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PIPELINE TRANSPORTATION OF SOLID MATERIALS

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This invention relates to methods of transporting normally solid materials and, in particular, refers to transportation by pipeline.

As is common knowledge, the most widely used transportation media for large quantities of solid materials are the railroad, the ship and the motor vehicle. In general, these media furnish an efficient and inexpensive method of transportation. There are conditions, however, to which such means of transportation are not well adapted and wherein their use becomes inefficient and costly out of all proportion to the value of the material being shipped. A particular industry in which such conditions are often found is the mining industry.

Many mines both old and new are located in isolated regions which are impossible to reach by ship and which are considerable distances, often including rough terrain, from established rail and truck lines. The shipping of material from these mines by conventional means involves a very large initial investment in rolling stock and a large regular outlay to maintain and operate the equipment. In addition to the transportation means itself, the investment must also provide for warehouses, stockpiles, loading equipment, etc., since, unless there is an excess of equipment, the shipping can only be done intermittently Because these and many other disadvantages of conventional transportation media greatly increase the cost of the mined products to the consumer, the marketability of many products is low in relation to their actual value and in many cases valuable by-products are simply abandoned at the mine because transportation costs price them out of the market. As a specific illustration of this, potash, one of the most valuable fertilizer materials in the United States, carries a minimum freight burden of seven and a half dollars a ton. (It sells for $20 per ton.) Any reduction in the cost of transporting potash would lower its price and directly aid the farming and agricultural industry and indirectly aid everyone in the country. In the mining of potash near Carlsbad, New Mexico, sodium chloride (common table salt) is a by-product. Because of the high cost of transportation 10,000 tons of this material are abandoned daily since its ultimate consumer price would be too high. A decrease in the cost of transporting sodium chloride would make it possible to use a product now being abandoned and lower the cost of an essential food item.

Because of these and many other instances of excessive costs due to misapplication of conventional transportation media, it has been a principal object of my inventive efforts to reduce the cost of transporting soluble materials and materials which are available in relatively small granules or particles.

In order to reduce transportation expenses for materials of the types mentioned, I incorporate

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them into suitable fluid transporting media which I then force through pipelines to the desired destination. The success of this method of transportation is largely dependent upon the transporting fluids which are employed. I have discovered various transporting media which can be successfully used and the invention described herein concerns the use of the colloidal clays. Other media are described and claimed in my co-pending applications, which are continuations in part of this application, entitled "Pipeline Transportation of Soluble Granular Materials," Serial Number 8,295, filed February 13, 1948, and "Pipeline Transportation of Solid Materials and Petroleum Products," Serial Number 8,296, filed February 13, 1948.

It will be immediately recognized that my method of transportation may be much more efficiently and cheaply employed than conventional methods under circumstances such as described above. A pipeline is available for continuous shipping of material as it is mined or made ready for transportation. No storing is necessary. The initial investment for a pipeline is considerably less and operating expenses, labor for example, are also considerably less. Figures show that while the cost of shipping a material such as potash by railroad freight averages about $0.014 per ton mile, the same material may be shipped by the method of my invention at a cost of about $0.003 per ton mile, including all amortization of capital, interest on investments, and operating costs. This is a reduction in transportation costs of about 80%.

If solid materials are to be successfully transported by pipeline, they must, of course, be put into a fluid condition and maintained in that condition until the point of delivery is reached. Solid materials may be put in a fluid condition by dissolving them in a suitable fluid medium or by suspending them in a fluid medium having sufficient viscosity and density to prevent settling. As a viscous fluid media for transporting solid granular articles, the present invention contemplates the use of gels or suspensions of the colloidal clays, especially aqueous colloidal suspensions. In a preferred form of the invention a special type of colloidal clay is used which has the property of forming a gel in aqueous solutions of salts (brines) thus making it possible to transport both suspended solids and dissolved salts. Transporting media of this type flow freely through pipes and recovery of the transported materials therefrom may be easily and cheaply accomplished by suitable processes such as filtration, evaporation and centrifuging.

In order to describe my invention more specifically, I shall now refer to several examples thereof which, it will be understood, are merely illustrative.

Example 1

According to this example of the invention a

gel is urged primarily as a suspending medium for the transportation of granular articles. A typical analysis of a mixture of materials being transported might be as follows:

Wyoming type bentonite clay parts (by weight)	6
Water parts	100
Granular material (coal for example) parts	80

When the clay and water in these proportions are violently agitated together, a gel is formed having a Stormer viscosity of about fifteen to twenty centipoises. The coal particles may be added to this gel and the mixture forced by suitable means, mechanical means or by gravity, through the pipeline to the desired point of delivery. The coal may be then separated from the mixture by suitable means, filtration for instance, and, if desired, washed and dried, after which it is ready for marketing or use.

Insoluble solids are most suitable for the bentonite base transporting medium since soluble materials, particularly the salts, have a tendency to flocculate the clay. This is true of the gels formed by all of the colloidal clay materials except that used in Example 2. This tendency to flocculation can be overcome to some degree, however, by careful dispersion of the clays in fresh water followed by addition of the soluble material which it is desired to transport. This material can, of course, be subsequently recovered by evaporation or similar methods.

Other colloidal materials such as the Texas type bentonite clay may be used in this process and obviously many other materials, iron ore, for instance, may be transported by means of the medium of this example.

Example 2

In this example a gel is used as both a dissolving and suspending medium for the transportation of a single soluble material or a plurality of soluble or soluble and insoluble materials. A typical mixture according to this example might be as follows:

Florida-Georgia type fuller's earth parts (by weight)	6
Water parts	100
(1) Potassium chloride parts (in solution)	35
(2) Potassium chloride parts (in crystals)	35

The Florida-Georgia type fuller's earth should contain a substantial amount of its natural water of hydration. It is then capable of forming a gel in salt solutions. At 70° F, a saturated water solution of potassium chloride consists of thirty-five parts of the salt and one hundred parts of water. Such a solution may be prepared and the six parts of fuller's earth added thereto. When these ingredients are thoroughly mixed by suitable means, such as the dispersion mill of Patent No. 2,044,757, a gel having a Stormer viscosity of about twenty centipoises is obtained. An additional quantity of potassium chloride crystals, preferably of sufficient fineness to pass a 100 mesh screen, equal to the amount in solution (35 parts) may be added to this gel without appreciable settling. This mixture of dissolved and suspended potassium chloride and a gel may then be forced through a pipeline to the desired destination.

At destination the solid crystals of potassium chloride may be filtered out, centrifuged, or separated by other suitable means from the remaining colloidal salt solution. This operation may be facilitated by the use of a thinning agent which may be sufficiently effective to reduce the viscosity to the point where the crystals will completely settle out. Surface tension modifying agents, such as the sulfonated alcohols, can also be added to facilitate separation of the granular material. The dissolved salt may be recovered from the solution by suitable methods of evaporation or precipitation.

The usefulness of the foregoing mixture may be increased still further by adding another material which can be dissolved in the solution of the potassium chloride. Such a material is sodium chloride and thirty parts of it may be dissolved in the saturated salt solution previously described. The dissolved sodium chloride and potassium chloride may be separated from each other and from the solvent by suitable methods at the pipeline terminus.

The foregoing mixture is of great practical value since sodium chloride is a by-product in the winning of potassium chloride from sylvinite deposits. Heretofore it has been abandoned because of high shipping costs. It is now possible to transport it at virtually no cost since it can be added with no liability to the transporting medium containing the mined potassium chloride.

It will be noted that the fuller's earth of the type above described is particularly valuable in regions where only mineral waters are available as solvents. This clay readily forms gels in these waters so that, even though an undesirable dissolved constituent is also transported, a transporting medium formed therewith will have sufficient viscosity to carry desired insoluble particles.

It will be clear that the specific ingredients, their proportions, and the viscosities of the transporting media may very widely and must be determined in each case by simple experiments or by the judgment of one practicing the invention. If a normally solid material (or materials) is to be transported in the dissolved state the solubility at the lowest temperature encountered en route should be taken into consideration, since an excess may be precipitated and settle in the pipeline. Solubility can be easily determined from handbooks or simple tests. When a dissolved material is used, a trial analysis should be prepared on a test tube scale to make certain that it does not flocculate the colloidal gel. As indicated, it is desirable to use Florida-Georgia type fuller's earth having a substantial amount of its natural water of hydration when a dissolved material is transported because of its resistance to flocculation.

Certain properties of the suspended articles should also be taken into consideration before proceeding with full scale operations according to the transporting method of my invention. These should be considered in conjunction with the viscosity and density of the liquid transporting medium. It will be realized that both the density and viscosity of the liquid medium provide resistance to the settling of the suspended solid particles. In general the density of the liquid medium or gel is increased by the dissolved material to be transported, hence a gel having the desired amount of material in solution should be used in the making of tests and decisions. If the solid particles to be transported are less dense than this liquid medium, there is no problem of settling and the transporting medium need not be viscous. This occurs only in unusual cases, however, and it is generally necessary to provide

viscous resistance to settling to supplement the density of the liquid medium.

Viscous resistance to settling can be increased in two ways. First, it can be augmented by increasing the amount of colloidal material relative to the liquid suspending medium. As viscosity increases, however, so does resistance to flow through the pipeline, though it should be noted that the colloidal clays form a slick gel having surprisingly low resistance. It is therefore necessary to determine viscosity in the light of the conflicting considerations of suspending power and resistance to flow. I have found that the most desirable range of viscosity is fifteen to twenty centipoises, as determined by the Stormer viscosimeter, though special considerations, especially pipe size, encountered in particular cases often make it desirable to use viscosities outside of this range.

The second factor which affects viscous resistance is the size and shape of the solid particles. It is elementary that the resistance to settling is directly dependent on the surface area of the particles. In general, little control can be exercised over the shape of the individual particle. When it can, the surface area should be as large as possible in relation to the particle's weight or specific gravity. Total surface area is increased by decreasing the size of the individual particles. While particle shape control may not be always possible, it is usually possible to control particle size to some extent by mechanical or other means. This provides a convenient means for controlling the viscous resistance when a specified viscosity is desired.

The desired particle size, shape and area as well as the viscosity of the liquid medium may be determined arbitrarily or, preferably, by simple tests. These tests consist merely in preparing a small sample of the viscous liquid medium, adding thereto some of the solid particles, and observing the rate of settling of these particles. I prefer to have the rate of settling fall within the range of zero to one foot per minute though it will be understood that a greater rate of settling may be tolerated if the pipeline is short or if there is sufficient agitation within the pipeline to inhibit settling. If such tests show too great a rate of settling, the viscosity of the liquid medium may be increased though, as indicated above, when the viscosity is about fifteen to twenty centipoises it is more desirable to decrease the particle size or increase the individual particle surface areas. If such tests show a very low rate of settling, it may be desirable to decrease the viscosity, by adding more solvent, and thus lower resistance to flow through the pipeline.

These tests can obviously also be used to determine the proportion of insoluble ingredients relative to the other constituents of the fluid transporting mixture.

In case it is not convenient or possible to obtain a suitable rate of settling by controlling viscosity or particle surface area, agitation within the pipeline may be employed. I prefer to do this by "rifling" the inside of the pipes somewhat similarly to the way in which gun barrels are rifled. When the fluid mixture passes through a rifled pipe it is stirred so that the solid particles remain in suspension. Another means of agitation consists in placing a device in the pipeline, at intervals, which scrapes the sides of the pipe and picks up any settlings. This type of device is used by pipeline companies to clean their lines.

When water is used as the solvent and dissolved materials are transported, there is of course, likely to be a problem of corrosion. I have found that by adjusting the pH of the fluid mixture to 8.0, if possible, that no corrosion occurs in steel pipe of good grade. In case pH control is not satisfactory, the pipes may, of course, be made of wrought iron or lines with glass, rubber, or other suitable materials.

In view of the foregoing it will be realized that one or more soluble materials and one or more insoluble materials may be simultaneously transported by my method at a cost which may, in many cases, be considerably less than that of other methods. It has been shown and should now be apparent that the precise details of my method may be rather extensively modified so that the scope of my invention should be determined by the claims.

In particular, it will be noted that my invention is not restricted to the transportation of the specific materials mentioned above. Others, such as trona, phosphate, rock, sodium sulphate, iron ore, etc., may be transported in accordance with my invention by regulating their particle size if necessary and suspending them in gel and forcing the mixture through a pipeline.

In the claims the term "insoluble" is used in relation to the particular solvent or solution described in that claim. Accordingly, a soluble material such as (2) potassium chloride of Example 2 would be "insoluble" so far as the claims are concerned since (1) potassium chloride formed a saturated solution.

I claim:

1. The method of transporting granular materials which comprises mixing said materials with a liquid and a colloidal clay capable of forming a gel with the liquid, forcing the mixture through a pipeline, and recovering the material from the mixture.

2. The method of transporting soluble materials which comprises mixing said materials with a solvent therefor and a colloidal agent capable of forming a gel with the solution of material in solvent, forcing the mixture through a pipeline, and recovering the material from the mixture.

3. The method of simultaneously transporting a soluble material and an insoluble granular material which comprises mixing said materials with a solvent for the soluble material and a colloidal agent capable of forming a gel with the solution of material and solvent, said gel having sufficient viscosity to suspend the granular material, forcing the mixture through a pipeline, and recovering the materials from the mixture.

4. The method of transporting a granular insoluble material which comprises mixing said material with a liquid colloidal solution of a colloidal clay having sufficient viscosity to suspend the material, forcing the mixture through a pipeline, and recovering the material from the mixture.

5. The method of transporting a granular insoluble material which comprises mixing said material with a gel formed by a colloidal clay and solvent, said gel having sufficient viscosity to suspend the material so that it settles at a rate of substantially one foot per minute or less, forcing the mixture through a pipeline, and recovering the material from the mixture.

6. The method of transporting a granular insoluble material which comprises mixing said

material with a gel formed by a colloidal clay and solvent, said gel having a viscosity of from fifteen to twenty centipoises, said material consisting of granules having surface areas such that their rate of settling is substantially one foot per minute or less, forcing the mixture through a pipeline, and recovering the material from the mixture.

7. The method of transporting a granular material which comprises mixing granules of the material having substantially predetermined surface areas with a gel having a substantially predetermined viscosity formed by a colloidal clay and solvent, said surface areas and viscosity being determined so that the granules have a substantially predetermined rate of settling through the gel, forcing the mixture of gel and granules through a pipeline, and recovering the granules from the mixture.

8. The method of simultaneously transporting a soluble material and a granular insoluble material which comprises mixing said materials with a solvent for the soluble material and a colloidal clay capable of forming a gel with the solution of material and solvent, said gel having a sufficient viscosity to suspend the insoluble material so that it settles at a rate of substantially one foot per minute or less, forcing the mixture through a pipeline, and recovering the materials from the mixture.

9. The method of simultaneously transporting a soluble material and granules of insoluble material which comprises mixing said materials with a solvent for the soluble material and a colloidal clay capable of forming a gel with the solution of material and solvent, the viscosity of said gel and the surface areas of said granules being such that the rate of settling of the granules is substantially one foot per minute or less, forcing the mixture through a pipeline, and recovering materials from the mixture.

10. The method of simultaneously transporting a soluble material and granules of insoluble material which comprises mixing said materials with a solvent for the soluble material and a colloidal clay capable of forming a gel with the solution of material and solvent, said gel having a viscosity of fifteen to twenty centipoises, said granules having surface areas such that their rate of settling in said gel is substantially one foot per minute or less, forcing the mixture through a pipeline, and recovering the materials from the mixture.

11. The method of transporting granular insoluble material which comprises mixing said material with a viscous liquid colloidal solution of a colloidal clay, forcing the mixture through a pipeline, stirring the mixture while it is in the pipeline, and recovering the material from the mixture.

12. The method of simultaneously transporting a water soluble material and an insoluble granular material which comprises mixing the materials with water and a colloidal clay capable of forming a gel with the solution of soluble material and water, said gel having sufficient viscosity to suspend the granules, adjusting the pH of the mixture to substantially neutral, forcing the mixture through a pipeline, and recovering the materials from the mixture.

13. The method of simultaneously transporting a water soluble material and an insoluble granular material which comprises mixing the materials with water and a Florida-Georgia type fuller's earth having a substantial amount of its natural water of hydration to form a gel of viscosity sufficient to substantially support the insoluble material, forcing the mixture through a pipeline, and recovering the materials from the mixture.

14. The method of transporting a water soluble salt which comprises mixing a Florida-Georgia type of fuller's earth containing a substantial amount of its natural water of hydration with a water solution of the salt to form a gel of predetermined viscosity, forcing the mixture thus obtained through a pipeline, and recovering the salt from the mixture.

15. The method of transporting a water soluble salt which comprises mixing a Florida-Georgia type of fuller's earth containing a substantial amount of its natural water of hydration with a saturated water solution of the salt to form a gel of predetermined viscosity, adding additional particles of the salt to the mixture thus formed of such surface area and amount as to cause only inappreciable settling, forcing the mixture through a pipeline, and recovering the salt from the mixture.

16. The method of transporting water soluble salts which comprises mixing a Florida-Georgia type of fuller's earth containing a substantial amount of its natural water of hydration with a water solution of the salts to form a gel of predetermined viscosity, said solution being saturated with respect to at least one of the salts, adding additional particles of the saturated salt to the mixture, said particles being of such surface area and in such amount as to cause settling at a rate of substantially one foot per minute or less, forcing the mixture through a pipeline, and recovering the salts from the mixture.

17. The method of claim 14 which includes the step of adjusting the pH of the mixture to substantially neutral.

18. The method of transporting particles of insoluble material by means of a liquid medium of a liquid and colloidal clay having a predetermined viscosity which comprises adjusting the particle size of the material so that its rate of settling in the medium is substantially one foot per minute or less, mixing the material and medium, forcing the mixture through a pipeline, and recovering the insoluble material.

19. The method of transporting particles of insoluble material of predetermined size by means of a liquid medium of a liquid and colloidal clay which comprises adjusting the viscosity of the medium so that the particles have a maximum rate of settling of one foot per minute, mixing the material and medium, forcing the mixture through a pipeline, and recovering the insoluble material.

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