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METHOD OF TRANSPORTING SOLID AND VISCOUS MATERIAL IN PIPE LINES

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The present invention relates to a method of transporting solid material in pipe lines by means of a liquid carrier medium.

It is well known to employ pipe lines for transporting gaseous and thin liquid bulk goods as for instance coke oven gas, natural gas and other fuel gases. It is also known to transport water, petroleum and other liquids in long distance pipe lines. In view of the frequently considerable reduction in transporting costs when employing pipe lines instead of other customary transporting means, efforts have been made to transport in pipe lines also solid materials especially bulk goods. Such solid materials may consist for instance of pit coal, lignite or brown coal, ores and other minerals in the form of corresponding fine pieces or in coarse granular, fine granular or pulverous condition.

It is furthermore known to transport solid materials as for instance macadam and broken stones through a pipe line by means of a gas stream such as air flow. This method is employed for instance in connection with the pneumatic stowing, underground mining for purposes of transporting mine waste or ashes. With this method, the energy costs for producing the gas stream are relatively high, and the pipe lines suffer a considerable wear so that this method is applicable in an economic manner over short distances only up to a few hundred yards.

Methods are also known according to which liquids are employed as carrier media for the solid materials to be transported. In these instances, the carrier medium is mixed with the solid material, and the mixture is then transported through the pipe line. As carrier media in this connection are employed water, oil, ordinarily liquid petroleum products, emulsions of water and oil or of water and liquid petroleum products as well as a foam produced from soap solutions or lyes by introduction of air.

It has also been suggested to intermix an aqueous brine containing the solid material with liquid petroleum products or to intermix the solid material with liquid hydrocarbons as for instance fuel oil, and then to introduce the mixture into a flow of water.

With all of the above mentioned methods, the carrier medium can only more or less be separated from the goods to be transported and under difficulties and considerable expenses only depending on the type and viscosity of the carrier medium. If the separation is effected merely by screening or sifting, considerable quantities of the carrier medium are lost due to the humidification of the goods being transported as well as due to the possible absorption of the carrier medium by the goods to be transported if the latter is porous, so that the goods which have been transported frequently possess an undesired humidity content. An additional recovery of the carrier medium and drying of the goods being transported, for instance by evaporation of the residue of the carrier medium, cause considerable costs. The separation of finest solid material from the carrier medium is particularly difficult and expensive. Therefore, with these known methods, the difficult and expensive separation of the carrier medium from the goods being transported has been considered a considerable drawback.

It is, therefore, an object of the present invention to provide a method of transporting solid materials in pipe lines, which will overcome the above mentioned drawbacks.

It is another object of this invention to provide a method of transporting solid materials in pipe lines by means of a carrier means, which will make it possible in an economic and relatively simple manner to separate the material being transported from said carrier means.

These and other objects and advantages of the invention will appear more clearly from the following specification.

The above mentioned objects have been realized according to the present invention by employing a gaseous liquefiable carrier medium which at least at the end of the pipe line and at the temperature and atmospheric pressure prevailing at said end will be gaseous, and which will be liquified by compression at the start of the pipe line and/or in the pipe line will be held in liquefied condition by compression, said carrier medium being at the end of the pipe line transformed by expansion (pressure release) into its gaseous condition and separated from the material transported by said carrier means.

Thus, the principle of the method according to the present invention consists primarily in employing a gas or a gaseous mixture in liquefied condition as a carrier medium for transporting a solid material, and after effected transport, in bringing said medium by expansion into a gaseous condition whereby said medium can in an extremely simple and effortless manner be separated from the transported material. If the gas or gas mixture is already at the start of the pipe line in liquefied condition, for instance due to the low temperature at the respective place, or because the gas is introduced into the pipe line already in compressed condition, it is merely necessary to see to it that the liquefied condition be maintained in the pipe line to which end the carrier medium has to be subjected to the required pressure in the respective section of the pipe line. If, however, the carrier medium is at the start of the pipe line in gaseous condition or in the form of a gas mixture, it will have to be liquefied by compression. Consequently, when selecting the gas or gas mixture to be employed as carrier medium, the conditions of operation at the end of the pipe line have to be considered above all, i.e. the conditions of operation at the place where the carrier medium is to be separated from the goods to be transported. Thus, a carrier medium is to be employed which at least at the temperature prevailing at the end of the pipe line and at atmospheric pressure will be gaseous. The atmospheric pressure at the end of the pipe line naturally depends on the altitude of the respective place above sea level. The temperature at the end of the pipe line will, of course, be determined by various factors. Thus, the temperature may for instance be affected by the local weather conditions which in their turn may be different at different seasons. A further factor is the temperature of the liquid carrier medium in the pipe line itself. This last mentioned temperature will, of course, with an underground pipe line be influenced by the temperature of the soil, whereas with an above-ground pipe line the temperature will be affected by the temperature of the air and direct radiation from the sun. Thus, a number of factors will determine the temperature of operation at the end of the pipe line. The carrier medium should, therefore, be so selected that when expanding to atmospheric pressure and at the respective temperature of operation it will transform from its liquefied into its gaseous condition. There will now be mentioned some gases with their boiling points at 760 torr=760 millimeters Hg column or approximately 14.7 lbs./sq. in which may, for instance, be employed as car-

rier medium in connection with the method according to the present invention:

Gas:	Boiling point, ° C.
Propylene (C_3H_6)	−47.0
Propane (C_3H_8)	−42.6
Difluordichloromethane (CF_2Cl_2)	−30.0
Methylchloride (CH_3Cl)	−24.0
i-Butane (C_4H_{10})	−10.2
n-Butane (C_4H_{10})	+0.5
Monofluortrichloromethane ($CFCl_3$)	+24.0
n-Pentane (C_5H_{12})	+36.1

Obviously, also mixtures of these gases such as a mixture of propane and butane may be employed as carrier medium. Inasmuch as the atmospheric pressures prevailing along the pipe line will not affect the method according to the invention, these atmospheric pressures will not effect the selection of the carrier medium. Also the temperatures prevailing along the pipe line are not decisive for the selection of the carrier medium because the latter is liquified by compression and will be held in its liquified condition within the pipe line. However, the required pressure maintaining the carrier medium in liquid condition will be determined by the maximum temperature occurring in the pipe line. Therefore, if for instance a pipe line extends from a place with a prevailing low temperature to a place with a prevailing low temperature but passes through an area of high temperature, the carrier medium will by means of a corresponding high compression be held in liquefied condition also in that pipe line section which extends through the area of high temperature. Particularly in such instances it may be advisable, in conformity with the temperature of operation at the end of the pipe line, to employ a carrier medium with as high a boiling point as possible so that in the area of high temperature, as low pressures as possible will suffice to maintain the carrier medium in the pipe line in its liquefied condition.

When very long pipe lines are employed, it is, of course, possible in a manner known per se to install in the pipe line pumping stations which will maintain the pressure required for the transport and also necessary to maintain the carirer medium in liquefied condition. Depending on the distance between the start and the end of the pipe line or the pipe line sections between the pumping stations if such are installed in the pipe line, a pressure drop will occur in the pipe line or pipe line sections. A pressure drop below the liquifying pressure at any point of the pipe line will be prevented by compressing the carrier medium at the start of the pipe line, and at the pumping stations if such are employed, at a pressure exceeding the liquifying pressure, the difference between these two pressures being greater than the pressure drop in the pipe line or pipe line sections. At the start of the pipe line, the carrier medium may be compressed to the required pressure above the liquifying pressure whereupon the material to be transported is fed into the carrier medium. However, it is also possible first to compress the carrier medium at the respective liquifying pressure and thereupon to feed the material to be transported into the liquified carrier means whereupon a further compression is effected at a pressure above said liquifying pressure. Instead of feeding the material to be transported into the already liquified carrier medium, it is also possible to feed the material to be transported into the gaseous carrier means and then to liquify the same.

When employing fuel oils as carrier means for solid fuels such as coal, it has already been found that following the separation of the coal from the fuel oil at the end of the pipe line, the fuel oil may be conveyed to consumers, and that with this method separate transporting means for the coal on one hand and the fuel oil on the other hand will not be necessary. The fine contamination of the fuel oil with solid particles reduces, however, the possibilities of use of the oil because such oil would easily clog up fuel nozzles and the like. On the other hand, purification the oil would be too expensive. These difficulties will not be encountered with the method according to the invention because the carrier medium which, at its expansion at the end of the pipe line transforms from its liquefied into its gaseous phase, can be separated from the transported goods in a manner in which it is completely free from solid particles. An essential advantage of the method according to the invention consists also in that when employing combustible gases as a carrier medium, for instance propane, butane or mixtures of said two gases which are to be supplied to consumers, these gases will easily and completely separate at the end of the pipe line from the transported material. If, however, the carrier medium is again to be employed for the transport of goods, the gaseous carrier medium separated from the transported material can easily be returned in gaseous condition from the end of the pipe line to the start thereof through a separate pipe line. Particularly when greater distances are involved, it may be more advantageous for reasons of costs to again liquify the gaseous carrier medium separated from the transported goods, by the employment of pressure and to return the thus liquified carrier medium from the end of the pipe line to the start thereof through a separate pipe line. If no continuous transport is to be carried out in the pipe line, it is also possible to store the carrier medium at the end of the pipe line and at certain time intervals to return the thus stored carrier medium through the same pipe line to the start thereof.

The expansion at the end of the pipe line may be effected in a pressure release chamber or in an expansion machine. In certain circumstances, the expansion of the liquified carrier medium may be effected in the end portion of the pipe line while the expanding or expanded carrier medium, which has partly or totally transformed into its gaseous condition, will bring about a pneumatic transport in the end portion of the pipe line.

Example

For the transport of hard coal with a granular size of 0 up to 3 mm. over a distance of 5 km. a pipe line with a diameter of 175 mm. is used. At the beginning of the pipe line the atmospheric temperature is 15° C., the atmospheric pressure 755 torr. At the end of the pipe line the atmospheric temperature is 16° C. and the atmospheric pressure 755 torr. Propane is used as carrier medium which at the atmospheric temperature and pressure mentioned above at the end of the pipe line will be in gaseous form. For keeping this carrier medium in liquid form at 16° C. a pressure of about 8 atmospheres absolute is necessary. The carrier medium propane is liquified at the beginning of the pipe line by compression to 18 atmospheres absolute, the heat of compression is removed, and the liquefied carrier medium is continuously fed into the pipe line while at the same time continuously feeding the coal to be conveyed. The proportion of coal and liquefied carrier medium in the pipe line is kept at 50:50 weight percent. During the transport in the pipe line a pressure drop of 10 atmospheres absolute will occur so that, according to the pressure of 18 atmospheres absolute at the beginning of the pipe line, at the end of the pipe line the pressure will be 8 atmospheres absolute. This pressure is sufficiently high to maintain the carrier medium propane in the liquefied state at a temperature of 16° C. The end of the pipe line is connected with a pressure release chamber in which the carrier medium vaporizes. The gaseous carrier medium is removed by suction from the pressure release chamber and carried off by a pipe line. The transported coal which is separated from the carrier medium is removed from the pressure release chamber in dry state.

It is, of course, to be understood, that the present invention is, by no means, limited to the specific examples set forth herein but also comprises any modifications within the scope of the appended claims.

What we claim is:

1. A method of transporting solid materials in a pipe line by means of a carrier substance, which includes the steps of: selecting as sole carrier substance a gaseous liquefiable substance which will be gaseous at the temperature and atmospheric pressure prevailing at the end of the said pipe line, inter-mixing the material to be transported and said carrier substance prior to passing the same together through said pipe line while at the latest at the start of said pipe line causing said carrier substance to assume its liquefied condition, passing the said mixture of material to be transported and carrier substance in liquefied condition through said pipe line while maintaining said carrier substance in liquefied condition, and at the end of said pipe line causing said carrier substance at and due to the there prevailing temperature and atmospheric pressure to reconvert from its liquefied condition into its gaseous condition to thereby separate said carrier substance from the material transported thereby.

2. A method of transporting solid materials in a pipe line by means of a carrier substance, which includes the steps of: for transporting the respective material employing as sole carrier a gaseous liquefiable carrier substance which will be gaseous at the temperature and atmospheric pressure prevailing at the end of the said pipe line, at the latest at the start of said pipe line liquifying said gaseous carrier substance by subjecting it to a liquifying pressure exceeding the liquifying pressure pertaining to the temperature prevailing at the end of said pipe line while making the difference between said two liquifying pressures greater than the pressure drop within said pipe line, inter-mixing the material to be transported and said liquefiable carrier substance, passing the thus obtained mixture through said pipe line, and at the end of said pipe line causing said carrier substance at and due to the there prevailing temperature and atmospheric pressure to reconvert from its liquid condition into its gaseous condition to thereby separate said carrier substance from the material transported thereby.

3. A method according to claim 1, in which the intermixing of the material to be transported and the carrier substance is effected by feeding the material to be transported into the liquified carrier substance.

4. A method according to claim 1, in which the material to be transported is fed into the carrier substance while the latter is in gaseous condition whereupon the carrier substance is liquified.

5. A method of transporting solid materials in a pipe line by means of a carrier substance, which includes the steps of: selecting as sole carrier substance a gaseous liquifiable substance which will be gaseous at the temperature and atmospheric pressure prevailing at the end of the said pipe line, inter-mixing the material to be transported and said carrier substance prior to passing the same together through said pipe line while at the latest at the start of said pipe line causing said carrier substance to assume its liquefied condition, passing the said mixture of material to be transported and carrier substance in liquefied condition through said pipe line while maintaining said carrier substance in liquefied condition, at the end of said pipe line causing said carrier substance at and due to the there prevailing temperature and atmospheric pressure to reconvert from its liquefied condition into its gaseous condition to thereby separate said carrier substance from the material transported thereby, and returning the thus separated gaseous carrier substance to the start of said pipe line.

6. A method of transporting solid materials in a pipe line by means of a carrier substance, which includes the steps of: selecting as sole carrier a gaseous liquefiable carrier substance which will be gaseous at the temperature and atmospheric pressure prevailing at the end of the said pipe line, inter-mixing the material to be transported and said carrier substance prior to passing the same together through said pipe line while at the latest at the start of said pipe line causing said carrier substance to assume its liquefied condition, passing the said mixture of material to be transported and carrier substance in liquefied condition through said pipe line while maintaining said carrier substance in liquefied condition, at the end of said pipe line causing said carrier substance at and due to the there prevailing temperature and atmospheric pressure to reconvert from its liquefied condition into its gaseous condition to thereby separate said carrier substance from the material transported thereby, and again liquifying the thus separated gaseous carrier substance and returning the same in liquefied condition to the start of said pipe line.

References Cited by the Examiner

UNITED STATES PATENTS

1,390,230	9/21	Bates.	
2,128,913	9/38	Burk.	
2,686,085	8/54	Odell	302—66

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