through the heat pipe to a treatment point, where the heat can be removed and the gases can be changed back to a liquid state and pumped back into the outer conduit to rejoin the refrigerant medium therein. This process prevents the buildup of pressure in the outer conduit, and because the heated gases can be transmitted much easier over long distances than the liquid refrigerant, treatment points can be spaced far apart. In addition, the present concept is uniquely capable of providing a closed system for protecting the permafrost layer in which the pipeline is installed.

There are two principal constructions contemplated for the present system. In the first the heat pipe is a separate conduit extending through the annular space between the outer and the intermediate conduits, and is either made entirely of the semipermeable material, or includes portions of such material. In a second embodiment the semi-permeable material is embodied in the wall of the intermediate pipe as patches or windows, and the annular space between the intermediate and the outer pipes serves as a conduit for the warm gases.

The present invention makes it possible to easily maintain the stability of the refrigerant medium. With this stability, and taking into consideration the temperature of the permafrost layer, the particular refrigerant employed, and the temperature of the material to be transported, a pipeline system with the desired operating characteristics can be designed.

While the present invention is described with reference to use in permafrost, where the object is to prevent warming of the medium through which the pipeline passes, it is to be understood that the invention can be adapted to other environments. For example, the same concepts could be employed in the tropics to prevent a cryogenic material transported by a pipeline from taking up heat from the surrounding warm soil.

The system of the present invention for stabilizing the refrigerant medium in the outer annular space can also be used by itself, in the transport of cryogenic materials. In this instance the removal and treatment of the warm gases, followed by their reinsertion into the pipeline, makes for a more efficient transmission method than where all of the contents of the pipeline must be periodically removed, treated, and reinserted.

It is the principal object of the present invention to provide a method and apparatus for transmitting heated material through a layer of permafrost by pipeline, without effecting thawing of the permafrost.

Another object is to provide a pipeline system including an inner conduit for transporting material, and an outer conduit containing a refrigerant medium, and including an arrangement for stabilizing the refrigerant medium.

It is also an object to provide a method and apparatus for effectively treating vapor from a refrigerant medium flowing in a pipe to remove heat therefrom, without the need to treat all of the medium.

Other objects and many of the attendant advantages of the invention will become readily apparent from the following Description of the Preferred Embodiment, when taken with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a fragmentary, axial sectional view of one embodiment of the invention showing a three-pipe conduit, with a heat pipe arrangement mounted within the outer annular conduit space;

FIG. 2 is an enlarged sectional view taken in the line 2—2 of FIG. 1;

FIG. 3 is an enlarged fragmentary view taken in the line 3—3 of FIG. 2, showing one of the separator post tips;

FIG. 4 is a view like FIG. 1, but of a two conduit pipeline embodiment of the invention;

FIG. 5 is a view taken in the line 5—5 of FIG. 4;

FIG. 6 is a fragmentary, axial sectional view of another embodiment of the invention, wherein the intermediate conduit of a three conduit pipeline is fitted with windows of a semipermeable material, the intermediate annular flow space of the pipeline serving as a heat pipe; and

FIG. 7 is an axial sectional view of a cryogenic pipeline employing the heat pipe system of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIGS. 1–3 of the drawings, a pipeline is indicated generally at 2, buried in a permafrost layer 4. The pipeline 2 includes an inner conduit 6 for transmitting petroleum or some other material, an intermediate conduit 8 and an outer conduit 10, the intermediate conduit 8 and the outer conduit 10 being concentrically disposed in spaced relation about the inner conduit 6, and forming an intermediate annular flow space 12 and an out annular flow space 14, respectively.

The three conduits 6, 8, and 10 are held in spaced-apart relationship by a plurality of radially-extending separator posts 16, the inner end of each post 16 being welded to one of the pipes 6 or 8, and the outer end thereof being fitted with a cap 18 of "Teflon," or a similar substance. Alternatively, the outer tips of the posts 16 can be fitted with rollers or some other friction-reducing means, the concept being to hold the conduits 6, 8, and 10 in spaced relationship, to provide for ease of assembly, and to allow for relative expansion and contraction movements of the conduits.

The pipeline inner conduit 6 is connected through suitable valving with the heated material to be transported, such as crude oil preferably pumped at a temperature of about 140°F, and the outer annular flow space 14 is filled with a suitable refrigerant medium, which can be liquified natural gas or liquid propane, or

posts 66, are buried in a layer of permafrost 68 to form a pipeline 70.

The intermediate conduit 62 has windows or openings 72 cut therein at intervals therealong, within which membranes or inserts 74 of the selected semipermeable material are secured by brackets 76. Refrigerant medium is placed in the outer annular space 78, the inner conduit 60 is utilized to transport the hot petroleum or other material, and the intermediate annular space 80 is utilized to receive and transport vapors from the refrigerant medium. The intermediate annular space 80 is connected by a conduit 82 to the inlet of a heat exchanger and pump treatment unit 84, and the outlet of said unit is connected by conduit 86 to the outer annular space 78.

The embodiment of FIG. 6 eliminates the separate collector pipes, and in use functions similarly to the embodiment of FIGS. 1–3.

The heat pipe system of the invention can also be utilized alone with a single conduit to efficiently transport cryogenic materials, like liquid propane or natural gas. At present it is necessary to periodically remove substantially the whole of the material being transported from the pipeline, for passage through cooling and pumping equipment. Normally, such treatment stations must be fairly closely spaced.

By utilizing the present heat pipe concept in such a pipeline, the gas vapor formed when heat is taken up is separated and removed from the refrigerant liquid medium, and is transmitted to a treatment station alone. This avoids treatment of the whole pipeline contents, and allows treatment stations to be placed far apart. Such a pipeline arrangement is shown in FIG. 7, wherein a cryogenic pipeline 90 is shown containing a heat pipe 92 of semipermeable material (or fitted with semipermeable inserts), the heat pipe 92 being connected to the inlet of a treatment unit 94, and the outlet of said unit being connected by a conduit 96 to the pipeline conduit 90 for returning the reliquified cryogenic material thereto.

Obviously, many other variations and modifications of the present invention are possible.

We claim:

1. The method of transmitting a liquid cryogenic material through a pipeline arrangement, comprising the steps of: transmitting said liquid material through a conduit; and removing from said conduit through a semipermeable means vapors formed from said liquid cryogenic material because of heat transfer thereto whereby to relieve pressure buildup in said conduit and to stabilize the liquid cryogenic material, said semipermeable means being impervious to said cryogenic material when such is in its liquid state.

2. The method as recited in claim 1, including the additional steps of: treating said vapor to return the same to substantially the same state as the cryogenic material in the conduit; and returning said treated cryogenic material to said conduit.

3. The method of transmitting materials through a pipeline, comprising the steps of: transmitting said material through an inner conduit; simultaneously maintaining a liquid refrigerant medium in an outer conduit disposed concentrically about said inner conduit; and removing from said outer conduit through a semipermeable means vapor formed by the transfer of heat to said refrigerant medium, whereby to maintain a relatively stable liquid state and temperature for said refrigerant medium, said semipermeable means being impervious to said refrigerant medium when such is in its liquid state.

4. The method as recited in claim 3, including the further steps of: treating said vapor to return the same to substantionally the same state as the refrigerant medium in said outer conduit; and returning said treated refrigerant medium vapor to said outer conduit.

5. The method of transmitting a heated material through a permafrost layer which is structurally unstable at temperatures above about 32° comprising the steps of: transmitting said heated material through an inner conduit; simultaneously maintaining a liquid refrigerant medium in an outer conduit disposed concentrically about said inner conduit; and removing from said outer conduit through a semipermeable means vapor formed by the transfer of heat to said liquid refrigerant medium from said inner conduit, said refrigerant medium being effective to maintain said permafrost layer adjacent said pipeline in a structurally stable state, and said semipermeable means being impervious to said refrigerant medium when such is in its liquid state.

6. The method as recited in claim 5, wherein said refrigerant medium is maintained in said outer conduit by establishing a continuing flow of said medium therethrough.

7. The method as recited in claim 5, including the additional steps of: treating said removed vapor to return the same to substantially the same state as the refrigerant medium in said outer conduit; and returning said treated refrigerant medium vapor to said outer conduit.

8. The method as recited in claim 7, wherein said outer conduit is closed to the flow of refrigerant medium therethrough, whereby a closed loop system is established.

9. The method as recited in claim 5, wherein said outer conduit is spaced from said inner conduit.

10. A closed system transmission line arrangement for transmitting liquid cryogenic materials, comprising: a first primary conduit for transmitting said cryogenic materials; a second vapor collector conduit; and semipermeable means connecting said first primary conduit with said second collector conduit, said means being porous only to vapors formed in said cryogenic material by the transfer of heat thereto and being impervious to said cryogenic materials when such are in their liquid state, whereby said second vapor collector serves to collect vapors occurring in said primary conduit without loss of cryogenic materials in a liquid state.

11. A transmission line as recited in claim 10, wherein said second conduit is received within said first conduit.

12. A transmission line as recited in claim 10, wherein said second conduit is external of said first conduit.

13. A transmission line as recited in claim 10, including additionally: treatment means connected with said second conduit for treating vapors collected thereby to return said vapors to substantially the state of said cryogenic material, the outlet of said treatment means being connected to said first conduit.

14. A pipeline for transmitting materials, including: an inner conduit for transmitting said materials; an outer conduit disposed about said inner conduit, for containing a liquid refrigerant medium; collector conduit means; and semipermeable means connecting said

one of the more conventional refrigerants. When natural gas or propane is utilized as a refrigerant, the outer conduit **10** can be tapped along the pipeline to draw off some of the fuel for use.

The arrangement as thus far described corresponds to that which is the subject of said prior application Ser. No. 124,065. The intermediate annular space **12** serves as a buffer or interface region, and the permafrost **4** is protected from the heated inner conduit **6** and is kept frozen by the refrigerant medium in the outer annular space **14.** As the refrigerant medium takes up heat from the conduit **6,** some of the refrigerant medium will be vaporized, increasing the pressure in the outer annular space **14.** The said previous patent application comtemplated providing pumping stations along the length of the pipeline **2** to accomodate these physical changes in the refrigerant medium, by boosting the pressure of the fluid and maintaining the liquidity thereof.

In the present invention a heat pipe arrangement is employed to take off the vapor formed in the refrigerant medium by the taking up of heat thereby. Referring again to FIGS. **1** and **2,** the heat pipe system includes a plurality of collector pipes **20** arranged to extend generally axially through the outer annular space **14,** said pipes being interconnected periodically by manifold rings **22.** It is to be understood that only one collector pipe **20** can be employed, if desired, or that any number in a suitable array might be used.

Periodically the collector pipes **20** have semipermeable cylindrical inserts **24** therein, which constitute membranes that are porous to gases formed in the refrigerant medium, but impermeable to the liquid medium. Thus, as heat is transfered to the outer annular space **14** and portions of the refrigerant medium are vaporized, the resultant heated gases pass into the collector pipes **20.** It is known that gaseous heat is easily and quickly transported in a conduit or heat pipe, and thus the collected gases flow quickly to spaced outlet points **26,** from where they are removed by conduits **28** to suitable heat exchanger pump units **30.**

In the units **30** the heat is removed from the vaporized refrigerant medium, and is either released to the atmosphere through exhaust conduits **32,** or returned to the inner conduit **6** through conduits **34.** The refrigerant medium is then reliquified, and is returned to the outer annular space **14** through conduits **36.**

With the present invention the refrigerant medium in the outer annular space **14** can thus be stabilized, to maintain a desired set of temperature conditions. Also of importance is that the refrigerant medium can be flowing continuously through the outer space **14,** if desired, or said space **14** can be divided off into sections and a closed system can be established wherein replenishment of the refrigerant medium is not needed. In either arrangement removal of the refrigerant medium from its annular flow space **14** periodically for treatment is unneeded. Rather, the much easier transported heated gases alone are treated. The easy transportability of the hot vapors over long distances also requires fewer treatment stations based farther apart, than when the whole of the refrigerant medium must be treated.

The semipermeable material used for the cylindrical inserts **24** can be selected from those available, to suit the design criteria of a particular system. For example, one such material now in use for such semipermeable membranes is frittered alumina. Depending on the semipermeable material employed and the demands of the system, the membranes can be employed as inserts in the collector pipe **20,** or the entire pipe **20,** and even the manifolds **22,** can be made of the semipermeable material.

The intermediate annular space **12,** as has been mentioned, serves as a buffer between the outer annular space **14** and the inner conduit **6** so that hot oil or other material in the latter is not quickly cooled by the refrigerant medium in the former, or vice-versa. This space **12** can also serve to transmit other materials to or from the oil field site, which materials might further serve to provide a buffer or balance between the temperatures of the oil and the refrigerant medium in the outer space **28.** The materials transported in the intermediate space **12** can be selected to aid, in the event of a pipeline break, in the freezing of oil flowing from the inner conduit **6** to thereby shut off flow to prevent spillage of oil to the surrounding area. The selected material could be, for example, an oil sorbent material-water slurry which would operate to absorb oil upon a pipeline break to further inhibit the flow of oil from the break. The sorbent material must be water repellent such that water is not absorbed. A material suitable for the purpose is an expanded perlite-asphalt-fiber compound marketed under the trademark "Sorbent C" by Clean Water, Inc. of Toms River, N.J.

The refrigerant medium in the outer annular space **14** can function to keep the permafrost **4** frozen even in periods of thawing, dependent upon the specific medium selected and the design of the system. Indeed, in some instances a year-round frozen roadway might be formed by the pipeline **2** across the permafrost, and in all cases it should be possible to ensure a structually sound base in the permafrost for the pipeline **2.**

It is also to be understood that the present pipeline **2** with its heat pipe system can be used elsewhere than in the Arctic. For example, in a hot climate the conduit **6** might be utilized to transport a cryogenic material, in which instance the refrigerant medium in the annular space **14** would be utilized to keep heat from warm soil in which it was buried from affecting the cryogenic materials being transported.

In certain situations, depending on the relative temperatures of the refrigerant medium and the material being transported, and upon the heat transfer characteristics of the inner conduit, it is possible to utilize a two-pipe arrangement for a pipeline, whereby the intermediate space **12** is eliminated. Such an embodiment is shown in FIGS. **4** and **5.**

Referring to FIGS. **4** and **5,** an inner pipe **40** is mounted within an outer pipe **42,** and is spaced therefrom by separator posts **44.** Refrigerant medium is received in the annular space **46** formed between the conduits **40** and **42,** and a heat pipe system including collector pipes **48,** ring manifolds **50,** and semipermeable inserts **52** is also received in said annular space, and is connected to treatment units **54.** The arrangement of FIGS. **4** and **5** functions similarly to the embodiment of FIGS. **1–3.**

It is also possible to eliminate the separate collector tubes **20** in the embodiment of FIGS. **1–3,** and to instead utilize the intermediate annular space **12** for transmitting heated vapor extracted from the refrigerant medium. Such an arrangement is shown in FIG. **6,** wherein an inner conduit **60,** an intermediate conduit **62,** and an outer conduit **64,** all separated by separator

outer conduit with said collector conduit means, said semipermeable means being porous only to vapors formed in said liquid refrigerant medium by the transfer of heat thereto and being impervious to said refrigerant medium when such is in its liquid state, whereby said collector conduit serves to collect vapors occurring in said outer conduit without loss of refrigerant medium in a liquid state therefrom.

15. A pipeline as recited in claim **14**, and further including: treatment means connected with said collector conduit means for treating vapors collected thereby to return the same to substantially the state of said refrigerant medium in said outer conduit, the outlet of said treatment means being connected with said outer conduit.

16. A pipeline for transmitting materials, including: an inner conduit for transmitting said materials; an outer conduit disposed about said inner conduit; an intermediate conduit disposed between and spaced from said inner conduit and said outer conduit, the space between said outer conduit and said intermediate conduit containing a refrigerant medium; collector conduit means; and semipermeable means connecting said outer conduit with said collector conduit means, said semipermeable means being porous only to vapors formed in said refrigerant medium by the transfer of heat thereto.

17. A pipeline as recited in claim **16**, wherein said collector conduit means is received between said intermediate conduit and said outer conduit.

18. A pipeline as recited in claim **16**, wherein the annular space between said inner conduit and said intermediate conduit comprises said collector conduit means, said semipermeable means being mounted in the wall of said intermediate conduit.

* * * * *