US004001584B2

United States Statutory Invention Registration [19]

[11] Reg. Number: H1584

[45] Published: Aug. 6, 1996

Moore et al.

[54] **MINE TAILINGS REPLACEMENT**

[75] Inventors: **Terry J. Moore**; **Winton G. Aubert**, both of Plano, Tex.

[73] Assignee: **Atlantic Richfield Company**, Los Angeles, Calif.

[21] Appl. No.: **518,072**

[22] Filed: **Aug. 22, 1995**

[51] **Int. Cl.**[6] **B09B 1/00**

[52] **U.S. Cl.** **588/250**

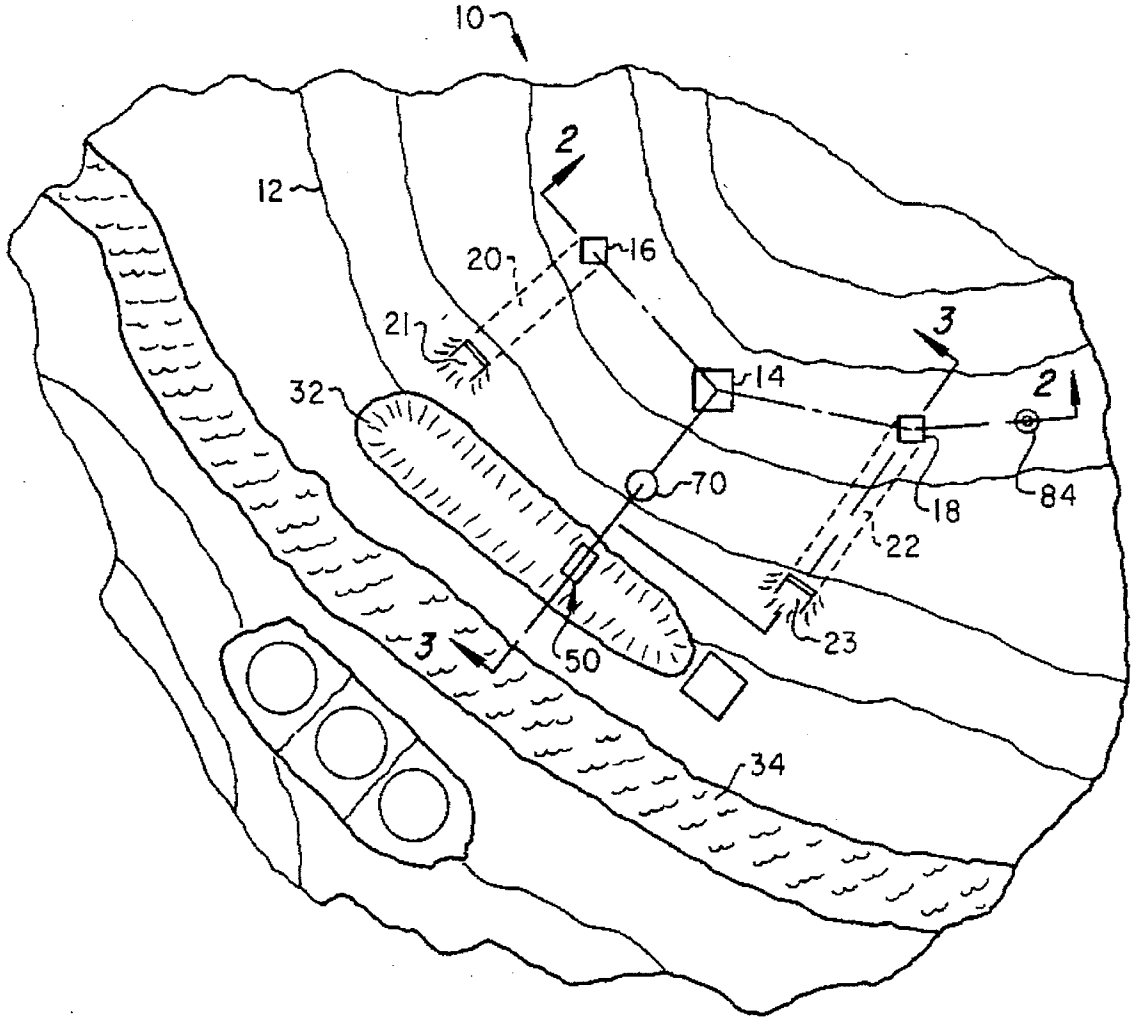
Primary Examiner—Stephen C. Bentley

Attorney, Agent, or Firm—Michael E. Martin

[57] **ABSTRACT**

Mine tailings and similar materials are disposed of by replacing the tailings in underground mineworks including the shafts, adits and drifts by forming a slurry of tailings using dredging or similar mixing processes and pumping the slurry to the mineworks. Cementitious materials may be added to selected quantities of the tailings slurries to form cement plugs for placement at selected intervals in the mineworks to minimize connectivity of the mineworks shafting, adits and drifts. The mineworks may be dewatered to provide a source of water for the slurrification process and the water may be reused after separation from the slurry. The disposal process provides a convenient way of replacing mine tailings in a repository of similar mineralogy and at least partially eradicates abandoned mineworks, including shafting, adits and drifts, which otherwise might require continual monitoring and dewatering.

9 Claims, 2 Drawing Sheets



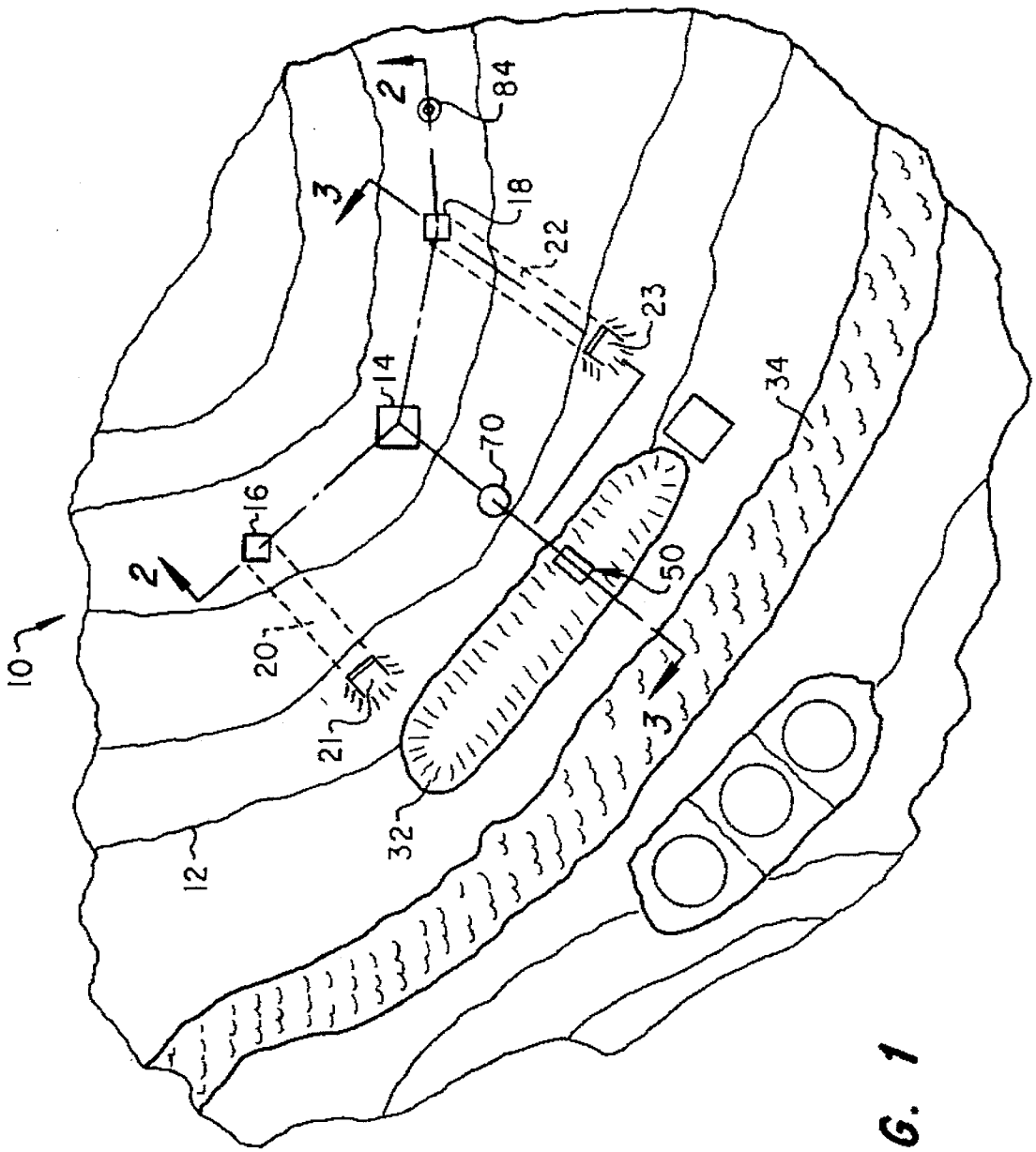


FIG. 1

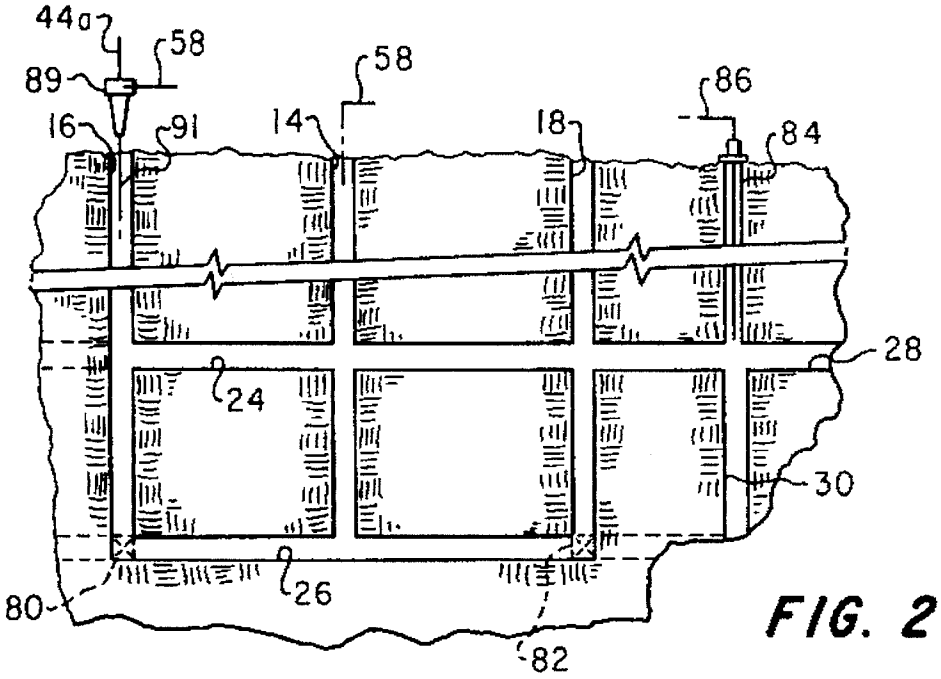

44a
58
89
58
86
16
91
14
18
84
28
24
30
26
80
82

FIG. 2

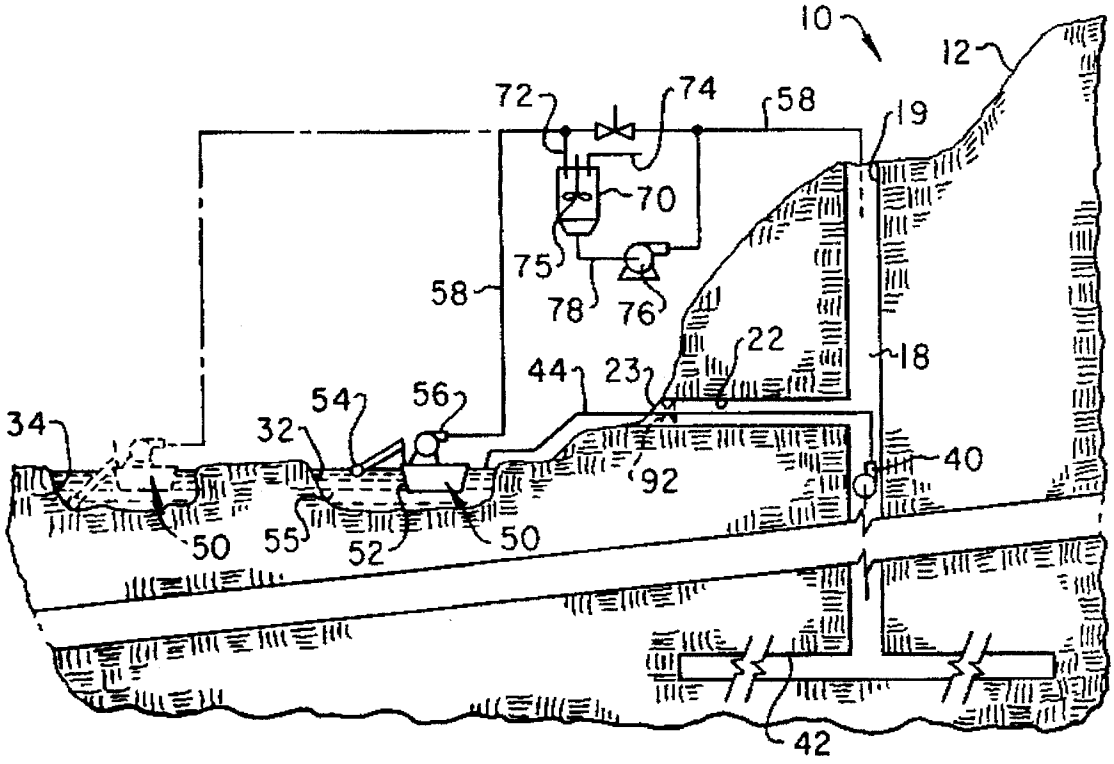

10
12
72
74
58
19
70
75
58
78
76
22
18
44
23
54
56
34
32
40
92
50
55
52
50
42

FIG. 3

MINE TAILINGS REPLACEMENT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention pertains to a method and system for replacing mine tailings and similar materials in abandoned mineworks.

2. Background

Certain particulate materials such as mine tailings and other earth materials which have been processed and disposed of may present certain environmental hazards if left to reside on the earth's surface in so-called tailings piles, ponds and other repositories which are exposed to wind and rain. In certain areas mine tailings and the residue of related earth material processing operations may also be found disposed alongside rivers or similar bodies of water or in conventional disposal pits or ponds.

Moving these materials may involve costly dewatering, excavating, drying and storage operations, including material conversion techniques which are or can be in themselves environmentally injurious. On the other hand mine tailings and the residue of other processing operations on earth materials and minerals produce particulate material which is suited to implementation of techniques that utilize mechanical or hydraulic disaggregation, suspension and pumping. For example, mine tailings disposed in piles, pits or ponds may be well suited to dredging operations, slurrification, pumping and transport by pipeline. Excavation of these materials using conventional dredging and pumping techniques can be carried out without contaminating groundwater in adjacent areas. Moreover, certain mine tailings and the residue of ore body processing operations may, when mixed with a cementitious material, form a suitable hardable composition which may, at least, be used as a filler or plugging material and may have certain structural applications. Moreover, hardened cementitious mixtures or grouts may be capable of neutralizing residual acidic components in the tailings and provide physical stability of these materials.

A related problem in dealing with abandoned mine sites pertains to handling groundwaters which accumulate in and leak through mine shafts, drifts and adits. Such sites may also cause contamination of surrounding groundwaters in many instances. However, dewatering underground mine sites can cause problems in regard to treatment and disposal of the removed water, and oxidation of in situ minerals and metals which become exposed to atmospheric air after the dewatering process. Accordingly, abandoned mine workings themselves can comprise environmental hazards and hazards to the personal safety of individuals present in the vicinity of the mineworks.

The problems associated with removing mine tailings and similar materials from stream beds, pits, ponds or tailings piles and the problems associated with reducing the risks to personal safety and the environment from abandoned mine workings have heretofore remained largely unsolved. However, in accordance with the present invention these problems can be substantially overcome.

SUMMARY OF THE INVENTION

The present invention provides a unique method for disposing of mine tailings and similar particulate earth materials by creating a transportable slurry of such tailings and related materials and replacing these materials in abandoned mineworks including mine shafts, drifts and adits.

In accordance with one important aspect of the invention particulate mine tailings or mine process wastes and similar materials disposed in tailings ponds, pits or piles or disposed along stream beds, are excavated using conventional hydraulic dredging techniques and transported to nearby mineworks for replacement in the mineworks as a disposal repository.

In accordance with another important aspect of the present invention, mine tailings are replaced in the earth in the same location whence they came by forming a slurry of tailings particulates and water, pumping the slurry into abandoned mineworks having substantially the same mineralogy as the particulates, including mine shafting, drifts and adits, to minimize the environmental risks associated with exposure of these materials. Moreover, the hazards associated with abandoned mineworks are also reduced through at least partial filling of the mineworks with the replaced tailings.

In accordance with yet another aspect of the invention, the hazards associated with abandoned mineworks are at least partially reduced by filling the mineworks with a particulate material which may be at least partially solidified by mixing the particulate material with a cementitious composition and transporting the mixture as a cement slurry to the mineworks to provide solidified plugs of material which at least may be adapted to plug or close off certain portions of the mineworks. The present invention further contemplates a technique of replacing mine tailings in abandoned mineworks through strategic placement of certain quantities of a slurry of tailings and water together with a cementitious material to form solid coherent plugs in the mineworks which will confine the tailings slurries.

The present invention still further contemplates a method of slurrification and transport of mine tailings and similar materials by utilizing a source of water from abandoned mineworks wherein the mineworks are simultaneously dewatered and the water is used to form a transportable slurry of tailings material which is then injected into the dewatered mine. Excess water may be reused to form additional slurry or, eventually, treated for surface or deep well disposal.

The treatment of mine tailings and similar materials in accordance with the invention provides several advantages. The tailings are replaced in workings from which they were initially removed and have similar mineralogy to the host rock, except that a substantial portion of sulfides and metals normally have been removed as a result of the original mining process. The tailings preparation and transport process may be carried out using essentially conventional excavation, pumping and transport equipment used in conventional hydraulic dredging operations, for example. The method of excavation and transport using dredging and pumping decreases or substantially eliminates the generation of airborne dust from the excavation site. Careful observation of the local water table and use of water collected from nearby abandoned mineworks minimizes the contamination of groundwater in adjacent areas. Transportation costs are minimal as a result of the use of dredging, mixing, slurrying and pumping operations.

Moreover, forming a grout or hardenable cementitious composition using the above mentioned tailings and similar materials provides a more permanent disposal technique and fine particles of tailings are substantially reduced or eliminated. Through careful placement of plugs of cement or grout, using the mine tailings material, in abandoned min-

eworks and the like, the entire tailings mass removed from a particular excavation site would not have to be stabilized by a cement material. Grouting portions of underground mineworks can decrease the pumping required for mine dewatering processes. Grouting the mineworks with a tailings based grout mixture or replacing loose tailings materials in the mineworks can also reduce the rate of water migration through the mineworks and reduces oxygen exposure to the minerals in the abandoned mineworks.

Those skilled in the art will recognize the above mentioned features and advantages of the invention together with other superior aspects thereof upon reading the detailed description which follows in conjunction with the drawing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plan view, in somewhat schematic form, showing a typical underground mine site with a tailings disposal pond and nearby stream bed which are being treated by the method of the present invention;

FIG. **2** is a section view of the mineworks shown in FIG. **1**, in somewhat schematic form, and taken generally from the line **2**—**2** of FIG. **1**; and

FIG. **3** is a schematic view taken generally along the line **3**—**3** of FIG. **1** showing the system used in practicing the method of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

In the description which follows like elements are marked through the specification and drawing with the same reference numerals, respectively. The drawing figures are not necessarily to scale in the interest of clarity and conciseness.

Referring to the drawing figures, there is illustrated in somewhat schematic form, and by way of example, a typical underground mineworks, generally designated by the numeral **10**, which has been at least partially worked out or abandoned, for example. The mineworks **10** is disposed under the side of a hill **12** in which a main, generally vertical mine shaft **14** has been extended together with adjacent secondary shafts **16** and **18**, for example. At least two adits **20** and **22**, see FIG. **3** also, extend from the shafts **16** and **18**, respectively, and open out of the side of the hill **12** at respective openings **21** and **23**. As shown in FIG. **2**, one or more generally horizontal drifts **24** and **26** interconnect the shafts **14**, **16** and **18**. A drift extension **28** extends from the shaft **18** and may include a secondary shaft **30** extending generally vertically therefrom. As shown in FIGS. **1** and **3**, the mine site **10** is also provided with a mine tailings disposal area, generally designated by the numeral **32**, which may comprise a pit or a pond wherein initial processing of material originally excavated from the mine resulted in the generation of tailings which were deposited in the pit or pond **32**. The tailings repository may also comprise a pile extending above grade elevation. At least some of the tailings deposited outside of the mineworks **10** may have become deposited in the stream bed of a river or the like, generally designated by the numeral **34**, through erosion from wind and runoff from rain or snow or as a result of processing operations. In any event, the pond or pit **32** and the stream bed **34** may include significant quantities of tailings materials in the form of relatively fine particulate solids having mineralogy similar to that defining the mineworks characterized by the shafts **14**, **16** and **18**, the adits **20** and **22** and the drifts **24**, **26** and **28**, for example. As shown in FIG. **3** the tailings pit **32** may be disposed at a lower elevation than the adits **20** and **22**, including the opening **23** from the adit **22**, as shown.

One or more of the mine shafts **14**, **16** and **18** may require periodic or even continuous dewatering to prevent migration of water through the mine and contamination of groundwater supplies. FIG. **3** shows a motor driven pump **40** disposed in the mine shaft **18** and operable to discharge water from the shaft, as well as a drift **42** connected thereto, to the exterior of the mine by way of a discharge conduit **44**.

The invention contemplates replacing mine tailings disposed in the pit **32** and/or in or adjacent to the stream bed **34** by employing a hydraulic dredge, indicated schematically in FIG. **3** and generally designated by the numeral **50**. The dredge **50** may be of a conventional type having a support vessel **52**, a movable cutter head and suction pipe assembly **54** and a pump **56** connected thereto in a known manner. Conventional dipper and elevator type excavating dredges may also be used. The dredge **50** is adapted for excavating tailings disposed in the pit **32** and which are mixed with water **5** disposed in the pit from one of several sources including the mine dewatering operation carried out by the pump **40** and the conduit **44**. The excavation of mine tailings from the pit or pond **32** is carried out by a slurrification and/or dredging operation whereby a slurry .of solids particulates of mine tailings and water is discharged from the pump **56** and is conducted by way of a conduit **58** either directly to the entrance **19** of the mine shaft **18**, FIG. **3**, or by way of a processing system to be described hereinbelow. The preparation of a slurry of mine tailings and water may not require dredging per se. Tailings or similar earth materials in relatively fine particulate form may be otherwise suitably mixed with water and pumped to the mineworks **10** in a manner somewhat similar to a dredging operation but not strictly considered a dredging operation.

Alternatively, as shown in FIG. **3**, the dredge **50** may be disposed in the adjacent river for excavating solids contaminants from the stream bed **34**, including the aforementioned mine tailings. The water source for slurrification of the tailings or similar materials may, of course, be the river itself. However, by using water from the mineworks **10**, as described above, to carry out the dredging and slurrification operation, a source of water for dredging is provided and the mine is simultaneously dewatered to provide a space for the mine tailings to be permanently stored. As the tailings are replaced in the mine the solids suspended in the slurry may settle out leaving additional water for continuous reuse in the dredging, slurrification and transport operation. The illustration of the drawings is merely exemplary in this respect and those skilled in the art will appreciate that, depending on the construction of the mineworks, replacement of the. tailings slurry in the shafting or drifts may displace water therein which can be collected and pumped to the pit or pond **32**, as desired.

Referring further to FIG. **3**, it may be desirable to mix the slurry discharged from the pump **56** with additional solids particulates or with a cementitious material to form a hardenable composition which may be pumped into the mineworks **10** at certain specific locations and allowed to solidify to block certain passages in the mineworks. In this way, the slurried tailings may be contained or totally encapsulated. Moreover, mixing the tailings with conventional cement materials may provide chemical changes such as reducing the acidity of the tailings. Accordingly, a suitable mixing tank **70** is shown schematically in FIG. **3** having a branch inlet conduit **72** leading from the conduit **58**, a second inlet conduit **74** for discharging selected materials into the tank and a mixing apparatus **75** interposed therein

for performing certain mixing operations. A pump **76** is also provided in a communication with an outlet conduit **78** from the mixing tank **70**. The pump **76** is suitably connected to the conduit **58** for discharging a slurry of cementitious material and mine tailings or similar materials for disposal in the mineworks **10**. Suitable control valving, not shown in detail in FIG. **3**, may be associated with the conduits **58**, **72**, **74** and **78** for controlling flow to and from the tank **70**. A system similar to that disclosed in U.S. Pat. No. 5,109,933 issued May 5, 1992 to James E. Jackson and assigned to the assignee of the present invention may also be utilized in preparing a slurry for placement in the mineworks **10**.

Accordingly, a slurry of mine tailings or similar materials may be prepared utilizing a dredging operation comprising a conventional dredge, such as the dredge **50**, or by preparing the tailings slurry in a system similar to that described above, or in the above mentioned patent, and pumped into the mineworks **10**. In order to appropriately fill the mineworks **10**, it may be necessary to plug certain intervals in the mineworks with a plug of hardenable cementitious material, including mine tailings, by mixing the tailings with an appropriate quantity of water and a cement such as Portland cement, slag cement, calcium hydroxide, pozzolanic materials or the mine tailings themselves may comprise a material suitable for forming a hardenable mass after proper hydration.

Referring to FIG. **2**, for example, a cement/tailings plug **80** may be formed at the intersection of the shaft **16** with the drift **26** to enable at least partial filling of the shaft **16** with a tailings slurry or dewatered tailings material until reaching the level of the drift **24**. In addition, a similar plug **82** may be formed at the intersection of the shaft **18** with the drift **26** whereupon the remainder of the drift **26** and the shaft **14** up to the level of drift **24** may also be filled with dewatered tailings or a tailings slurry. Still further, the entire mineworks below the drift **24** may be filled with a tailings slurry or a hardenable tailings/cement slurry composition. Various combinations of plugging the intervals of the mineworks **10** may be carried out to properly fill and contain the tailings material in the various shafts and drifts.

Alternatively, if a shaft, drift or adit cannot be adequately filled by pumping the slurry into one or more of the shafts, one or more wells, such as a well **84**, may be drilled into the earth to intercept a drift **28** or a shaft extension **30** and the well then connected to the slurry discharge conduit **58** by way of a wellhead injection conduit **86**. The well **84** may be a simple open hole structure without casing or injection conduit structures or a wellhead, depending on the terrain through which the well is drilled.

The tailings slurry may also be dewatered at or near the point of deposit into the mineworks **10** using suitable separation equipment such as a hydrocyclone type separator **89**, FIG. **2**, situated for discharging dewatered tailings into shaft **16** by way of a conduit **91**. The water separated at the separator **89** may be returned to the pond **32** via a conduit **44***a*.

As shown in FIG. **3**, the entrance **23** to the adit **22** may be suitably plugged with a tailings/cement plug **92** prior to filling the shaft **18** so that the adit **22** and shaft **18** may contain replaced mine tailings. The pump **40** and the conduit **44**, would be removed prior to filling the remainder of the shaft **18** and the adit **22**.

Although forming a cementitious slurry which would harden into a solid mass may not be necessary for every bit of the tailings slurry pumped into the mineworks **10**, cement could be added periodically to the tailings slurry as it is pumped into the mineworks to form plugs within the selected shafting, adits or drifts that would physically stabilize and prevent movement of the tailings slurry. Once the tailings slurry has been injected, dewatering from points below the slurry location, in the vicinity of placement, can prevent excess accumulation of waters which could eventually effect groundwater quality or eventually require pumping from the mineworks. This early removed water could, of course, be returned to the excavation site, such as the pond **32**, for use in excavating additional tailings material.

By dredging tailings and similar materials from pits, ponds and other repositories in the vicinity of mineworks, such as the mineworks **10**, the resulting slurry may be effectively transported over the relatively short distances required by pumps and pipelines. The slurries are typically dewatered once in place in the mineworks by settling, or mechanical separation may take place at discharge into the mineworks with return of the water to the slurrification process. Stabilizing the tailings, once deposited in the mineworks or similar repositories, may be carried out by adding the aforementioned cement materials to form a solid mass usable as plugs at strategic locations in the mineworks or throughout. The cement materials have the added advantage of neutralizing residual acidic components in the tailings. Differences in density between the cementitious slurry and groundwater in the mineworks also facilitates placement of the slurry into underground works. Gravity flow may be utilized in most cases once the slurry has been conveyed by pipeline to the mine inlets such as the inlets to the shafts **14**, **16** and **18** or to the injection well **84**. The ultimate disposition of the mine tailings is advantageous in that, particularly, if the tailings are formed as a grout or cement composition, a permanent location is assured. Moreover, replacing the tailings into a host rock with almost identical mineralogical composition provides certain advantages. Still further, filling abandoned mineworks with the tailings reduces the exposure of the mineworks to oxidation.

Placing cement plugs at intersections of the mine shafting and drifts reduces the connectivity of these structures and the disadvantageous of leaving such connectivity in place. Still further, by filling the mineworks with the tailings slurry, either loose or in solidified form, the mine shafts and adit entrances may be secured and unwanted access restricted or prevented.

Those skilled in the art will recognize that various substitutions and modifications may be made to the invention described above without departing from the scope and spirit of the appended claims.

What is claimed is:

1. A method for disposing of mine tailings and similar materials comprising the steps of:

forming a slurry of said mine tailings;

transporting said slurry to an underground mineworks; and

depositing said slurry in said mineworks.

2. The method set forth in claim **1** including the step of:

pumping water from said mineworks and adding said pumped water to said mine tailings to form said slurry.

3. The method set forth in claim **1** wherein:

the step of forming said slurry comprises dredging said mine tailings from a tailings disposal site.

4. The method set forth in claim **3** including the step of:

pumping water from said mineworks to said disposal site and forming said slurry from said tailings at said disposal site and said pumped water.

5. The method set forth in claim 1 including the step of:

adding a cementitious material to said slurry to form a hardenable mass for disposition in said mineworks at a predetermined place therein.

6. The method set forth in claim 1 including the step of:

forming said slurry by mixing said mine tailings with a quantity of water in a mixing tank and pumping said slurry from said mixing tank to said mineworks for disposal therein.

7. The method set forth in claim 1 including the step of;

separating water from said slurry of tailings and water prior to depositing said tailings in said mineworks.

8. The method set forth in claim 7 including the step of:

conducting said water separated from said slurry to a location for forming an additional slurry of said tailings and said separated water.

9. The method set forth in claim 1 wherein:

the step of depositing said slurry in said mineworks comprises conducting said slurry through an injection well drilled into a part of said mineworks.

* * * * *