July 7, 1964 I. G. BOWEN 3,140,123

HANDLING OF SLURRIES

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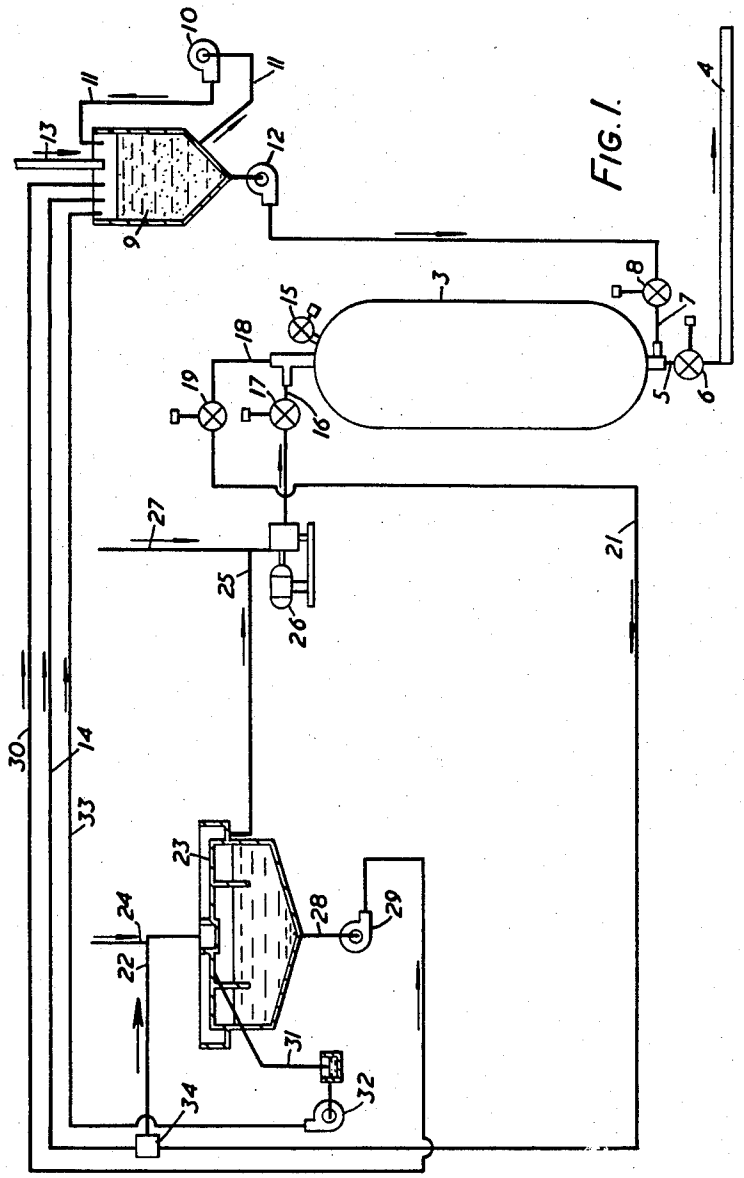


FIG. 1.

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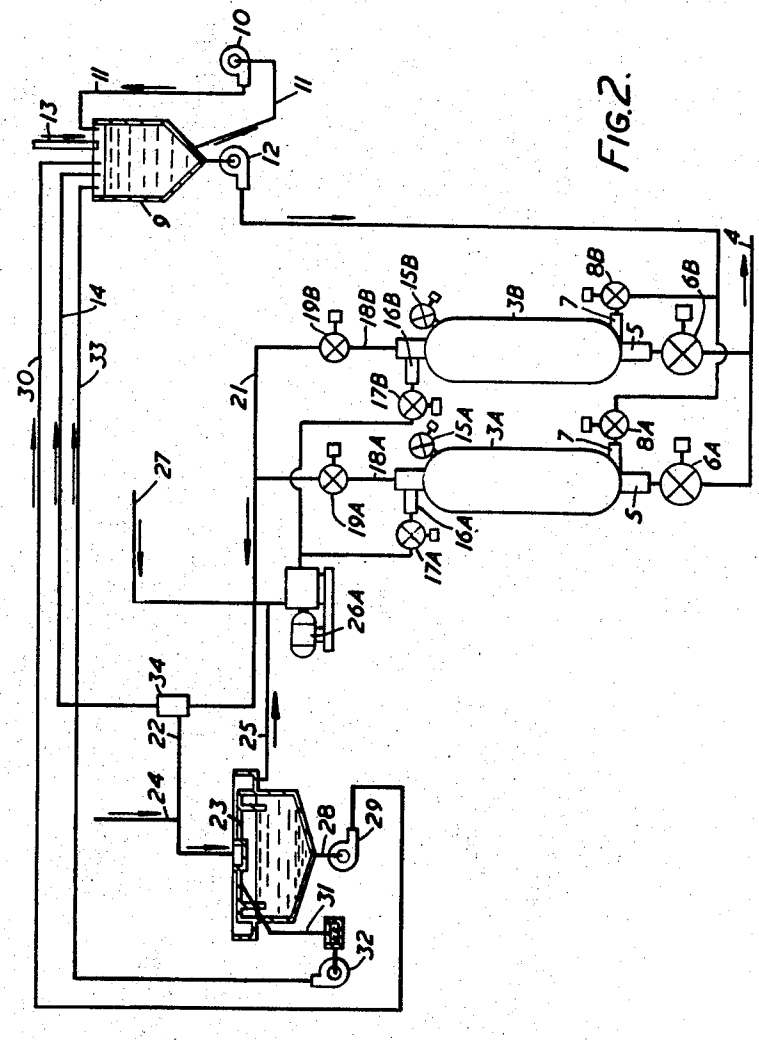


FIG. 2.

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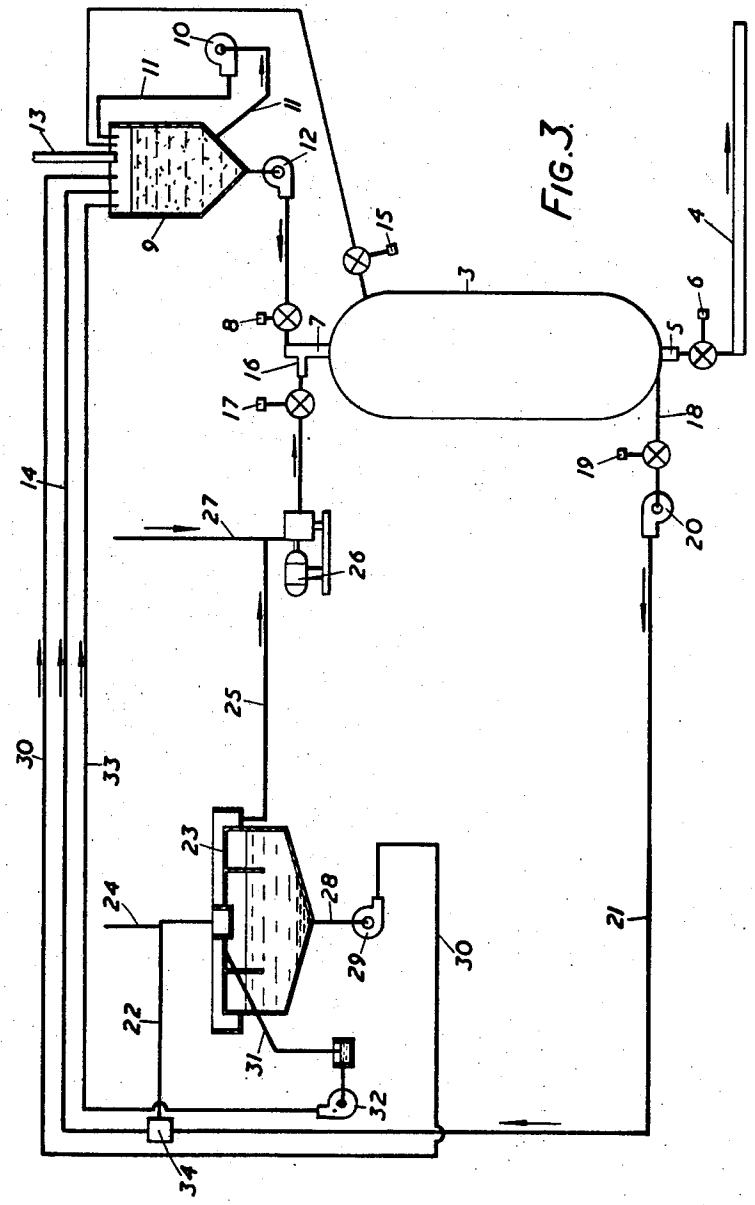


FIG. 3.

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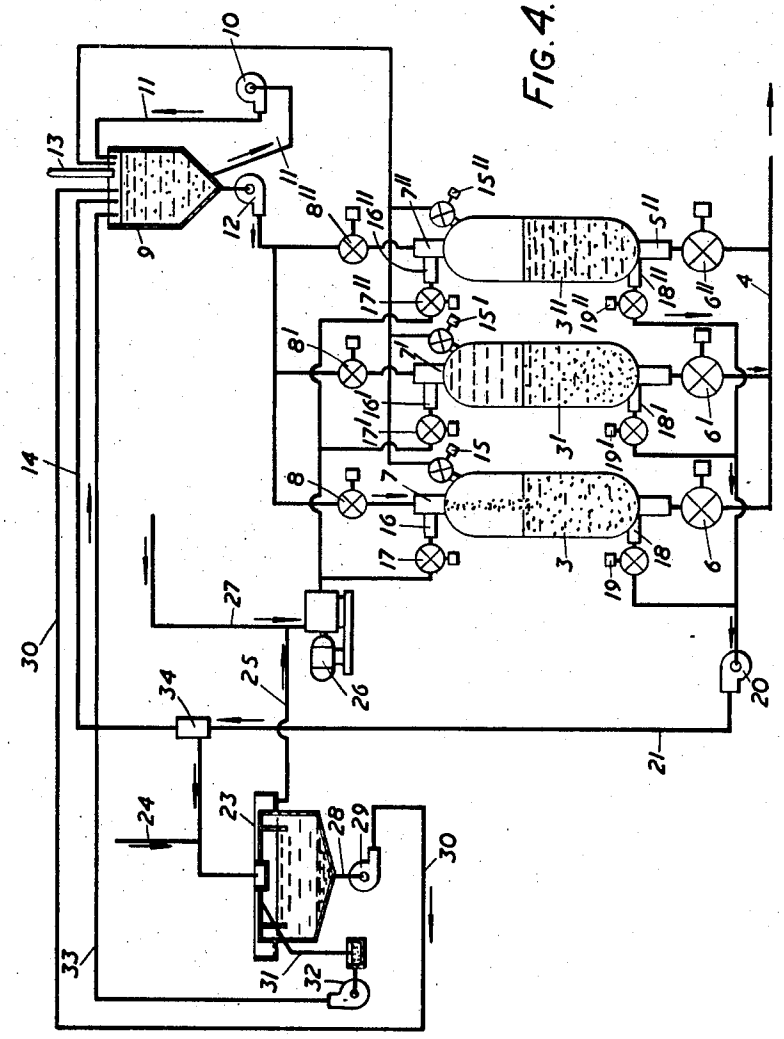
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FIG. 4.



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HANDLING OF SLURRIES

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The present invention relates to the handling of slurries which for the purposes of this specification are defined as suspensions of solids in liquids, the stability of the suspension being such that deposition of the solid content does not occur quickly. Slurries are found, for example, in metallurgical processes, mining processes, certain types of chemical processes, coal washing processes and in some material handling plants. The slurry is frequently abrasive and its handling presents problems.

For example, modern coal-fired power stations burn very large quantities of coal and produce very large quantities of ash. Both the transportation of the coal for burning and the disposal of the ash produced present problems and one solution is to transport the coal and/or ash as a slurry with water. Such coal/water or ash/water slurries are very abrasive and would normally be handled by specially designed slurry pumps. For short distances and moderate pressure heads, the use of such pumps is common practice despite the wear on the pumping parts which necessitates frequent replacement and constant maintenance. However, for higher pressure heads, the pump design necessitates finer clearance with the tendency to greater wear resulting in a heavy charge on operating costs due to maintenance.

It is possible to discharge slurries against high pressure heads by means of lock hoppers. Essentially a lock hopper comprises a vessel provided with a slurry inlet, a clean pumping liquid inlet, a dirty liquid outlet and a slurry outlet connected for example to a pipeline along which the slurry is to be transported. Separate valves control each inlet and outlet. In operation the lock hopper is filled with slurry which is then expelled into the pipeline by pumping into the hopper a quantity of clean liquid, for example water. After the slurry has been expelled, the liquid is replaced by a further quantity of slurry and the cycle repeats. The use of a lock hopper enables the latter to be filled with slurry using a low pressure slurry pump and the slurry to be expelled from the hopper against a high pressure by means of clean liquid pumped into the latter by a high pressure pump which because it is pumping clean liquid is not exposed to the deleterious action of the slurry.

The clean liquid used in such a cycle becomes contaminated and on discharge from the lock hopper is not suitable for further use through the high pressure pump. Contamination occurs by deposits left by the slurry on the walls of the lock hopper and by slight mixing of the clean liquid and the slurry which occurs during displacement of the latter from the hopper although careful design of the inlet ports of the lock hopper reduces that mixing to a minimum. The contaminated liquid is therefore used in the slurrying process where it is mixed with dry solids to form the slurry which is supplied to the lock hopper. However, the volume of displacement liquid used to expel slurry exceeds the volume of liquid used in the slurrying process by an amount equal to the volume of solid in the slurry. That excess liquid is normally not used and thus creates a disposal problem. For instance, if the system is used to remove ash from a power station at a rate of 2,000 tons per day, the quantity of excess contaminated water to be disposed of is equal in volume to 2,000 tons of ash, i.e. 220,000 gallons per day.

It is an object of the present invention to provide a

method of pumping slurries along a pipeline which substantially obviates the water disposal problem outlined above.

According to the present invention, a method of pumping slurries introduced into a pipeline by means of a lock hopper wherein a volume of slurry is first pumped from a slurry reservoir into a lock hopper and is then expelled from the hopper into the pipeline by an equal volume of displacement water supplied from a water source and subsequently removed from the hopper after the expulsion of the slurry is characterised in that a proportion of water equal in volume to the volume of solid content of the slurry is separated from the displacement water, clarified and recycled to the water source and the remaining displacement water is conducted to the slurry reservoir.

Further according to the present invention, apparatus for introducing slurry into a pipeline comprises a slurry reservoir arranged to supply slurry to a lock hopper, a water source arranged to expel slurry by displacement from the lock hopper, a water by-pass conduit connecting said lock hopper to water clarifying means, a water return conduit connecting the water clarifying means to the water source, and a dirty water conduit connecting said lock hopper to the slurry reservoir the apparatus being such that, in operation, a quantity of displacement water equal in volume to the volume of the solid content of the slurry is clarified and returned to the water source and the remaining displacement water is conducted to the slurry reservoir.

The slurry must, of course, remain stable during the cycle time of the process, i.e. deposition of suspended solids must not occur to any substantial extent during that time.

The clarification of water recycled to the water source may be carried out in a thickener.

A plurality of lock hoppers may be arranged so that the pipeline is continuously fed with slurry.

Two embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

FIG. 1 shows diagrammatically an intermittently operated lock hopper installation for handling abrasive slurries,

FIG. 2 shows diagrammatically a constant-flow lock hopper installation for handling pulverised fuel ash, and,

FIGS. 3 and 4 correspond with FIGS. 1 and 2 but show further embodiments.

In FIG. 1 of the accompanying drawings, a lock hopper vessel **3** is connected to a pipeline **4** by a slurry outlet **5** leaving the bottom of the vessel **3** and controlled by a slurry outlet valve **6**.

A slurry inlet **7** controlled by a slurry inlet valve **8** also connects with the bottom of the vessel **3** and is fed from a slurry reservoir **9**. A low pressure slurry circulating pump **10** is connected to the reservoir **9** by pipes **11**, the arrangement being such that, in operation, the pump **10** circulates the slurry in the reservoir **9** and so maintains effective mixing of the slurry. A slurry feed pump **12** is located in the slurry feed between the slurry inlet valve **8** and the slurry reservoir **9**.

The reservoir is fed with the pulverized solid content of the slurry by a powder pipe **13** and with a liquid, for example water, through a pipe **14**.

The vessel **3** has an air relief valve **15** and leading into the top of the vessel is a clean liquid, e.g. clean water, inlet **16** controlled by an inlet valve **17**, and a dirty liquid, e.g. dirty water, outlet **18** controlled by an outlet valve **19**.

Dirty water from the water outlet **18** discharges into dirty water pipe **21** which is connected to the pipe **14** and a clarifier feed pipe **22**. A control valve **34** at the junction of pipes **14**, **21** and **22** is such that from the dirty displacement water discharged into pipe **21** a proportion

equal in volume to the volume of the solid content of the slurry is fed through the pipe **22** to a thickener **23**, a flocculent injector **24** treating the water fed to the thickener **23** by the pipe **22**. The remaining dirty water is conducted through the pipe **14** to the slurry reservoir **9**.

A clean water pipe **25** connects the thickener **23** to a water pump **26** which is also connected to a make-up water pipe **27** which supplies fresh water to make good inevitable wastage losses of such a cycle. The water pump **26** feeds the water inlet **16**.

A sludge outlet **28** from the thickener **23** is connected via a sludge pump **29** and a thickenings pipe **30** to the reservoir **9**, and a "floaters" outlet **31** from the thickener **23** is similarly connected through a scum pump **32** and a scum pipe **33** to the slurry reservoir **9**.

In operation, the proportion of dirty displacement water equal to the volume of the solid content of the slurry and passing through pipe **22** to the thickener **23** is clarified. The clarified water is recycled through the pipe **25** and the water pump **26** to the water inlet **16**. The sludge collecting at the bottom of the thickener is returned through pump **29** and pipe **30** to the slurry reservoir **9**, and similarly "floaters" and other scum removed from the top of the thickener **23** through the outlet **31** are returned through pump **32** and pipe **33** to the slurry reservoir **9**.

The sequence of operation of the lock hopper itself is as follows, starting with the slurry inlet valve **8**, the slurry outlet valve **6**, the water inlet valve **17** and the water outlet valve **19** all closed, and the air relief valve **15** opened. The water inlet valve **17** is first opened and the vessel **3** filled with clean water. The air relief valve **15** is then closed and remains closed during subsequent operation.

The slurry inlet valve **8** and the water outlet valve **19** are then opened and slurry pumped by the pump **12** into the vessel **3** so displacing the water therein which leaves via water outlet **18**. The slurry inlet valve **8** and the dirty water outlet valve **19** are then closed and the slurry outlet valve **6** and the water inlet valve **17** are opened and water pumped into the vessel **3** by water pump **26** through water inlet **16** to displace the slurry through the slurry outlet **5** into the pipeline **4**. By careful design of the water inlet, a clean interface is produced between the water and the slurry and there is no appreciable mixing. When the slurry has been displaced from the vessel **3**, the valves **6**, **17** are closed and the slurry inlet valve **8** and dirty water outlet valve **19** are opened. The water in the vessel, soiled mainly by contact with the walls of the vessel **3**, is removed by displacement by incoming slurry and passes through the pipe **21**, part being recycled through the thickener **23** to the water pump **26** as described above and the bulk being conducted through pipe **14** to the slurry reservoir **9**. The cycle of operation is then repeated.

FIG. 2 shows a continuous flow installation for pumping pulverised fuel ash which is a development of the installation described with reference to FIG. 1.

A battery of two lock hopper vessels **3A**, **3B** feed the pipeline **4** and the valves and pipes to each vessel also are duplicated. The same reference numerals are used as when describing FIG. 1 with appropriate differentiation letters for references specfic to each vessel.

The lock hopper vessels are arranged to discharge in sequence, the sequence having a slight overlap so as to ensure continuity of pumping and hence of pipeline flow.

As vessel **3A** is emptying of slurry, vessel **3B** is refilling preparatory to discharging slurry into the pipeline **4**.

The valves **6A**, **6B**, **8A**, **8B**, **17A**, **17B**, **19A**, **19B** are interlocked and are arranged to act automatically in sequence. The interlocking of the valves is achieved in this installation by hydraulic operation of the valves controlled by a timer in a sequence calculated in accordance with the flow rates of the pumps. Alternatively, the operation of the valves could be achieved electrically and detecting means could be incorporated to act when the flow past a control point changed from opaque liquid to clear liquid to no liquid in turn.

In one particular instance, with a slurry feed containing 33% wt. of ash in water, 19.3% of the dirty water is recycled through the thickener (approximately 220,000 gallons a day) and 80.7% of the dirty water is used to produce slurry. This produces a slurry of 2,000 tons of ash in approximately 880,000 gallons of water. The system is sensitive to slurry concentration which is controlled by the proportions of make-up water and added solids (ash). The system of the invention is also accordingly sensitive to the proportion of water recycled through the thickener and this is controlled to maintain the required slurry concentration in the reservoir.

FIG. 3 of the drawings shows a further embodiment which corresponds approximately with that of FIG. 1. Instead however of the slurry being fed into the bottom of the vessel **3**, it is fed into the top and a pump **20** is included in the line **21** to pump dirty water from the vessel, the outlet for such water being at the bottom of the vessel. In addition, an air inlet valve **15** is provided for the vessel **3** to control the ingress and exhaust of air therefrom.

Consequent upon these structural alterations, the operation of the embodiment of FIG. 3 is a little different. Starting with the air valve **15**, the slurry inlet valve **8**, the slurry outlet valve **6**, the water inlet valve **17** and the water outlet valve **19** all closed.

The air valve **15** and the slurry inlet valve **8** are first opened and slurry pumped by the pump **12** to fill the vessel **3** whereupon the valves **8** and **15** are closed. The slurry outlet valve **6** and the water inlet valve **17** are next opened and water pumped into the vessel **3** by water pump **26** through water inlet **16** to displace the slurry through the slurry outlet **5** into the pipeline **4**. A clean interface is produced between the water and the slurry and there is no appreciable mixing. When the slurry has been displaced from the vessel **3**, the valves **6**, **17** are closed and the air valve **15** and the water outlet valve **19** opened. The water in the vessel, soiled by contact with the walls of the vessel **3**, is removed by the dirty water pump **20** through the pipe **21**, part being recycled through the thickener **23** to the water pump **26** as described above and the bulk being conducted through pipe **14** to the slurry reservoir **9**. The cycle of operations is then repeated.

FIG. 4 of the drawings shows a continuous flow installation for pumping pulverised fuel ash using the basic system just described.

A battery of three lock hopper vessels **3**, **3'** and **3''** feed the pipeline **4** and the valves and pipes to each vessel are also triplicated. The same reference numerals are used as when describing FIG. 1 with appropriate differentiation for references specific to each vessel.

The lock hopper vessels are arranged to discharge in sequence, the sequence having a slight overlap so as to ensure continuity of pumping and hence of pipeline flow.

As vessel **3** fills with slurry, vessel **3'** discharges slurry into the pipeline **4** and vessel **3''** is emptied of dirty water. Then, as vessel **3** discharges slurry into the pipeline **4**, vessel **3'** is emptied of dirty water and vessel **3''** is filled with slurry. Finally, as vessel **3** is emptied of dirty water, vessel **3'** is filled with slurry and vessel **3''** discharges slurry into the pipe line **4**.

The valves **6**, **6'**, **6''**, **8**, **8'**, **8''**, **15**, **15'**, **15''**, **17**, **17'**, **17''**, **19**, **19'**, **19''** are interlocked and are arranged to act automatically in sequence. The interlocking of the valves is achieved in this installation by hydraulic operation of the valves controlled by a timer in a sequence calculated in accordance with the flow rates of the pumps. Alternatively, the operation of the valves could be achieved electrically and detecting means could be incorporated to act when the flow past a control point changed from opaque liquid to clear liquid to no liquid in turn.

Although in the embodiments of the invention described above, water has been used as the slurrying liquid, it will be understood that other different liquids may be used in other conditions of use.

I claim:

1. Apparatus for introducing slurry into a pipeline comprising a slurry reservoir arranged to supply slurry to a lock hopper, a dry material input line feeding said reservoir, a clean liquid source arranged to expel slurry by displacement from the lock hopper, a liquid by-pass conduit connecting said lock hopper to liquid clarifying means, a liquid return conduit connecting the liquid clarifying means to the liquid source, and a dirty liquid conduit connecting said lock hopper to the slurry reservoir the apparatus being such that, in operation, a quantity of displacement liquid equal in volume to the volume of the solid content of the slurry is clarified and returned to the liquid source and the remaining displacement liquid is conducted to the slurry reservoir.

2. Apparatus as claimed in claim 1 in which the liquid clarifying means includes a thickener for concentrating solids in liquid fed thereto.

3. Apparatus for introducing slurry into a pipeline comprising in combination a slurry reservoir, a dry material inlet for said reservoir, a lock hopper having a top and a bottom, a slurry inlet in said hopper at the bottom thereof, a connection from said reservoir to said slurry inlet for the supply of slurry to said hopper, a liquid source connected to said hopper for expelling slurry in the latter into said pipeline, liquid clarifying means, a liquid by-pass conduit connecting said lock hopper to said clarifying means, a liquid return conduit connecting the clarifying means to the liquid source, a dirty liquid outlet at the top of said hopper, and, a dirty liquid conduit connecting said dirty liquid outlet with said slurry reservoir whereby a quantity of displacement liquid equal in volume to the volume of the solid content of the slurry is clarified and returned to the liquid source and the remaining displacement liquid is conducted to the slurry reservoir.

4. Apparatus for introducing slurry into a pipeline comprising a slurry reservoir arranged to supply slurry to a lock hopper, a dry material input line feeding said slurry reservoir, a clean liquid source arranged to expel slurry by displacement from the lock hopper, a liquid by-pass conduit connecting said lock hopper to liquid clarifying means, a liquid return conduit connecting the liquid clarifying means to the liquid source, a liquid flow control valve in said by-pass conduit, and, a dirty liquid conduit connecting said lock hopper with said slurry reservoir.

5. Apparatus for introducing slurry into a pipeline comprising in combination a slurry reservoir, a dry material inlet for said reservoir, a lock hopper having a top and a bottom, a slurry inlet in said hopper at the top thereof, a connection from said slurry reservoir to said slurry inlet for the supply of slurry to said hopper, a clean liquid source connected to said lock hopper for expelling slurry in the latter into said pipeline, liquid clarifying means, a dirty liquid outlet at the bottom of said hopper, a dirty liquid conduit connecting said dirty liquid outlet and said reservoir, a dirty liquid by-pass conduit interconnecting said dirty liquid conduit and said clarifying means, a liquid flow control valve in said by-pass conduit, and, a clean liquid return conduit interconnecting said clarifying means and said clean liquid source.

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