

June 27, 1972

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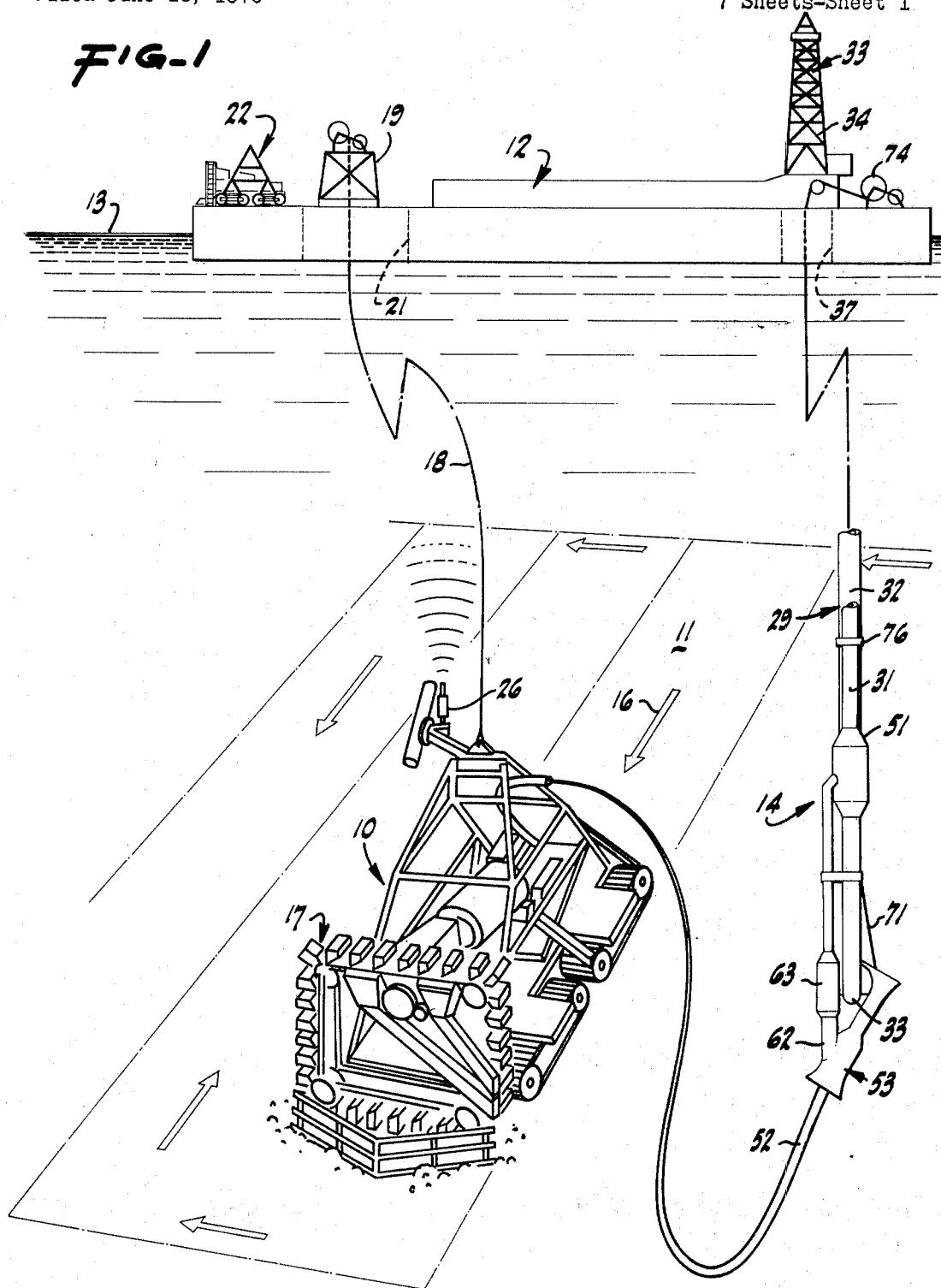
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DEEP SEA MINING METHOD AND APPARATUS

Filed June 15, 1970

7 Sheets-Sheet 1

FIG-1



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7 Sheets-Sheet 2

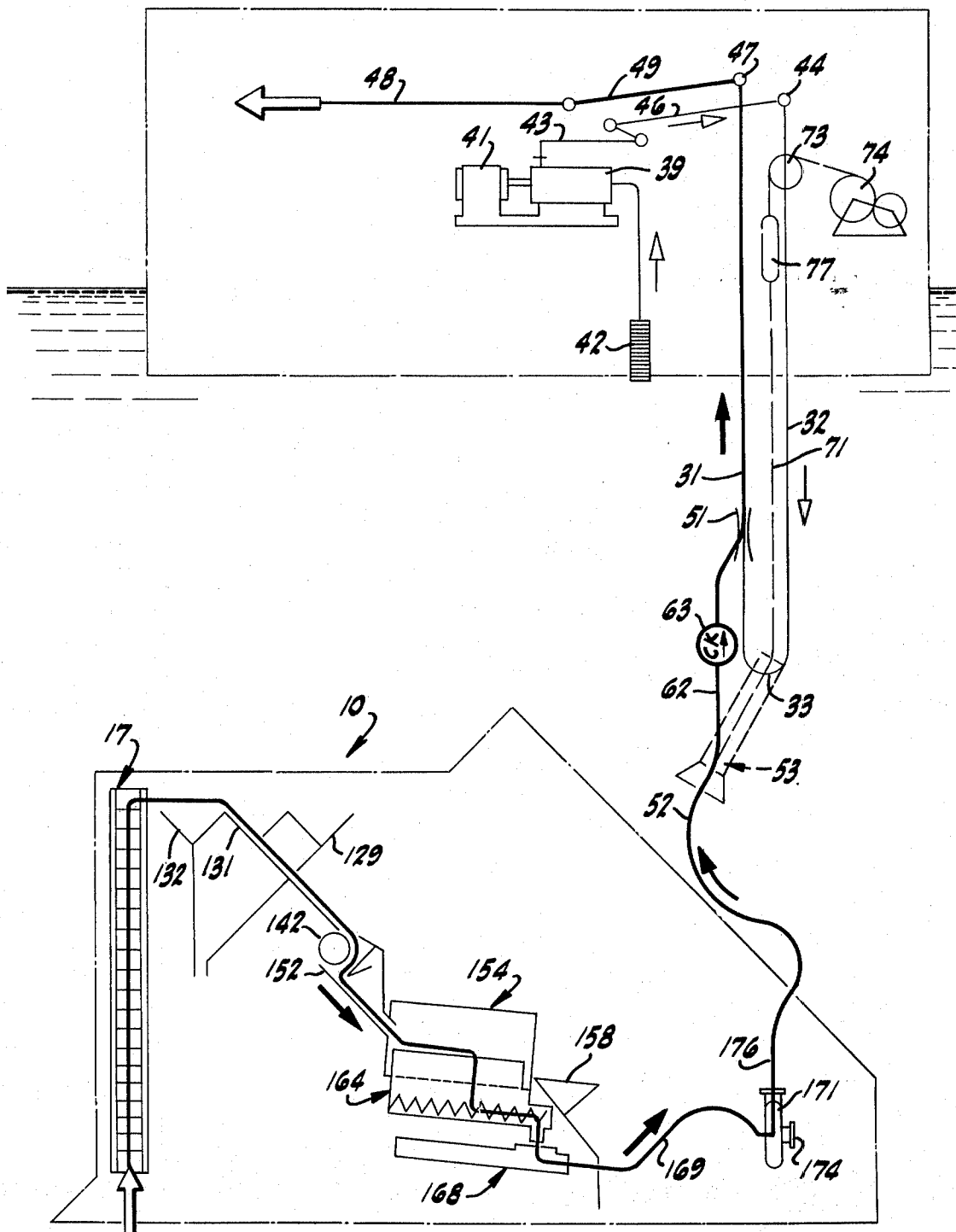


FIG. 2

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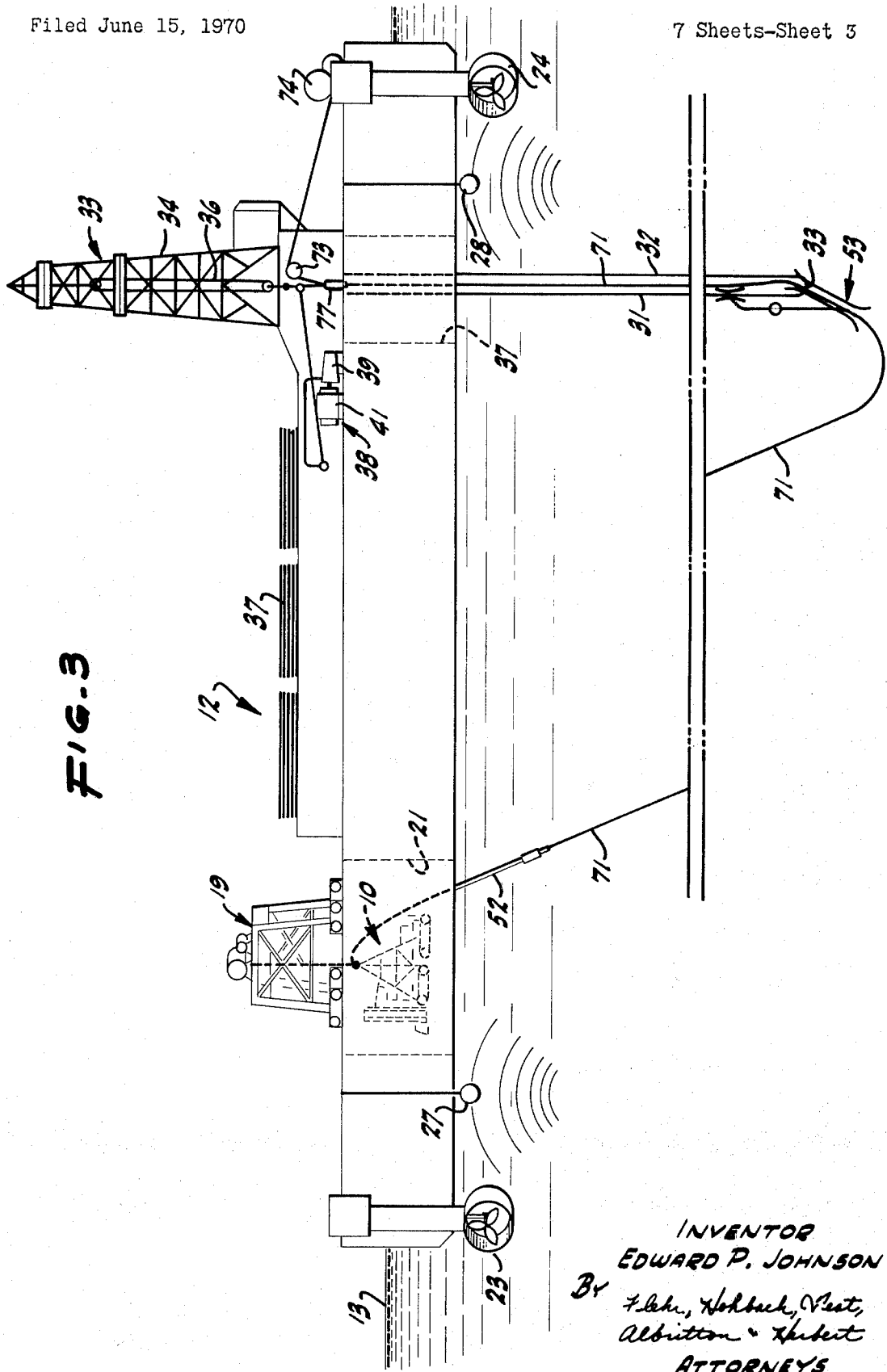
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DEEP SEA MINING METHOD AND APPARATUS

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7 Sheets-Sheet 3



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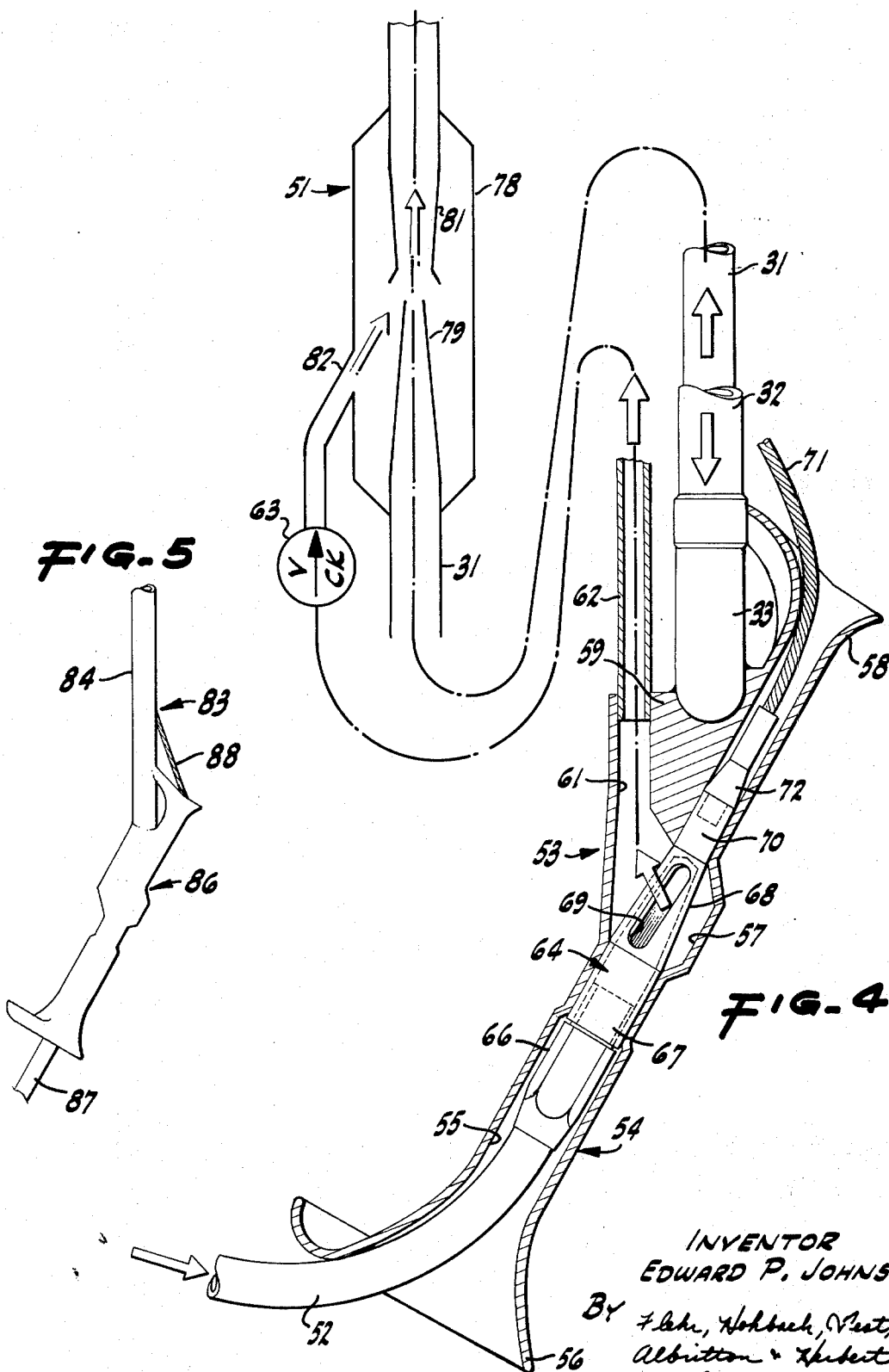
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DEEP SEA MINING METHOD AND APPARATUS

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7 Sheets-Sheet 4



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DEEP SEA MINING METHOD AND APPARATUS

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7 Sheets-Sheet 5

FIG. 9

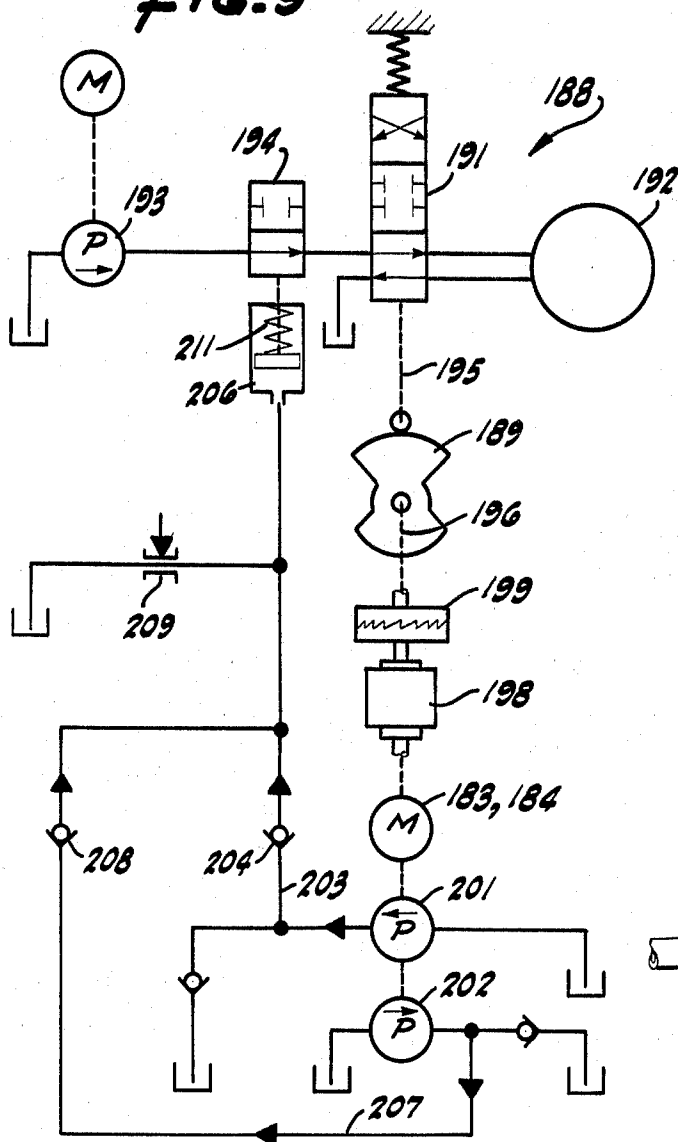
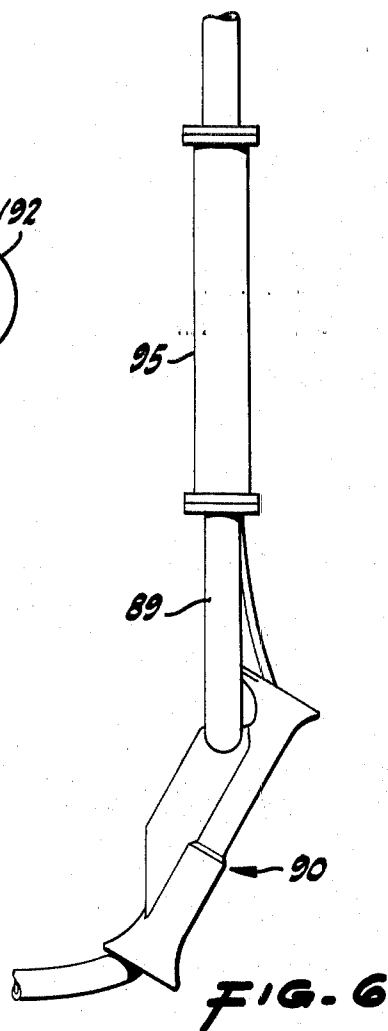


FIG. 6

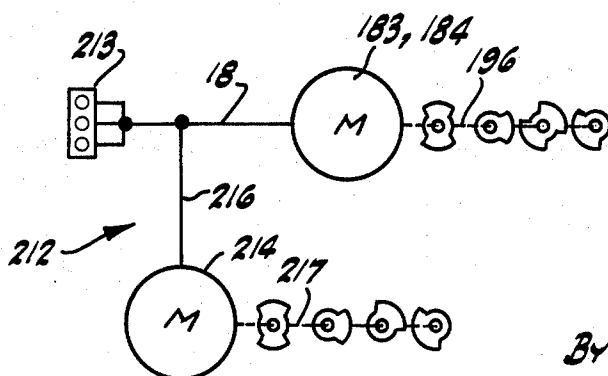


FIG. 10

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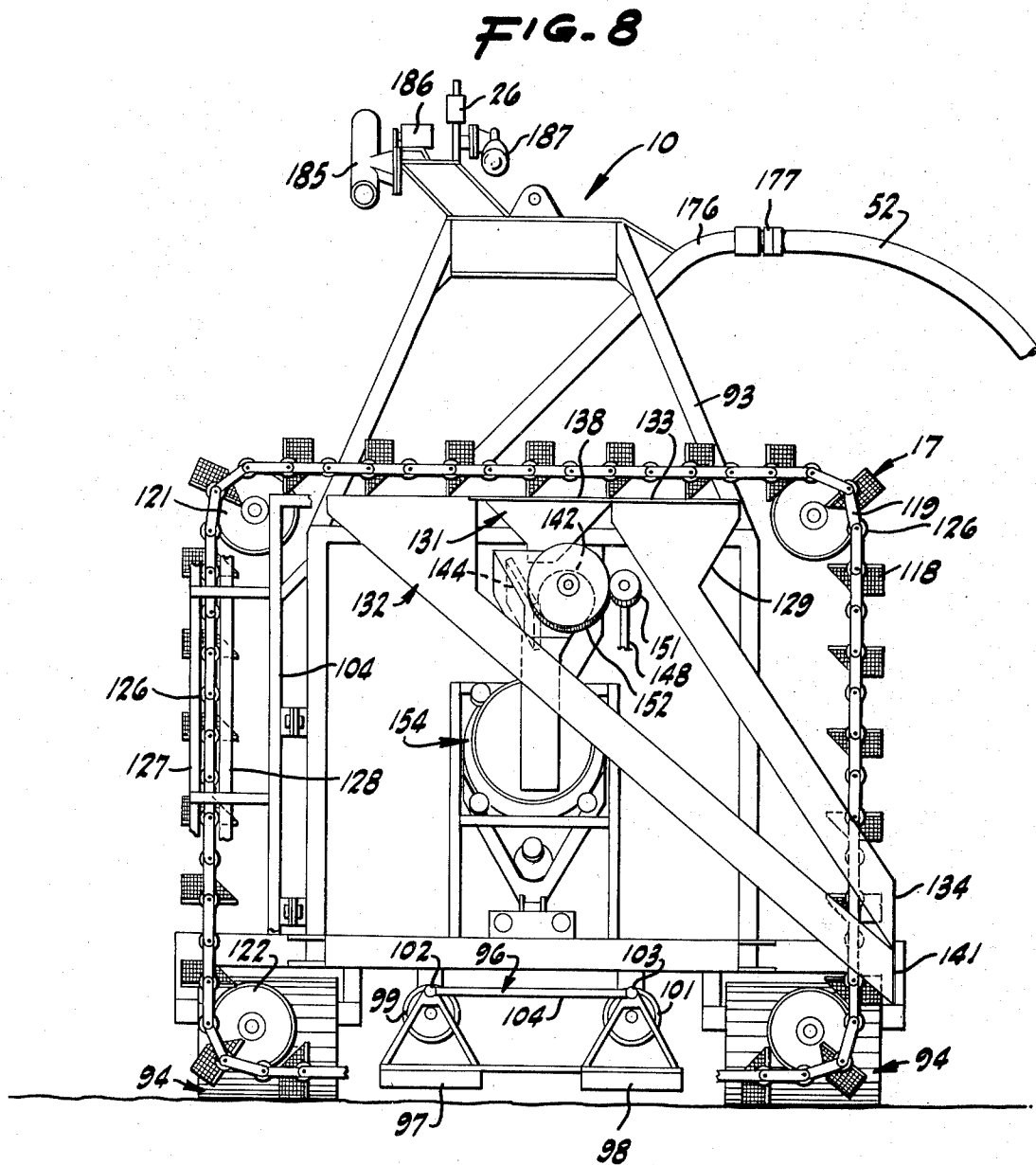
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DEEP SEA MINING METHOD AND APPARATUS

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7 Sheets-Sheet 7



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DEEP SEA MINING METHOD AND APPARATUS
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21 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus and method for mining material from an ocean floor. A mining vehicle traverses a predetermined path on the ocean floor while a mother vessel on the ocean surface positions itself over the mining vehicle. The material is collected by the vehicle along the path of travel, crushed, and classified to form a mixture having a predetermined solid/fluid ratio range. The mixture is pumped to the vessel through a fluid transport system including a flexible conduit extending from the vehicle and discharging into a releasable connection with the lower end of a riser conduit suspended from the vessel. The releasable connection is adapted to provide re-entry capabilities to re-establish fluid communication in the transport system and permit the vehicle to be easily raised and lowered from the mother vessel.

BACKGROUND OF THE INVENTION

This invention relates generally to deep sea mining. This area has been of increasing importance as a result of the realization that the ocean floor provides a plentiful source of valuable material, particularly minerals. Manganese, for example, is in particular demand for uses such as alloying, and in view of the relative scarcity of the metal modern industry has turned to the ocean as a source of supply.

Present techniques in deep sea mining include operations such as suction hoses sweeping across the ocean floor and dredge buckets operating from a barge. These systems have not been entirely successful, especially in view of their low efficiency in material recovery. The suction hose operation is not adapted to work at great depths, is limited to random sweeping across the ocean floor, and tends to pick up waste or extraneous material rather than segregating the desired material for lifting to the surface. A dredge bucket operation is highly inefficient in view of the cycle time involved in lowering and raising the bucket for each load. At greater depths this cycle time becomes prohibitive.

Oceanography has also found a requirement for sampling the ocean floor and conveying the material to the surface for analysis. Sample recovery by coring would be desirable.

Conventional oceanography or deep sea mining equipment is limited in its range of application in view of the great pressures encountered many thousands of feet below the surface. At these depths man must be protected from the crushing pressure by an extremely strong shell and expensive equipment to provide him with a comfortable working environment, such as a bathysphere. Encased in such a shell man is severely limited as to what he can accomplish on the ocean floor, and such a system would be impractical for large scale mining operations. The need has thus been recognized for a system which can recover material from great depths and efficiently transport it to a surface vessel. Methods and apparatus have been sought which are capable of withstanding the great pressures at these depths, are compatible with the hostile environment encountered on the ocean floor, and are relatively simple

2

in construction and operation for continuous operation through automatic control features.

SUMMARY AND OBJECTS OF THE INVENTION

A general object of the invention is to provide apparatus and method for the recovery or mining of material from the ocean floor.

Another object is to provide deep sea mining apparatus and method in which a mining vehicle traversing the ocean floor collects material along the path of travel and moves the collected material to a mother vessel on the ocean surface through a fluid transport system.

Another object is to provide deep sea mining apparatus and method in which a mining vehicle automatically traverses a predetermined path along the ocean floor while collecting and crushing material laying along the path, a mother vessel moves in substantially vertical registry above the vehicle, and a slurry or saltation of material and water is pumped through a conduit system to the vessel.

Another object is to provide apparatus and method for transporting material from an ocean floor to a vessel on the surface by crushing and classifying material on the floor to a predetermined particle size range for pumping with water at an optimum solids/fluid ratio through a conduit system discharging into the vessel.

Another object is to provide apparatus and method for deep sea mining with a mining vehicle transversing the ocean floor in which a mixture of recovered material and water is pumped through a length of flexible conduit releasably coupled with a conduit system suspended from a mother vessel, and in which the mixture is carried through the conduit system to the vessel by a stream of high pressure water.

Another object is to provide apparatus and method for deep sea mining with a mining vehicle traversing the ocean floor below a mother vessel supporting a riser conduit, and with a sea socket device adapted to releasably lock the discharge end of a material conveying conduit from the vehicle in communication with the riser conduit with provision for release and re-entry of the coupling permitting the vehicle to be raised and lowered from the mother vessel.

The foregoing and other objects of the invention are provided in the present invention through an automatically operating mining vehicle working on the ocean floor in concert with a mother vessel on the ocean surface and with material transport means for conveying the material recovered from the floor to the vessel. All components of the mining apparatus are compatible with the deep sea environment and are adapted to operate at great depths under extremely high pressures. The vehicle is programmed to automatically traverse a predetermined path along the ocean floor while collecting, crushing, and classifying the material to an optimum particle size for use in the transport system. The crushed and sized particles are pumped through a conduit system at an optimum velocity to develop the desired material/water mixture. Discharge of the mixture from the vehicle is directed through a length of flexible conduit which is releasably connected with a relatively rigid riser conduit suspended from the mother vessel. The discharge is entrained with a stream of high pressure water pumped upwardly through the riser conduit and discharging into the vessel for processing or storage. In one embodiment, a pair of interconnected pipes are provided for deep water operation and water is forced through the pipes by pump means on the vessel. In another embodiment a single riser pipe is provided for shallow water operation and the mixture is pumped through this pipe from the vehicle, while alternate boost pump means may be provided to assist in lifting the mixture. In the double pipe system discharge

3

from the flexible conduit is entrained with the stream of water in the riser pipe by means of a venturi arrangement. The releasable connection between the flexible conduit and the riser pipe is provided by a sea socket having interfitting male and female elements with a tension cable controlled from the vessel and adapted to lock the elements together in fluid communication, and to release the elements permitting discharge pressure to disconnect the coupling. As the vehicle is raised to the vessel the cable is payed out through the socket. When the vehicle is lowered to the ocean floor re-entry with the socket connection is established by reeling in the cable and locking the elements together by maintaining cable tension.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a combined elevation and partially schematic view of the deep sea mining system of the invention with a perspective view of an exemplary mining vehicle incorporating features of the invention;

FIG. 2 is a schematic diagram of the deep sea mining system showing the material handling and transport aspects of the invention;

FIG. 3 is an elevation view to an enlarged scale of the mining system illustrating the vehicle hoisted to the mother vessel;

FIG. 4 is a partially sectioned, elevation view to an enlarged scale of the sea socket used in the material transport system;

FIG. 5 is a partial elevation view of another embodiment of the material transport system;

FIG. 6 is a partial side elevation view of another embodiment of the material transport system;

FIG. 7 is a side elevation view to an enlarged scale of the mining vehicle of FIG. 1;

FIG. 8 is a front elevation view, partially broken away, of the mining vehicle of FIG. 5;

FIG. 9 is a schematic diagram of a control system for the mining vehicle; and,

FIG. 10 is a schematic diagram of a master-slave control system for controlling vehicle operating modes from the vessel.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the drawings, a preferred embodiment of the deep sea mining system of the invention is illustrated in FIG. 1. The mining system includes a mobile unit or vehicle 10 adapted to transverse across the ocean bed or floor 11, a mother barge or vessel 12 floating on ocean surface 13, and material transport system 14 for transporting material collected by the vehicle upwardly to the vessel.

The mining system of the illustrated embodiment has particular application in mining material such as manganese nodules found in abundance on the ocean floor. The system would also find application in other deep sea material recovery operations, such as in oceanography where material from corings along the ocean floor is conveyed to the mother vessel, or in reclaiming material from drowned river valleys by trenching. The vehicle traversing the ocean floor is capable of working at great depths under high hydrostatic pressures where the environment is hostile to man. The operations performed by the mining system, whether for mining or oceanography, are performed in programmed sequence under remote control from the surface. The material recovered is transported to the surface in a slurry or saltation of reduced material and water through the transport system, which is capable of lifting the material from great depths.

Mining vehicle 10 is of the endless track type operating to traverse a predetermined path 16 along the ocean floor below mother vessel 12. In the path illustrated the vehicle is programmed to cover a defined area by making a run of a predetermined length, moves sideways substantially the width of the vehicle, return along a run parallel with that of the first run for the same length, move sideways again and repeat this pattern an indefinite num-

4

ber of times to complete the assigned task. This preset path can be varied as desired depending upon the type of mining or recovery operation, or topography of the ocean floor, and the like. As the vehicle traverses this path it functions to collect the material and prepare it in a slurry or saltation form adaptable for injection into material transport system 14.

In the illustrated embodiment vehicle 10 is provided with a digger-conveyor apparatus 17 adapted for collecting, elevating and conveying nodules of material, such as manganese nodules, lying on the ocean floor along the path of the vehicle. For use in a coring or trenching operation, digger-conveyor 17 would be replaced by conventional coring or trenching apparatus, not shown.

A combination mechanical-electrical cable 18 interconnects vehicle 10 with the mother vessel. Cable 18 is conventional and includes a high strength tension cable for hoisting and lowering the vehicle to and from a gantry crane 19 on the deck of the mother vessel. The cable also includes multiple conductors supplying electrical power and control functions to the vehicle.

A seawell 21 is provided in the hull of the mother vessel for receiving the mining vehicle. FIG. 3 illustrates vehicle 10 hoisted within the seawell, while FIG. 1 illustrates both a vehicle operating on the ocean floor and an additional mining vehicle 22 on the deck of the vessel in a service and repair area. With at least two such mining vehicles on the vessel the gantry crane can move a vehicle on deck for service or repair, and then lower the remaining vehicle to the ocean floor for the mining operation.

Vessel 12 is provided with means for continuously positioning itself in substantially vertical registry with vehicle 10 as the latter traverses along the predetermined path. This positioning means may include a plurality of positioning thrusters 23, 24 which preferably comprise four such thrusters with one thruster positioned at a respective corner of the vessel. The thrusters are conventional and include screws or propellers powered from the vessel and adapted to swivel about a vertical axis under influence of the thruster control system. The control system includes a conventional hydrophone locator system providing information on the vertical positioning of the vehicle with respect to the vessel and operating the thrusters to reposition the vessel as either the vehicle moves from beneath the vessel, or the vessel is carried away by wind or current. The hydrophone system may include a pinger or transponder 26 emitting sonar or sound signals from the vehicle. A plurality of hydrophones 27, 28 are provided, preferably including four hydrophones with each suspended into the water from respective corners of the vessel. The hydrophones receive the locator signals from the pinger and supply this information to the positioning control system for repositioning the vessel as required to maintain the vertical registry with vehicle 10.

Material transport system 14 conveys the material recovered from the ocean floor upwardly to vessel 12 by means of a fluid carrier. The material is combined with seawater into a heterogeneous mixture constituting a slurry or saltation effective to be transported upwardly from the ocean floor through conduits which may be many thousands of feet in length. As used herein, the term mixture is intended to include either the slurry or saltation forms. A slurry would be formed where the entrained material is sized relatively fine, such as pulverized ore, while a saltation would be formed with coarser material, such as up to pebble size or larger.

Transport system 14 includes conduit means 29 comprising a length of interconnected riser pipe 31 and a parallel length of interconnected down pipe 32, with the riser and down piping in fluid communication at their lower ends through hairpin connection 33, as illustrated in FIGS. 2 and 3. Down pipe 32 in the illustrated embodiment would preferably have a diameter on the order of 8" to reduce friction losses and develop a high static pressure, while riser pipe 31 would have a smaller diameter

on the order of 6" to provide a higher riser velocity where water is pumped at the rate of 1,000 g.p.m. through the system.

As an alternate embodiment conduit means 29 may comprise a pair of concentric pipes, not shown, suspended from the vessel with the outer and inner pipes serving respectively as the down and riser pipes in the system.

Conduit means 29 is positioned in place, supported and recovered by means of derrick system 33. This derrick system includes a derrick frame 34 and conventional hoist 36. A pipe rack area 37 is provided for storing riser and down pipe to be used in the transport system. A seawall 37 is formed in the hull of the vessel below the derrick, and conduit means 29 is suspended through this seawall into the ocean.

A stream of seawater is pumped downwardly through down pipe 32 and then upwardly through riser pipe 31 by means of pump system 38. This pump system includes a high pressure pump 39 driven by motor 41, as best illustrated in the schematic of FIG. 2. Pump 39 draws in seawater through strainer 42 and discharges water under pressure through outlet conduit 43. Outlet conduit 43 is in fluid communication with inlet 44 of down pipe 32 by means of a floating pipe system including a conduit 46 swivel connected at either end with outlet conduit 43 and down pipe inlet 44. Similarly, discharge end 47 of riser pipe 31 is in fluid communication with conduit 48 leading to suitable storage or settling tanks, not shown, through a floating connection including conduit 49 swivel connected at either end with riser pipe outlet 47 and conduit 48. The water pumped under high pressure through floating conduit 46 moves downwardly through down pipe 32, reverses at hairpin 33, and moves upwardly through riser pipe 31 where it entrains or picks up the material/water mixture from vehicle 10 by means of venturi device 51. The material is then carried through floating conduit 49 and conduit 48 for the desired processing, beneficiation, or storage in the vessel. Hoist device 36 in the derrick is connected at its lower end with the riser and down pipes and suspends these pipes from the vessel in a manner permitting some vertical play or movement relative to the vessel. Thus, a rising or falling of the vessel, such as from wave action, results in elastic lengthening of the hoist due to the weight of conduit means 29. This is accommodated by the swiveling action of floating conduits 46 and 49. When the riser and down pipes are being connected and dropped from the derrick, or disconnected for recovery, the swivel connections with the floating conduits are disconnected.

The mixture comprising the slurry or saltation is pumped from vehicle 10 into venturi 51 and the riser pipe through a length of flexible hose 52 releasably connected at its free end with sea socket 53. This length of hose accommodates any change in topography of the ocean bottom over which the vehicle traverses permitting change in elevation of the vehicle with respect to conduit means 29 and sea socket 53. At the same time, hose 52 is of a length sufficient to permit the vehicle to traverse along its path and change directions for accommodating the lag time involved while mother vessel 12 is repositioning itself through action of its thruster motors.

Releasable connection device or sea socket 53 is shown in greater detail in FIG. 4 and comprises a female fitting 54, preferably of a non-corrosive material such as stainless steel, defining a through passageway 55 formed with a trumpet-shaped or outwardly flaring lower end 56, a chamber 57, and an outwardly flaring upper end 58. A web portion 59 connects fitting 54 with hairpin 33. A passageway 61 formed through the web portion provides fluid communication between chamber 57 and a conduit 62 leading to venturi 51. A one-way valve means or check valve 63 is provided in conduit 62 for preventing backflow of fluid in the transport system after the hose is disconnected, thereby precluding material from reaching fitting

54 and otherwise interfering with the hose connecting operation.

A male fitting 64 is connected with a ferrule 66 mounted on the free end of hose 52. Fitting 64 is formed with a hollow shank segment 67, hollow tapered segment 68, and reduced diameter nose segment 70. A pair of elongate slots 69 are formed at diametral positions in tapered segment 68 to communicate fluid from the hose to chamber 57. The side edges of the slots are canted with respect to radii of the male fitting to impart a swirling action to the fluid discharging into chamber 57, with the fitting in the illustrated locked position.

A tension cable 71 is connected to male fitting nose segment 70 by means of threaded coupling member 72, and the cable is trained through flared end 58 of fitting 54. This cable extends upwardly between the riser and down pipes to idler pulley 73 on the mother vessel where it is guided to tension winch 74. The cable may be trained through suitable bushings or guide apertures, not shown, provided in a plurality of vertically spaced brackets 76 which brace the riser and down pipes together. Tension cable 71 provides a means for both locking hose 62 in sea socket 53 when under tension, and releasing this connection when the tension is released. For locking the connection, winch 74 is operated to reel in the cable until male fitting 64 engages into fitting 54. In the locked position, shank segment 64 and nose segment 70 are in close-fitting sealing engagement with passageway 55 so that discharge from the hose into chamber 57 is forced upwardly through conduit 62 into venturi 51. After the sea socket fitting is locked tension cable 71 is locked with respect to the upper ends of riser and down pipes 31, 32 by means of conventional cable lock device 77. With the tension cable thus locked the power on winch 74 may be released to slack off the tension on the length of cable between lock 77 and the winch. The cable lock will now ride with the floating pipe system while the latter rises and falls relative to the vessel as a result of any wave action.

To release hose 52 from the sea socket cable lock 77 is released and tension winch 74 operated to pay out the cable while continuing to pump fluid from the hose into the sea socket. The slackening of cable 71 releases the locking force holding male fitting 64 in the socket. The fluid pressure in chamber 57 then acts against fitting 64 which, because of the differential in outer diameters between shank segment 67 and nose segment 70, provides a piston effect forcing the male fitting and hose end downwardly and outwardly from the sea socket. As fitting 64 blows from the socket it carries tension cable 71 through female fitting 54, with the cable continually payed out from the mother vessel. Mining vehicle 10 may then be hoisted to the mother vessel by means of cable 18, carrying with it hose 52 and the length of tension cable 71 running through the sea socket. This permits the mining vehicle to be hoisted to the vessel for servicing and repair, or to lower the auxiliary vehicle 22 to the ocean floor, without the need of disassembling the riser and down pipes. At the same time, when the vessel is again lowered to the floor reentry of hose 52 with sea socket 53 may be easily made to reestablish fluid communication therebetween because the connection between the tension cable and sea socket is never lost.

The control system of mining vehicle 10 may be programmed to operate so that when re-entry of the hose fitting with the sea socket is being made clean seawater without entrained material is being pumped through the hose. This flushes out the system, including the hose and socket, as the connection is being made to insure that pebbles or other foreign matter do not interfere with a fluid-tight seating engagement of the male and female fittings.

Venturi 51 comprises an outer shell 78 enclosing venturi nozzles 79, 81 in riser pipe 31. The slurry or saltation moving upwardly through conduit 62 and check valve

63 is injected into the venturi housing through opening 82 and is entrained with the stream of seawater moving upwardly through the riser pipe.

In the embodiment of FIG. 5 a modified material transport system 83 is illustrated for use in relatively shallow water applications, such as within the range of 300' depths. In this transport system only a single riser pipe 84 is employed. The riser pipe would be suspended from a mother vessel, not shown, in a manner similar to that described above for the double pipe system. The lower end of the riser pipe is in fluid communication with a sea socket 86 which may be of similar construction to that described above in relation to sea socket 53, and provides a releasable connection for a length of flexible hose 87 on a deep sea mining vehicle, not shown. A tension cable 88 releasably locks the hose in the sea socket through operation of a winch on the mother vessel. With the hose end connected and locked in the sea socket the slurry or saltation of material and seawater pumped from the mining vehicle passes upwardly through hose 87, sea socket 86, and riser pipe 84 to the vessel.

In applications where additional pumping is required to move the slurry or saltation from relatively shallow depths, the embodiment of FIG. 6 may be employed. In this form a single riser pipe 89 and sea socket 90 are provided, in the manner of the single pipe system of FIG. 5. The additional pumping is supplied by a boost pump 95 of the conventional submersible pump type mounted in the lower end of the riser pipe and powered by a suitable electric cable, not shown, extending down from the vessel along the riser pipe.

FIG. 3 illustrates the position of vehicle 10 as it is hoisted into seawell 21 of the mother vessel for servicing, repairs, or changing the control functions. Tension cable 71 has been payed out through the sea socket and remains in connection with hose 52 so that re-entry can be easily established when the vehicle is again lowered to the ocean floor.

An important advantage with the present invention is that the flexible hose 52, which is expensive, subject to damage, difficult to handle, and lacks the tensile strength of steel, may be of relatively short length as compared to the riser pipe system, which is of relatively inexpensive steel pipe construction. Moreover, the re-entry capabilities of material transport system 14 permits the entire mother vessel to be separated from vehicle 10, such as in emergencies where bad weather and heavy seas are encountered, with lift cable 18 and tension cable 71 connected to marker buoys for relocating and coupling up with the vehicle at a later time.

FIGS. 7 and 8 illustrate in greater detail mining vehicle 10 which would be used in the deep sea mining system of the invention for recovering material such as manganese nodules from the ocean floor. The vehicle includes a main frame 93 supported from the ocean floor by four crawler type endless track units 94. The track units are each powered by individual drive motors, not shown, preferably hydraulic motors mounted in the track units and connected in a conventional chain and drive sprocket arrangement with the driving sprocket of the tracks. The track driving motors are adapted for forward and reverse operation for moving the vehicle along the pre-selected path.

Lateral travel means are provided to move the vehicle sideways at selected intervals for traversing along an adjacent run in the path. This lateral travel means includes a pair of walking leg units 96 mounted below frame unit 93 between the track units, with each unit 96 positioned at respective front and rear ends of the vehicle. Each unit 96 includes a pair of support pads or feet 97, 98 mounted on driving wheels 99, 101 at rotatable connections 102, 103. A cross bar 104 interconnects the pads for conjoint movement. Suitable driving means, preferably hydraulic motors, not shown, are provided to rotate the driving wheels through a predetermined number of

revolutions for walking the unit to the left side, as viewed in FIG. 8, a distance sufficient to traverse the return run. As the driving wheels rotate together the pads move downwardly below the lower treads of the track units to lift the vehicle off the floor, move it a short distance to the side, and return for the next cycle. The control circuit governing the driving wheel operation is programmed to terminate after the predetermined number of revolutions with the pads stopping in the retracted position clearing the ocean floor.

Digger-conveyor unit 17 is mounted on an end of vehicle 10 designated herein as the front end. Unit 17 is adapted to dig or pick up and convey material, such as manganese nodules, both during forward and reverse travel of the vehicle. The unit includes a conveyor frame 104 mounted on frame 93 by means of a floating linkage arrangement comprising pairs of support arms 106, 107 pivotally connected between conveyor frame 104 and vehicle main frame 93 on either side of the vehicle.

A bumper unit 108 is mounted at the forward end of conveyor unit 17 by means of mounting bracket 109 and spring-loaded arm 111. The underside of the bumper unit is provided with a plurality of skid members 112 to follow the contour of the ocean floor as the vehicle traverses. Bumper unit 108 operates to keep the lower flight of the conveyor unit from sinking into the ocean floor as the contour changes by elevating the digging-conveyor unit relative to the vehicle frame through the floating linkage arrangement. Also, bumper unit 108 serves to stop the vehicle where it may run into any large object on the floor to enable the control circuit to reverse vehicle movement and avoid the obstacle. A similar bumper unit 113 is mounted on the rear end of the vehicle frame by means of mounting arm 114 and spring loaded arm 116. Skid members 117 are provided underneath bumper unit 113 to follow the contour of the ocean floor as the vehicle traverses a reverse direction and thus prevent the rear track units from sinking into the bed. Suitable pressure sensing devices, not shown, may be provided with both bumper units to signal the control system for stopping when any obstacle is encountered.

Digging-conveyor unit 17 includes an endless conveyor having a plurality of digging buckets or baskets 118 mounted between endless chain type links 119 trained around a driving sprocket 121 and three idler sprockets 122, 123, 124 rotatably mounted on frame 104. A plurality of support rollers 126 are mounted at spaced intervals along the length of the chain links 119, and these rollers run between spaced guide rails 127, 128 mounted on frame 104 to define a substantially rectangular conveyor path. This path guides the buckets along a lower reach for digging and collecting the nodules, an upwardly moving elevating reach on the right-hand side for lifting the material, an upper reach for dumping the material from the buckets at a discharge zone, and a downwardly moving return reach on the left-hand side. The buckets are moved in this path by means of a suitable drive motor, preferably an hydraulic motor, not shown, connected to rotate driving sprocket 121 counter-clockwise as viewed in FIG. 8. This positioning of the driving sprocket serves to tension the loaded flights.

Digging buckets or baskets 118 are illustrated as perforate for screening out and removing fines, sand, muck, or ooze from the collected material. The invention also contemplates that the buckets may be of imperforate construction with any fines or the like collected by the buckets and removed by subsequent screening operations.

Buckets 118 are affixed to the conveyor to move with their open ends facing in the direction of travel. As the buckets move along the lower digging reach, they are effective in scooping up or digging the nodules or material lying on the ocean floor. The buckets will turn upwardly on the elevating reach for carrying the nodules, and the buckets turn downwardly as they move along

the upperreach for dumping the material from the downwardly inclined bucket ends for classifying.

The classifying system includes a fines chute 129, crusher feed chute 131, and oversize chute 132 disposed in material receiving relationship below the upper reach of the conveyor and mounted on the forward end of vehicle frame 93. Fines chute 129 is positioned to first receive the material dumped from the buckets and is provided with a screen or grizzly 133 mounted above the upper opening of this chute. The chute extends downwardly and to the side of the vehicle for depositing the fines material through lower opening 134 in a windrow on a side opposite the path to be subsequently traversed. A pair of spaced, upstanding side walls 136, 137 are mounted to the upper sides of the classifying chutes to define a trough enclosing the buckets moving along the upper reach. This trough serves to confine the material as it is moved over the chutes for classification.

A screen or grizzly 138 is mounted above the open end of crusher feed chute 131 and functions to pass through nodule material within the desired size range which can efficiently be crushed. The lower end of chute 131 discharges into the upper end of crusher device 139. While a single crusher is disclosed, it is understood that a plurality of grizzlies, feed chutes, and crusher devices could be provided in tandem along the upper reach of the conveyor to process a greater size range of material. Thus, an upstream crusher feed chute and crusher device would process the smaller nodules, while a downstream feed chute and crusher would process the larger nodules.

Oversize chute 132 opens upwardly under the upper reach of the conveyor downstream of feed chute 131 to receive material which has not entered the fines or feed chutes, and to convey the oversize chute downwardly and to the side for discharge through opening 141 at the side of the vehicle opposite the path subsequently to be traversed. Any further material moved by the conveyor which does not enter chute 132 is discharged to the opposite side of the vehicle as the buckets turn downwardly entering the return reach.

Crusher 139 comprises a single roll 142 journaled for rotation about an upwardly and forwardly diverging axis within crusher housing 143. The input material feeding from chute 131 is deposited in the bite between roll 142 and a hingle plate 144 mounted in the crusher housing. The crusher roll is powered to turn counter-clockwise as viewed in FIG. 8 for crushing the nodules, and the diameter of this roll is sized to provide the most efficient crushing action for intermediate size nodules which pass through grizzly 138. Nodules of manganese, for example, would be crushed to within 1/2 inch particle size. The crusher roll is powered by means of drive motor 146, preferably an hydraulic motor, which turns drive shaft 147, intermediate shaft 148 through U-joint 149, pinion gear 151, and driven gear 152 keyed to the crusher roll shaft. Material crushed by the roll drops into chute 152 which discharges through opening 153 into rotary screen device 154. The material cascades down the incline of the crusher bite, and any overflow which is not crushed passes through overflow chute 156 at the end of the crusher housing where it falls downwardly for discharge through opening 157 into the rotary screen. Any of this overflow material which is within the correct size range will subsequently be classified together with the crushed material of the desired size range in the rotary screen, with oversize material discharging from the screen into overs dump chute 158 which discharges to a side of the vehicle.

Rotary screen device 154 includes a conventional cylindrical screen journaled for rotation within housing 159 about an upwardly and forwardly diverging axis. The screen is driven by hydraulic motor 146 through a drive arrangement including a chain or gear drive 161 driven from the motor, counter-shaft 162, and a chain or gear drive 163 driven from the counter-shaft and in turn driving the screen.

An auger or screw type conveyor 164 is mounted in material receiving relationship below rotary screen 154 to receive crushed material passing through the screen. The conveyor is journaled for rotation about an upwardly and forwardly diverging axis and is driven by motor 166, preferably an hydraulic motor. Conveyor 164 functions to collect the screened material and feed the same through discharge chute 167 into product pump 168.

Product pump 168 comprises a pair of reciprocating pistons and is of the conventional type known in the art as a concrete pump. The pistons are operated preferably by hydraulic fluid and establish a given feed rate for pumping the material/water mixture received from discharge chute 167 into conduit 169 connected with the inlet of a booster pump 171, as best illustrated in the schematic of FIG. 2.

Booster pump 171 is conventional and may be of the impeller type. This pump is driven through shaft 172 from prime mover 173. Pump 171 adds a small amount of seawater through water feed inlet 174 for combination with the mixture received from conduit 169 into the desired slurry or saltation effective to be conveyed in the material transport system.

The present invention controls the particle size and feed rate in relation to flow rate of the fluid stream in the transport system to establish and maintain an optimum, calculated ratio by volume of solids to water mixture in accordance with known principles of slurry or saltation transport systems. A ratio smaller than the optimum can be accommodated, although at the expense of reduced carrying capacity. The control system for vehicle 10 is adaptable for varying material feed rate in relation to a change in other variables, such as particle size or density, or fluid stream flow rate. The control system would be programmed for the selected feed rate for a particular recovery operation when the vehicle is on the mother vessel prior to lowering to the ocean floor. The variable which determines this programming could be ascertained from studies or surveys of the ocean floor area to be mined.

The material/water mixture in slurry or saltation form is pumped from booster pump outlet 175 into conduit 176, and then into hose 52 which is connected with this latter conduit through coupling 177. Hose 52 injects the mixture into sea socket 53 and the high pressure water stream through riser pipe 31 of the double pipe transport system, or sea socket 86 and riser pipe 84 of the single pipe transport system of FIG. 5.

Prime mover 173 preferably is a high voltage electric motor of conventional construction having an armature adapted to run in water and including pressure compensating means to equalize hydrostatic pressure within the housing at variable depths. Power for motor 173 may be supplied from the mother vessel through combination cable 18.

Hydraulic fluid under pressure for operating the various drive motors is supplied by means of hydraulic pumps, not shown, in pump housing 178 and driven by shaft 179 from motor 173. Suitable pressure compensating means may be provided to equalize pressure within the housing at variable depths. The pumps may be of the gear type adapted to pump oil under pressure through hydraulic lines, not shown, leading to the drive motors for the track units 94, walking leg unit, digger-conveyor 17, motor 146 driving the crusher and rotary screen, motor 166 driving the conveyor, and product pump 168. The discharge from the hydraulic pumps is controlled by means of a series of control valves and adjustable cams positioned in control valve housing 181, 182 and operated by a control system of the type described in FIG. 9. Housing 181 contains the series of cams and control valves which in turn operate respective motors for the travel function and these cams are driven by reversible electric control motor 183. Housing 182 contains the series of cams and control valves which in turn operate respective motors for the

11

mining, processing, and pumping functions and these cams are driven by reversible electric control motor 184.

Remotely controlled television camera 185 and flood lights 187 are mounted above main frame 93 to supply visual information to the vessel's operator on the progress or condition of the vehicle. A motor 186 is provided to swing the camera through an arc for observing the full scope of the vehicle and surrounding area.

FIG. 9 illustrates in schematic form a control circuit 188 for programming the operation of the hydraulic control valves. While one exemplary circuit 188 is illustrated, each of the control valve housings 181, 182 would enclose a circuit of identical configuration. Control circuit 188 is shown as including a single cam 189 operating a three-position valve 191 which in turn controls fluid flow to hydraulic motor 192. Motor 192 is exemplary and operates a given one of the mining or travel functions. In use the control system would include a plurality of similar cams, valves and motors with each such combination operating a separate one of the functions. Thus, separate cam and valve pairs within control valve housing 181 would be provided for controlling vehicle travel functions such as the track unit and walking leg motors for the forward, reverse, and sideways functions. The mining functions, including processing and pumping, would be controlled by similar cam and valve pairs within control valve housing 182.

In control system 188 pump 193, which would be enclosed within housing 178 and driven by motor 173, supplies pressurized working fluid through block valve 194 and valve 191 for operating reversible motor 192. Valve 191 is actuated by cam 189 through cam follower 195 between the upper, illustrated position for operating motor 192 in a forward sense, a centered position terminating flow to the motor, and a lower position reversing the flow for operating the motor in a reverse sense. Cam 189 is provided with a series of lobes effective to actuate valve 191 between its three positions as cam shaft 196 is rotated under influence of reversible electric control motor 183, 184. A gear reducer 198 and one-way clutch 199 drive the cam shaft from the control motor. Motor 183, 184 further drives a hydraulic pump 201 serving as a clockwise block pump, and hydraulic pump 202 serving as a counter-clockwise block pump. During clockwise operation of the control motor, pump 201 is effective to supply control fluid through conduit 203 and check valve 204 into actuator 206 moving block valve 194 to open position establishing communication between pump 193 and valve 191. During counterclockwise operation of the control motor, pump 202 is effective to supply control fluid through conduit 207 and check valve 208 into actuator 206 operating block valve 194 to open position. With motor 183, 184 and the cam shaft at rest neither of the block pumps is operating permitting fluid to bleed from actuator 206 through bleed orifice 209 and in turn allowing actuator 206 to be biased by spring 211 moving block valve 194 to closed position.

Each of the control motors 183, 184 is operated from the vessel through control cable 18 for three modes of control. The first mode would be the normal operating sequence with the control motor turning in clockwise rotation. Clutch 199 engages for turning cam shaft 196 clockwise and the plurality of cams 189 rotate and operate their associated valves 191 in the programmed sequence effective to traverse the vehicle in the predetermined path while the mining, processing, and pumping functions are in operation. During this first mode block pump 201 supplies the control pressure holding block valve 194 in open position.

The second mode of operation is the stop mode in which the control motor is stopped by the operator on the vessel. Valves 191 remain at the settings established when the cam shaft rotation ceases, but fluid flow into the function motors 192 is terminated as a result of block valve 194 moving to closed position after the pressure bleeds from actuator 206. In this mode vehicle travel is

12

stopped and the mining, processing and pumping functions are terminated. However, booster pump 171 continues in operation as long as main electric motor 173 is operated.

The third operating mode is with the functions controlled by motor 192 continuing in operating at a selected point in the program without further valve sequencing. This is established by operating control motor 183, 184 in counter-clockwise rotation disengaging clutch 199 so that the cam shaft and cams stop in the selected position with associated valves 191 operated in a respective position. At the same time pressurized fluid is available to be supplied to hydraulic motors 192 as a result of counter-clockwise block pump 202 operating actuator 206 to insure that block valve 194 remains in open position.

The use of the two control motors 183, 184 driving separate cam shafts, each in the manner of control circuit 188, permits separate control of the mining and travel functions. This is important in ending a mining sequence where it is desired to clean the various processing equipment and material transport system of the rock, sand and nodules prior to a full stop, such as where it is desired to hoist the vehicle to the vessel.

In operation, the cams in housings 181, 182 would be adjusted while the vehicle is on the deck of the vessel so that the desired sequencing program is established. Vehicle 10 is then lowered by gantry crane 19 to the ocean floor. Winch 74 is then operated to reel in tension cable 71 until flexible hose 52 is connected into sea socket 53. Cable lock 77 then secures and locks cable 71, and winch 74 is de-energized.

Main electric motor 173 is then energized to drive booster pump 171 and the hydraulic pumps within housing 176. Control motor 183 is energized for clockwise rotation to operate in its first mode for sequencing the cams and control valves which in turn operate their respective hydraulic motors for the travel function. Typically the cams would be programmed so that the track unit motors are operated to first move the vehicle in a forward direction. Control motor 184 for the mining functions is then energized for clockwise rotation to sequence its associated cams and valves for controlling their associated hydraulic motors. Typically, the cams are programmed to simultaneously operate the rotary screen and crusher motor 146, digging conveyor motor, auger motor 166, and concrete pump 168. All functions of the vehicle are now operating as the vehicle traverses along its first run while collecting, classifying, crushing and pumping the material/water mixture into transport system 14 through which the stream of high pressure water is pumped by operation of pump system 38 on the vessel.

When the vehicle reaches the end of the first run, control motor 183 sequences its associated cams to positions which terminate operation of the track unit motors and stop forward travel of the vehicle. Further rotation of the cam shaft actuates the appropriate valve for actuating the motors operating walking leg units 96. This valve remains open until the vehicle travels sideways to the adjacent run, and the valve then closes to terminate lateral travel with the walking leg pads in the retracted position. Further rotation of the cam shaft moves the cam for the track unit motors to a position actuating the associated valve for reverse fluid flow thereby operating the track unit motors in the reverse travel mode for returning the vehicle the predetermined distance along the adjacent run. The foregoing sequence continues until the desired area of the ocean floor is covered. The relative angular positioning of the travel control cams may be adjusted to selectively vary the length of the forward and reverse runs, or the distance for lateral travel.

Where it is desired to override the normal sequencing operating for continuing vehicle travel in any desired direction, motor 183 is selectively controlled to rotate in its counterclockwise mode when the vehicle is travelling in such direction, for example where it is desired to continue forward travel beyond the predetermined path.

Control circuit 188 operates in the manner described above to stop rotation of the cam shaft with the main travel valves in open position supplying fluid to the track unit motors. The vehicle will continue in the forward travel operating mode until motor 183 is again operated in clockwise rotation for continuing the normal program, or is operated to its stop mode.

At the end of the mining operation the control system is operated to establish a clean-out sequence to remove all material from the processing equipment and material transport system. The clean-out sequence is initiated by de-energizing motor 183 to establish its associated control circuit in the stop mode to terminate forward and lateral travel operation. At the same time, mining control motor 184 continues in its normal operation sequence to allow the digger-conveyor, crusher, screen, auger, and product pump to operate along with booster pump 171 while the vehicle is at rest. This cleans the rock, sand and nodules from the mining equipment, flexible hose, and conduit system since no further material is collected by the digger-conveyor. After a period of time substantially clean seawater will be pumped through the complete material transport system permitting termination of the processing and pumping operations without the possibility of any entrained material settling back and plugging the riser pipe, sea socket or flexible hose.

To hoist vehicle 10 to the vessel after the clean-out sequence hose 52 is first released from the sea socket. During continued pumping of seawater through hose 52 cable lock 77 is released and winch 74 operated to pay out tension cable 71. Water pressure within the sea socket blows out the male fitting at the end of hose 52 pulling with it the tension cable through the sea socket. Control motor 184 is then actuated to its stop mode terminating operation of the mining equipment. At the same time main electric motor 173 is de-energized, and all functions on the vehicle are now stopped. Gantry crane 19 is then operated to raise the vehicle to the vessel while simultaneously operating tension winch 74 to pay out the tension cable through the sea socket.

FIG. 10 illustrates control circuit 212 incorporating a master-slave simulated control arrangement for permitting the operator on the vessel to quickly determine and follow the operating mode through which the vessel on the ocean floor is cycling. An operator's control console 213 is provided with conventional control switches adapted to direct signals through combination control cable 18 for activating one of the control motors 183, 184, into a selected one of the three operating modes described above for cycling cam shaft 196 through the predetermined program.

On the mother vessel a slave control motor 214 is provided which follows the control signals from console 213 through parallel connected control cable 216. A simulated cam shaft 217 operated by control motor 214 is formed with a series of cams identical in shape to those on cam shaft 196, and these cams are adjusted in the same operating program as that established for the master control motor and cam shaft. While only one slave control motor and cam shaft are illustrated for clarity, it is understood that a separate slave control motor and cam shaft pair would be provided for each control motor 183, 184. The slave motors are energized and de-energized when their associated master control motors are operated so that the slave cam shafts follow an identical operating sequence to that of the master cam shafts. The operator on the vessel may thus follow the operating sequence of the vehicle on the ocean floor merely by observing the positioning of the slave cam shaft. Suitable indicator lights, not shown, may be provided for actuation by the slave cams to provide visual indication of the master-slave cam shaft program.

An example of the use of the deep sea mining method and apparatus of the invention would be in mining manganese nodules on the ocean floor at a depth of 3500

feet. After establishing the predetermined programs for the mining and travel control circuits, the mining vehicle is lowered to the ocean floor in an area known from previous surveys to be rich in these nodules. The connection of the flexible hose and sea socket is established by reeling in the tension cable which is locked with respect to the conduit system. The mining and travel control motors are then actuated to their first or normal operating modes. The vehicle is traversed along the path described in FIG. 1 at a velocity of 30 feet per minute in forward and reverse directions with the vehicle travelling laterally 15 feet at the end of each run to begin the adjacent run. The manganese nodules are collected by the digger-conveyor and classified through the screens to remove sand, ooze and fines for delivery to the crusher which reduces the nodules to substantially 1/2 inch particle size. Oversize material, such as pebbles or other nodulous material, is rejected in the rotary screen and the nodule particles are fed by the screw conveyor into the product pump which establishes a mixture feed rate for injection into the material transport system. The booster pump adds a small amount of water to the mixture for pumping through flexible hose 52. In the material transport system a 600 HP motor on the vessel drives a pump operating at approximately 600 p.s.i.g. pressure pumps water through the down pipe for return in the riser pipe where it entrains the material/water mixture for discharge into the vessel. A manganese nodule deposit density on the ocean floor of 1 gram/cm.² is harvested at the rate of 1000 lbs. of crushed nodules per minute. The total output in a 20 hour working day would be 600 tons of crushed nodules.

While the embodiment herein is at present considered to be preferred, it will be understood that numerous variations and modifications may be made therein by those skilled in the art, and it is intended to cover in the appended claims all such variations and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A method for recovering deposits of material on an ocean floor with a mining vehicle comprising the steps of: controlling the vehicle to traverse a predetermined path across an area of the floor, controlling a vessel on the ocean surface to move in substantial vertical registry with the moving vehicle, causing the vehicle to collect the material deposits along the path of vehicle movement, crushing the larger sized collected material, removing oversize particles from the crushed material, combining the collected and crushed material with water to form a pumpable mixture, maintaining the solids to liquid ratio of the mixture substantially constant and optimum, and pumping the mixture through a conduit upwardly for discharge into the vessel.

2. A method as in claim 1 in which the step of crushing the material includes reducing the material to at least a predetermined particle size to provide the material for combining with the water.

3. A method as in claim 2 in which the reduced material is mixed with said water in a predetermined solid to liquid ratio range by volume for pumping through the conduit.

4. A method as in claim 1 in which the step of collecting the material includes moving a conveyor having a series of buckets along the ocean floor for picking up the material, moving the buckets with the collected material on the conveyor to a discharge zone, discharging the material from the buckets, and separating particulate material within a given size range from the discharged material to supply said larger sized material for crushing.

5. A method of recovering material from a collecting vehicle traversing an ocean floor for transport to a receiving vessel on the ocean surface comprising the steps of: combining material collected by the vehicle within a given size range with water to form a pumpable mixture, pumping the mixture through a flexible hose, pumping

15

water from the vessel through a flow path extending downwardly toward the vehicle, combining the mixture from the flexible hose with the water pumped through the flowpath, and directing the combined mixture and water upwardly for discharge into the receiving vessel.

6. A method as in claim 5 in which the step of combining the mixture and water includes aspirating said mixture with the water at a lower portion of the flowpath.

7. A method of recovering material from an ocean floor with a vehicle adapted to traverse the floor while collecting the material therefrom for transporting the same through a riser conduit to a vessel on the ocean surface, the vessel including a discharge end, including the steps of: holding the discharge end of the flexible conduit in fluid communication with the riser conduit for a material recovery operation, mixing the collected material with water, pumping the mixture through said flexible conduit, pumping a transport stream of water upwardly through said riser conduit, discharging the mixture from the flexible conduit into the riser conduit for entrainment with the transport water, discharging the transport water and entrained mixture from the riser conduit into the vessel, releasing said discharge end from the riser conduit for terminating the recovery operation, and causing fluid pressure within the discharge end of the flexible conduit to force the same from said communication with the riser conduit.

8. A method as in claim 7 wherein the step of applying the locking force includes drawing the discharge end of the flexible conduit with a tension cable into mating engagement with a socket at the lower end of the riser, and the step of releasing the locking force includes releasing the force on the tension cable and paying out the tension cable from the vessel and through the socket as the vehicle is raised to the vessel whereby the cable remains interconnected between the flexible conduit and vessel through the socket to facilitate subsequent re-entry of the discharge end into the socket.

9. A method of controlling the operation of a mining vehicle on the ocean floor including the steps of: traversing the vehicle on a path along the ocean floor, initiating operation of a material collecting means on the vehicle to collect material from the floor, initiating operation of means for crushing the collected material, initiating operation of means to separate the crushed material within a predetermined size range from the remaining crushed material, combining the sized and crushed material with water within a predetermined ratio range by volume to form a mixture, pumping the mixture to the vessel, and terminating the mining operation including the steps of terminating vehicle traversing, continuing operation of the material collecting, crushing, screening and pumping means to reduce the ratio of material to water in the mixture until substantially no material is pumped to the vessel, and terminating operation of the material collecting, crushing, and separating means.

10. A method as in claim 9 wherein a flexible conduit is releasably connected with a riser conduit for entraining the mixture with water pumped through the riser conduit upwardly to the vessel, and including the steps of releasing the connection between the flexible conduit and riser conduit after said ratio is reduced, and continuing the pumping step whereby fluid pressure in the connection forces the conduits apart.

11. A method as in claim 9 wherein a flexible conduit is releasably connected with a riser conduit by a cable extending from the vessel, and including the steps of applying a tension force from the cable to the flexible conduit in fluid communication with the riser conduit for a recovery operation, releasing the cable tension to unlock said conduits after a recovery operation, hoisting the vehicle to the surface while paying out said cable through the connection, lowering the vehicle to the ocean floor for resumption of the recovery operation, and drawing in said cable through the connection while the vehicle is

16

lowered to relock the flexible conduit with the riser conduit.

12. Apparatus for use in a system for recovering material from an ocean floor for transport to a surface vessel, including the combination of: a vehicle adapted to traverse a path along the ocean floor, means to collect the material along the path, means to crush the larger size collected material, conduit means extending from the vehicle to the vessel, means to form a pumpable mixture of the collected and crushed material with water, and means to pump said mixture through the conduit means to the vessel.

13. Apparatus as in claim 12 and further including means to classify the material picked up along the path and to deliver material within a predetermined size range to the crushing means.

14. Apparatus as in claim 12 wherein the means to pump the mixture includes material pump means receiving the crushed material and discharging the same with water at a predetermined feed rate, and booster pump means to pump the discharge from the material pump means with additional water in at least a predetermined volume ratio of material to water through the conduit means.

15. Apparatus as in claim 12 wherein the conduit means includes a length of flexible hose connected with the pump means to receive the pumped mixture and having a discharge end extending from the vehicle, riser conduit means suspended from the vessel and having a lower end in proximity with the vehicle, and connector means to releasably connect the discharge end of the flexible conduit in fluid communication with the lower end of the riser conduit means.

16. Apparatus as in claim 15 wherein the means to pump the mixture includes pump means to move water upwardly through the riser conduit means to the vessel, and means to entrain the mixture discharging from the flexible conduit with the water pumped through the riser conduit means.

17. Apparatus as in claim 16 wherein the means to entrain the mixture includes venturi means in the path of water flow through the riser conduit means, and means to inject said mixture from the flexible conduit into the venturi means.

18. Apparatus as in claim 15 wherein the riser conduit means includes first and second conduits suspended from the vessel with lower ends thereof in fluid communication, the means to pump the mixture includes means on the vessel to pump water downwardly through the first conduit and upwardly through the second conduit, and said connector means being adapted to connect the discharge end of the flexible conduit in fluid communication with the second conduit means.

19. Apparatus for use in a system for recovering material from an ocean floor for transport to a vessel on the ocean surface including the combination of: a vehicle adapted to travel over the ocean floor, means on the vehicle to collect material along the path of vehicle travel, conduit means extending between the vehicle and vessel, means to pump the collected material in a mixture with water through the conduit means, means to control vehicle movement along a predetermined path for a material recovery program simultaneous with operation of said collecting and pumping means and to terminate vehicle movement for a material clean-out program simultaneous with operation of said collecting and pumping means, and means to control vessel movement to maintain substantially vertical registry of the vessel with respect to the vehicle.

20. Apparatus for use in a system for recovering material from an ocean floor for transport to a vessel on the surface including the combination of: a vehicle adapted to move along the ocean floor, means on the vehicle to collect material along the path of vehicle travel, a flexible hose mounted on the vehicle and extending outwardly to a discharge end, means to pump the collected material in a mixture with water through the flexible hose, riser

17

conduit means suspended from the vessel and having a lower end positioned in proximity with the vehicle, releasable connector means to releasably connect the discharge end of the flexible hose in fluid communication with the riser conduit means, and means to pump water upwardly through the riser conduit means for entraining the mixture therein.

21. In a system for recovering material from an ocean floor to a vessel on the surface including the combination of: a vehicle adapted to move along the ocean floor, means on the vehicle to collect material along the path of vehicle travel, a flexible hose on the vehicle and having a discharge end, means to pump the collected material in a mixture with water through the flexible hose, riser conduit means suspended from the vessel and having a lower end in proximity with vehicle, releasable connector means to releasably connect the discharge end of the flexible hose in fluid communication with the riser conduit means, the releasable connector means comprising a female socket at the lower end of the riser conduit means, the socket being provided with a through passageway and a chamber in fluid communication with the riser conduit means, a

18

male fitting on the discharge end of the flexible hose, the fitting adapted to releasably engage with the socket and having an opening providing communication with the discharge from the flexible hose and the chamber when in seated position in the socket, a cable secured to the fitting and trained through the passageway, and means to tension the cable and lock the fitting in the socket, and to release the cable tension and unlock the fitting whereby discharge pressure within the chamber forces the fitting from the socket to allow the cable to be payed through the passageway for raising the vehicle from the ocean floor, and means to pump water upwardly through the riser conduit means for entraining the mixture therein.

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