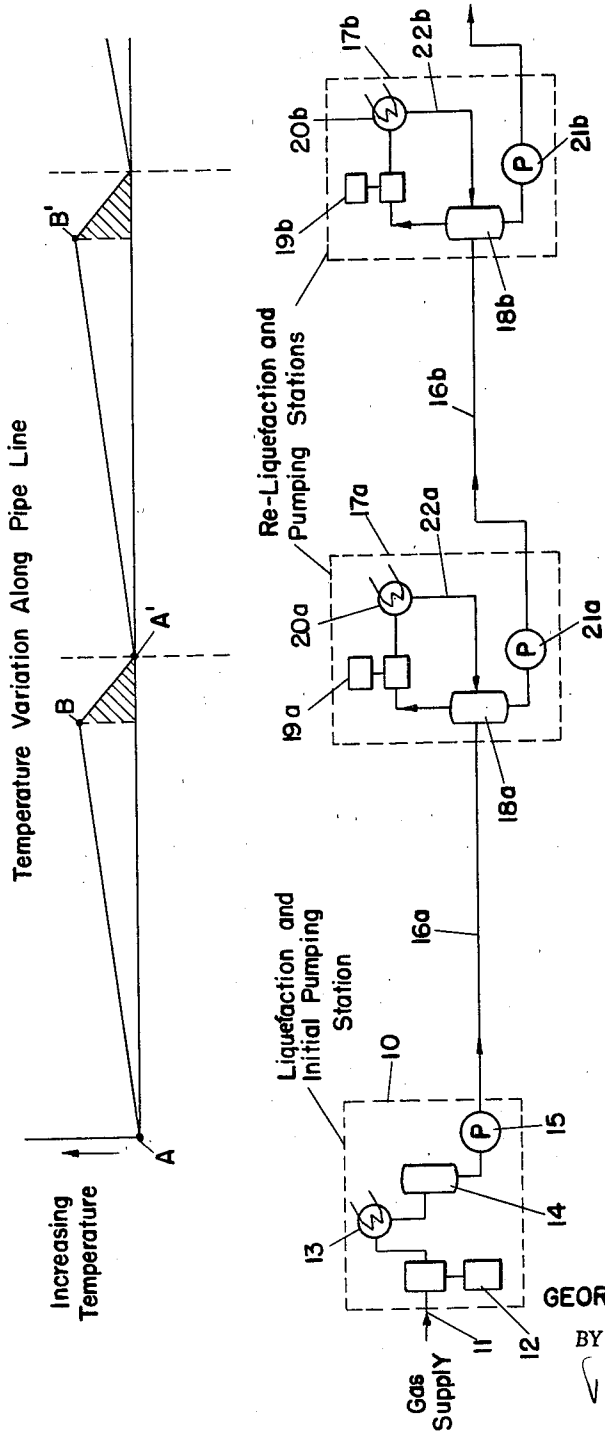
187-13 CROSS REFERENCE SEARCH ROOM

Nov. 1, 1960 G. B. McCONKEY 2,958,205

TRANSPORTATION OF NORMALLY GASEOUS FLUIDS IN PIPE LINE SYSTEM

Filed Oct. 22, 1958



INVENTOR.
GEORGE BOYD MC CONKEY
BY
Robert O. Spindle
ATTORNEY

United States Patent Office 2,958,205 Patented Nov. 1, 1960

2,958,205

TRANSPORTATION OF NORMALLY GASEOUS FLUIDS IN PIPE LINE SYSTEM

George Boyd McConkey, Wallingford, Pa., assignor to Sun Oil Company, Philadelphia, Pa., a corporation of New Jersey

Filed Oct. 22, 1958, Ser. No. 769,008

3 Claims. (Cl. 62—54)

This invention relates to method and means for the transportation of normally gaseous fluids over long distances and more particularly concerns a pipe line system for transporting a normally gaseous fluid wherein the transporting is effected with the fluid in liquid phase during a major portion of its travel and in mixed phase during the remainder. The invention, for example, is applicable to the transportation of natural gas across country.

Conventional systems for transporting a low boiling, normally gaseous fluid over long distances operate with the fluid in gaseous phase. For instance, pipe line systems for natural gas conventionally have spaced apart pumping stations which pump the material in gas form. The present invention is distinguished from commonly used transportation systems in that the normally gaseous fluid is transported mainly in liquid phase. However, the invention is practiced in such a manner that the fluid is purposely transported over a minor part of its distance of travel in mixed vapor and liquid phases. This effects substantial economies as compared to transporting the fluid entirely in liquid phase, as hereinafter more fully explained.

According to the invention a pipe line system is provided with spaced apart pumping stations and with means adjacent each station for liquefying that portion of the fluid which has vaporized before arriving at the station. The temperature and pressure of the fluid are regulated at the first station in the system such that the fluid will be entirely in liquid phase when it enters and will remain in liquid phase for a major part of the distance to the next pumping station. As the fluid flows toward the next station, its temperature progressively rises due to heat transfer from the pipe and frictional effects and its pressure progressively decreases due to pressure drop through the line. The regulated temperature and pressure conditions for the entering fluid are such that, after it has travelled a major portion of the distance toward the next station but substantially before it has arrived there, it will begin to vaporize in the pipe line. This vaporization proceeds as the fluid mixture flows toward the next pumping station, thereby causing the temperature to progressively decrease. The distance between pumping stations is such that, as the fluid arrives at the next pumping station, its temperature has dropped to approximately the original regulated temperature. At this point the mixture is passed to a separator where the gas phase is separated from the liquid, the gas is condensed, the condensate is admixed with the liquid, and the mixture is then pumped at regulated pressure toward the next station. Again, the mixture flows a major part of the distance between stations in liquid form and then begins vaporizing, which causes the temperature to drop to approximately the original temperature as the mixture arrives at the next station. The same procedure is then repeated between each adjacent pair of pump stations.

The invention is more specifically described with reference to the accompanying drawing which schematically illustrates a pipe line system according to the present invention and which also illustrates the fluid temperature variation that occurs along the line. For purpose of discussion the system will be considered as one adapted for the transportation of natural gas over long distances.

Referring to the drawing, the portion enclosed by dotted line **10** represents the initial liquefaction plant and pumping station for the natural gas which enters in vapor form through line **11** from a gas supply source. Station **10** has a liquefaction section which is illustrated schematically by compressor **12**, condenser **13** and liquid collecting tank **14** and a pumping section represented by pump **15**. The liquefaction section serves for liquefying the feed and reducing the temperature of the liquid to the desired low value, and pump **15** supplies the cold liquid to pipe line section **16***a* under the necessary pressure as shown in the drawing. The liquefaction section is a simplification of the equipment that would actually be required for reaching the low temperature that would be used in practice. For example, a cascade refrigeration system generally would be employed wherein the natural gas would be condensed by indirect heat exchange with evaporating ethylene, the vaporized ethylene would be recondensed similarly by means of ammonia or propane, and the ammonia or propane would be recondensed by water cooling. However, any suitable manner of cooling the natural gas to the desired low temperature can be employed, and hence a detailed description of the liquefaction and reliquefaction stations is not required for proper understanding of the invention.

Following the initial pumping station the system includes a plurality of additional stations, represented in the drawing by the portions enclosed by dotted lines **17***a* and **17***b* which are connected by pipe line section **16***b*. While only two such stations are shown in the drawing, it will be understood that the system will include any required number of stations for transporting the material across country the desired distance. The stations are approximately equally spaced apart at a distance which will depend largely upon the rate of heat build-up in the flowing fluid resulting from heat transfer through the pipe **16** and from frictional effects in the line. Pipe **16** should be carefully insulated, as by means of a jacketing outer pipe with insulation or a vacuum or both provided in the annulus. With efficient insulating means provided, the distance between adjacent pumping stations typically may be of the order of 100 miles for a system designed for transporting 3200 gals./min. of liquefied natural gas.

At each pumping station **17**, means are provided for separating the fluid into vapor and liquid portions, condensing the vapor portion, admixing the condensate with the liquid portion and then pumping the mixture at regulated pressure into the next section of the pipe line. Thus, station **17***a* is provided with vapor-liquid separator **18***a* and reliquefaction means again illustrated schematically by compressor **19***a*, condenser **20***a* and pump **21***a*, while station **17***b* correspondingly has separator **18***b*, compressor **19***b*, condenser **20***b* and pump **21***b*. This arrangement allows the fluid to be fed as a liquid into all sections of line **16** following the pumping stations at about the same temperature and pressure conditions as originally employed at station **10**. Hence, between each adjacent pair of pumping stations, the fluid will flow about the same distance before vaporization begins to occur.

The upper portion of the drawing illustrates the variations in fluid temperature that occur along the sections of line **16**. For example, assume that at station **10** the temperature of the liquefied feed has been regulated to

—205° F. and that pump **15** supplies the cold liquid to line section **16***a* at a pressure of about 1100 p.s.i.g. The temperature level at this stage is indicated by point A in the upper part of the drawing. As the liquid flows through section **16***a*, heat build-up will cause the temperature to rise as indicated by line AB. At the same time the liquid pressure along the line progressively decreases. At point B pressure and temperature conditions are reached at which the liquid begins to vaporize. For example, B may occur at a distance which is 90% of that between stations **10** and **17***a*, and the temperature and pressure at this point typically may be —158° F. and 304 p.s.i.g., respectively. This vaporization continues to occur as the liquid flows toward station **17***a*, thus causing the temperature to progressively decrease as indicated by line BA'. The point A' indicates that the temperature has again reached approximately the low value of —205° F., the pressure at this point being about 100 p.s.i.g. The shaded area under line BA' indicates the zone in which vaporization occurs; and under the conditions assumed herein about 22% of the fluid would vaporize during its travel through this zone.

Upon reaching station **17***a*, the mixture is passed into separator **18***a* and the 22% portion of vapor is removed through compressor **19***a* and liquefied by means of condenser **20***a*. The condensate returns to the separator via line **22***a* where it mixes with the 78% liquid portion of the fluid. The mixture, which has a temperature of about —205° F., is pumped via pump **21***a* into line section **16***b* which it enters at a pressure of about 1100 p.s.i.g. During its passage toward station **17***b*, its temperature increases as indicated by line A'B', reaching a maximum of about —158° F. at point B' which is about 10 miles from the next pumping station. Again the material proceeds to vaporize, causing the temperature to drop back to —205° F. by the time it reaches pumping station **17***b*. The vapor is again separated and condensed, and the material is pumped into the next line section at a temperature of about —205° F. and a pressure of about 1100 p.s.i.g.

Operation between succeeding pumping stations proceeds in the same manner as above described until the transported fluid has reached its final destination.

From the foregoing description it can be seen that the transporting operation conducted in accordance with the present invention involves substantially identical flow stages between adjacent pumping stations. In each stage the fluid enters the pipe line at about the same predetermined temperature and pressure conditions, which conditions are adapted to maintain the fluid in liquid form throughout a major portion, preferably 65–95%, of its distance of travel and then to cause continuous partial vaporization throughout the remainder of the distance. The distance of travel until vaporization begins is selected so that the cooling effect in the vaporization zone will bring the temperature of the vapor-liquid mixture approximately down to the initial low tempertaure as the material reaches the next pumping station.

By operating in the foregoing manner, substantial economies are effected as compared to maintaining liquid phase flow over the entire section between pumping stations. When natural gas is transported entirely in liquid phase with pumping stations spaced so that the liquid approaches but does not reach its bubble point, a considerably lower fluid temperature (e.g. 50° F. lower) is required or else the distance between pumping stations must be substantially shorter as compared to operating in accordance with the present invention. When a lower temperature is used, the heat transfer rate through the pipe line to the flowing material is materially greater and recooling costs are correspondingly increased. Decreasing the distance between pumping stations necessitates having more of them for a given distance of transportation and likewise increases the costs.

While the foregoing description has been directed largely to the transportation of natural gas, it is to be understood that the principles of the invention also are applicable to the transportation of other normally gaseous materials. For example, the transportation of materials such as oxygen, nitrogen, ethylene and acetylene over long distances can advantageously be carried out by employing the present invention.

I claim:

1. Method of transporting a normally gaseous fluid over long distances in a pipe line system having spaced apart pumping stations which comprises regulating the temperature and pressure of the fluid at the first station such that the fluid enters the pipe line in liquid form at a temperature substantially below that at which vaporization would occur; pumping the fluid alone toward the next pumping station, whereby the temperature of the fluid within the pipe line progressively increases and the pressure progressively decreases; permitting fluid to begin vaporizing within the line after the fluid has travelled a predetermined major portion in the range of 65–95% of the distance to the next pumping station, whereby vaporization causes the temperature of the fluid to progressively decrease; passing fluid, when its temperature has decreased due to vaporization to approximately the aforesaid regulated temperature, into a separating zone and therein separating vapor from liquid; condensing the vapor; mixing the condensate with the separated liquid; pumping the mixture alone at a temperature and pressure approximately the same as said regulated temperature and pressure toward the next pumping station; and repeating the specified operation between each adjacent pair of pumping stations.

2. Method according to claim 1 wherein the normally gaseous fluid is natural gas.

3. Method according to claim 2 wherein said temperature and pressure at each pumping station approximate —205° F. and 1100 p.s.i.g., respectively, and vaporization occurs when the fluid has travelled about 90% of the distance between stations.

References Cited in the file of this patent

UNITED STATES PATENTS

1,762,423	Scharpenberg	June 10, 1930
1,956,009	Dieschur	Apr. 24, 1934
2,021,394	Wade	Nov. 19, 1935
2,392,783	Stevens	Jan. 8, 1946