Nov. 26, 1968 D. M. FRAZIER 3,413,038

TRANSPORTATION OF SOLIDS

Filed April 10, 1967

Fig. 1

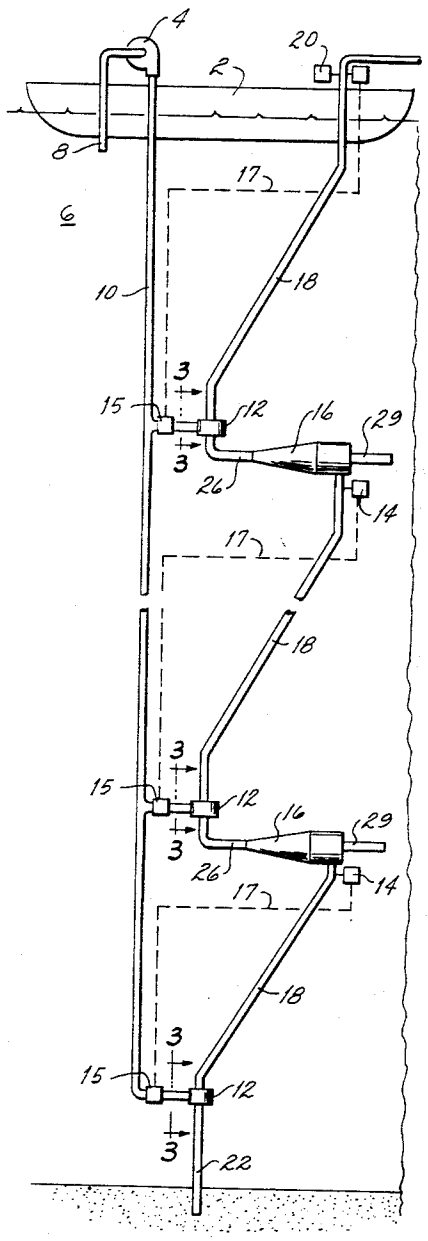


Fig. 2

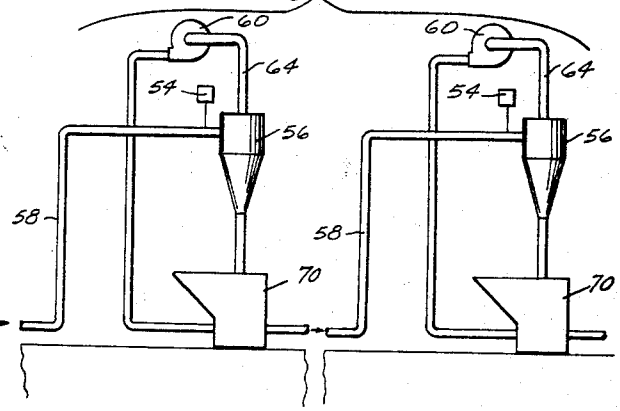
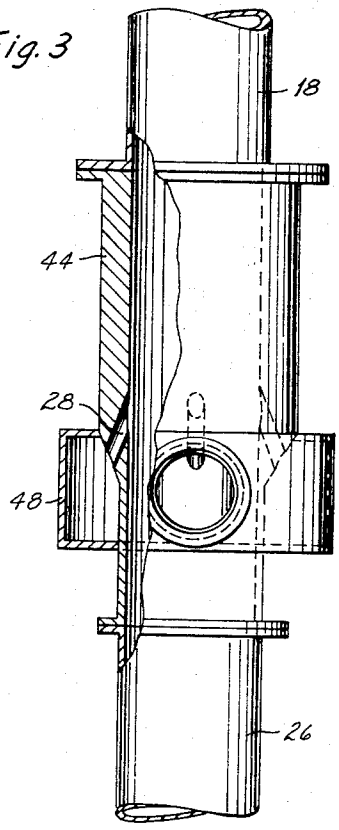


Fig. 3



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3,413,038

TRANSPORTATION OF SOLIDS

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ABSTRACT OF THE DISCLOSURE

Method and means for transporting solids in a slurry whereby low energy liquid is periodically removed from the slurry and replaced by high energy liquid to effect more efficient transportation of the desired fraction of the slurry. Removal is accomplished via a solids separator and replacement is accomplished via a jet pump. The system is useful both in dredge and in overland operation.

This invention relates to method and means for transporting solids through pipelines, and more particularly, to the more efficient transportation of subdivided mineral solids while suspended in a liquid medium.

It is well known in the hydraulic sciences that liquid when pressurized possesses energy and the capacity to do work. Energy, as used herein, is defined as the energy possessed by a liquid by virtue of its pressure or velocity.

When the pressurizing process is continuous, the pressurized liquid will transmit power. One of the practical uses of such energy, or power, is in the transporting of solids by combining the solids with a liquid and pumping the mixture through pipes and hoses, as a slurry. U.S. Patent Nos. 2,672,370, 2,672,371 and 2,672,372 are typical examples of teachings of such art.

The technique is widely used on a large scale in dredging and mining, as well as on a small scale in manufacturing foods, pharmaceuticals, paints and chemicals.

In such transmission of solids as a slurry, it is customary to introduce the slurry directly into a pressurizing device, such as a centrifugal or a positive displacement pump. Unfortunately, excessive wear on the pump occurs with this technique. The necessary energy to accomplish transmission may also be accomplished by introducing the energy required to support movement in the pipeline by means of a jet pump, or pressure nozzle. The solids are diverted around the jet inlet.

In dredging, the centrifugal or positive displacement pump is usually mounted at surface level aboard a dredge. However, the pump is only effective at relatively shallow depths, becoming almost completely unproductive of bottom materials below 100 feet. This is so because the pressure energy, which may be developed at the dredge pump suction is limited to the vapor pressure of water. Since, it is so limited, the weight of solids and/or the depth from which bottom material may be reclaimed is also limited.

To assist the dredge pump suction, a jet booster pump, such as described in U.S. Patent No. 3,213,807, is frequently used. It is mounted in series on the suction pipe, at some distance below the water surface in order to add additional energy to the suction side of the dredge pump, thereby increasing production of bottom materials. Practical dredging depth by the use of a single jet booster pump of conventional design is unfortunately limited to 250 feet, especially if a high concentration of solids is to be lifted. Also, the energy that a single jet booster pump may add to the dredge pump suction is limited by the product of the jet water volume and the jet water pressure. Thus, even by adding another jet pump in series, the energy level within the suction may be increased somewhat but there would be further dilution of the slurry resulting in an increase in total power requirement and ultimate pumping cost. In essence, a major problem exists in the practical and economic recovery of minerals from the mineral rich, deeply submerged continental shelves of all continents.

An object of this invention is to provide means for pumping slurry over long distances or up high heights without dilution of the mixture.

Another object is to provide means, of the above character, especially useful for deep water dredging and mineral recovery.

Still another object is to provide a jet pump arrangement which supplies high energy liquid to the slurry pipeline while simultaneously controlling the quantity of liquid added to the pipeline.

A further object is to provide means for controlling slurry velocities within pipelines.

A still further object is to provide means for pumping slurry whereby low energy liquid is separated from the slurry and replaced by high energy liquid, while the slurry is in continuous transport.

Another object is to provide means for continuously upgrading mineral ores while in continuous transport whereby fines and lighter solids are continuously rejected while the desired ore fraction is concentrated thereby reducing the volume and weight of the slurry that must be transported and thereby enabling the use of smaller pipes with less power.

Another object is to provide means of continuously diverting solids from centrifugal and positive displacement pump circuits thereby reducing pump wear and increasing pump efficiency.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

A method and apparatus has now been found for the more efficient transportation of subdivided solids while suspended in a liquid medium, also known as a slurry. The slurry may be pumped over long distances or up high heights by the application of pumping pressure thereto utilizing a system of jet pumps. However, portions of the low energy liquid are separated via a solids-liquid separator. The low energy liquid is either removed and replaced by high energy liquid or reenergized and returned to the system to maintain pumping pressures. The slurry is kept in continuous transport substantially in its same solids content form.

More particularly, a slurry may be pumped over long distances or up high heights by utilizing pressurized liquid from a jet pump upon a concentrated form of the slurry to carry the solids therein over a distance or up a height and then repeating said process until the distance or the height desired has been accomplished. The slurry is concentrated in solids by a liquid-solids separator such as a cyclone just before the slurry reaches the jet pumps. A sensor coupled to the jet pump and/or to the separator controls the application of pressurized liquid upon the slurry to effect an optimum economical transportation system for solids.

The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the others thereof, which will be exemplified in the method hereinafter disclosed, and arrangement of parts which will be exemplified in the the features of construction, combination elements, and arrangement of parts which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIG. 1 illustrates a preferred embodiment of the in-

vention showing the system utilized for deep water dredging.

FIG. 2 illustrates a preferred embodiment of the invention showing the system utilized for overland transport of the bottom materials of FIG. 1.

FIG. 3 is a side view, partly in section, of a preferred embodiment of a jet nozzle useful in the system of this invention.

Similar reference characters refer to similar parts throughout the several views of the drawings.

As seen in FIG. 1, the system for deep water includes a dredging barge **2** on which a high pressure centrifugal pump **4** is mounted. The pump supplies high pressure water from the ocean **6** via pump inlet **8** to jet liquid supply pipe **10**. This pipe distributes high pressure liquid, water in this instance, to jet pumps **12** spaced in vertical series to the ocean bed. A pressure sensing device **14** is located at the head of each section of slurry pipe **18** and generally at the entrance to each solids-liquid separator, in this instance a cyclone **16**, to measure the pressure at that location. The sensing device also acts to control jet liquid supply valve **15** in series position with each jet pump. Each sensing device **14**, as shown by dotted line **17**, controls the operation of valve **15** of the energy supplying pump **12** to that section of slurry pipe **18**.

The cyclones are spaced in series along slurry pipe **18**. Each cyclone is of conventional design and is employed as a means of separating solids from the liquid of the slurry and for classifying solids by size and weight. By properly selecting the cyclone, it is therefore possible, and in many instances, desirable to also reject to waste, the slimes, fines and lighter particles of the slurry which have been classified in the cyclone as the next fraction to the liquid. Such classification and rejection of slimes, fines, and lighter particles eliminates the energy requirements thereafter needed to lift these unwanted solids to the surface. Furthermore, it reduces the beneficiation process requirements aboard the dredge or ashore.

Upon receiving a signal from the pressure sensing device **14**, which sense pressure in slurry pipe **18**, the pumps **12** act to introduce pressurized water or water energy into slurry pipe **18** which causes continued transport of the slurry up slurry pipe **18**.

A flow meter **20** is mounted on the slurry delivery pipe **18** and acts in conjunction with the several pressure sensing devices **14** to establish the desired flow rate within the slurry pipe.

Once an optimum liquid flow has been established, suction mouth **22** of the lowest jet pump is lowered to take in bottom materials or solids along with water. As solids are introduced, the energy requirements of the entire slurry delivery system increases in direct proportion to the weight of the solids in the pipeline. Thus, it should be evident that the energy level will be greater at the discharge of the jet pump **12** than at the entrance to the subsequent cyclone **16** because energy is spent lifting the slurry to the next cyclone. Idealistically, at the entrance of the cyclone **16**, the liquid in the slurry has lost substantially all its productive energy.

As the slurry moves through the cyclone **16**, a portion of the low energy liquid is separated from the slurry and wasted to the sea through cyclone overflow **29**. The slurry, in its now more concentrated form, moves through cyclone underflow **26** into the next-in-line jet pump **12**. At this point, the concentrated slurry mixes with high energy water being continuously introduced through jet orifices **28** (see FIG. 3) and the resultant mixture travels upwardly to the next cyclone-pump station.

As seen in FIG. 3, each jet pump comprises a product inlet pipe **26** (of low energy) and a product outlet pipe **18**, separated by a jet nozzle section **44**. Section **44** contains a series of jet orifices or nozzles **28** fed with high pressure liquid from jet water supply plenum **48**. The plenum **48** is supplied with liquid under high pressure via jet liquid supply pipe **10** (compare to FIG. 1).

It should be evident from the above description that all energy entering the slurry delivery pipe **18** is introduced via pump **4**, and that, as the energy is used to lift the solids up each section of slurry pipe **18**, the liquid (and undesired slimes, fines, and lighter particles) are separated from the solids and a fresh supply of energy-charged water is injected via jet nozzles **28** in each jet pump.

When the slurry reaches the surface, the slurry pumping system of this invention changes slightly for overland transport to accommodate the fact that liquid (water, usually) is not as readily available. So, in such instance, the liquid is reused after being energized.

The overland system comprises a slurry pipe **58** (similar to pipe **18** of the deep dredge system), which is in sections (dependent upon the distance the slurry is to travel), each section of which contains a pressure sensing device **54**. As with the deep dredge system, each section of slurry pipe feeds into a cyclone **56**, where liquid of low energy (and fines, slimes and lighter particles) are separated from the slurry, recirculated via pipe **64**, reenergized via centrifugal pump **60** (or other pump), and reused, as described hereinafter. The heavier solids in the slurry drop into collection chamber **70**, where the slurry tends to settle. If desired, decantation of liquid may be employed to remove further amounts of low energy water.

The reenergized liquid from pump **60** is now reused to give further impetus to the concentrated slurry in chamber **70** whereby it will be carried over the next section of slurry pipe **58** to the next sensing device **54**, cyclone **56**, etc. A similar jet pump arrangement, such as in FIG. 3, may be used to accomplish such.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained, and since certain changes may be made in carrying out the method and in the construction without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention, which, as a matter of language, might be said to fall therebetween.

Now that the invention has been described, what is claimed is:

1. Apparatus for the more efficient transportation of solids while suspended in a liquid medium as a slurry via the application of pumping pressure thereto comprising a slurry pipe, at least one jet pump in series connection therewith, jet liquid supply means coupled to said pump, solids-liquid separating means comprising a centrifugal separator in series connection with said slurry pipe, each said separating means being coupled to one jet pump for delivery of solids separated from said slurry thereto and pressure sensing means for sensing pressure in said slurry pipe and for controlling the operation of said jet pump.

2. The apparatus of claim **1** wherein said slurry pipe is positioned substantially vertically to lift said slurry.

3. The apparatus of claim **1** wherein said slurry pipe is positioned substantially horizontally to transport said slurry over a distance.

4. The apparatus of claim **2** wherein said slurry pipe is used as a dredge means in a body of water and wherein a plurality of pumps, separating means and sensing means are positioned vertically thereon whereby bottom material can be lifted from the bed of the body of water even if said body of water is more than 200 feet deep.

5. The apparatus of claim **4** wherein said separating means has an overflow outlet to the body of water for removing the low energy liquid of the slurry and undesired fines, slimes, and lighter particles to the body of water whereby efficiency in the dredge means is accomplished.

6. The apparatus of claim **4** wherein said jet liquid supply means comprises a pump means on a floating barge,

a liquid inlet from the body of water upon which the barge floats and a liquid outlet coupled in parallel relationship to each of said pumps.

7. The apparatus of claim **3** wherein a plurality of pumps, separating means and sensing means are positioned along said slurry pipe and the overflow of said separating means is coupled to a pump whereby the liquid from said slurry is converted to high energy liquid and then recirculated to said jet pump by a conduit.

8. A method for the more efficient transportation of subdivided solids while suspended in a liquid medium as a slurry via the application of pumping pressure thereto comprising the steps of determining the pressure existing in said slurry, separating a portion of the low energy liquid of said medium with the subsequent replacement thereof with high energy liquid of a controlled pressure when said pressure falls below a predetermined level to maintain pumping pressures in said liquid medium and to maintain said solids suspended therein in continuous transport.

9. The method of claim **8** wherein the velocity of said slurry is measured before determining said pressure, and the level of high energy liquid replaced is correlated to said velocity of said slurry.

10. The method of claim **8** wherein said separation and replacement occurs more than once to accomplish greater height or distances in the transportation of said solids.

11. The method of claim **8** wherein said low energy liquid is separated to waste.

12. The method of claim **8** wherein said low energy liquid is separated, then re-energized and then reused as the high energy liquid.

13. The method of claim **8** utilizing in addition a method for the beneficiation of said subdivided solids whereby undesired fines, slimes and lighter particles may be separated along with the low energy liquid comprising establishing a sufficient head for said slurry prior to said determination of pressure, and spearating both said low energy liquid and the undesired fines, slimes and lighter particles in a gradient pattern in accord with said determination of pressure with subsequent replacement of said low energy liquid with high energy liquid.

14. The method of claim **12** wherein said separation and replacement occurs more than once to accomplish greater height or distances in the transportation of said solids.

15. The method of claim **13** wherein said low energy liquid and said undesired fines, slimes and lighter particles are separated to waste.

16. The method of claim **13** wherein said low energy liquid is further separated from said undesired fines, slimes and lighter particles, then re-energized and then reused as the high energy liquid.

References Cited

UNITED STATES PATENTS

2,852,313	9/1958	Mickel	302—14
3,010,232	11/1961	Skakel et al.	302—14
3,038,760	6/1962	Crooke	302—14
3,339,984	9/1967	Berkowitz et al.	302—14

ANDRES H. NIELSEN, *Primary Examiner.*

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,413,038 November 26, 1968

David M. Frazier

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, lines 62 and 63, "arrangement of parts which will be exemplified in the the features of construction, combination elements," should read -- the features of construction, combination of elements, and arrangement of parts which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims. --. Column 6, line 6, "spearating" should read -- separating --.

Signed and sealed this 10th day of March 1970.

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER, JR.

Commissioner of Patents