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N. KOOT ET AL

3,433,531

METHOD AND APPARATUS FOR UNDERSEA MINING

Filed Dec. 27, 1966

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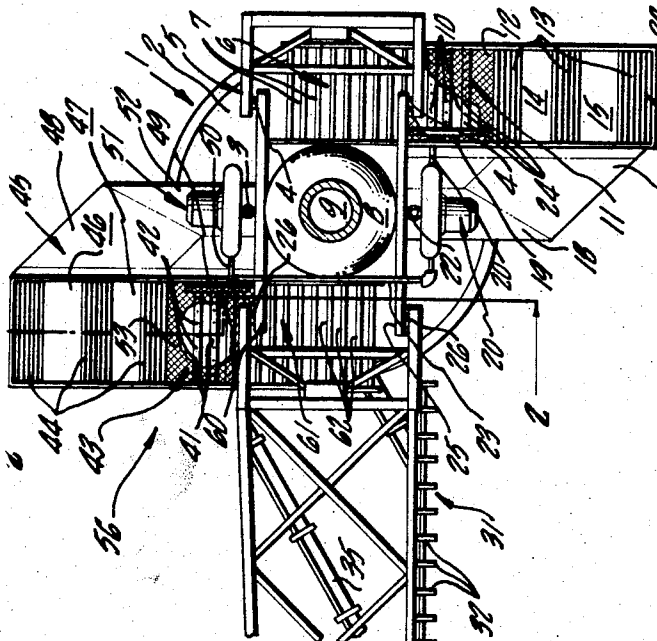


FIG. 1

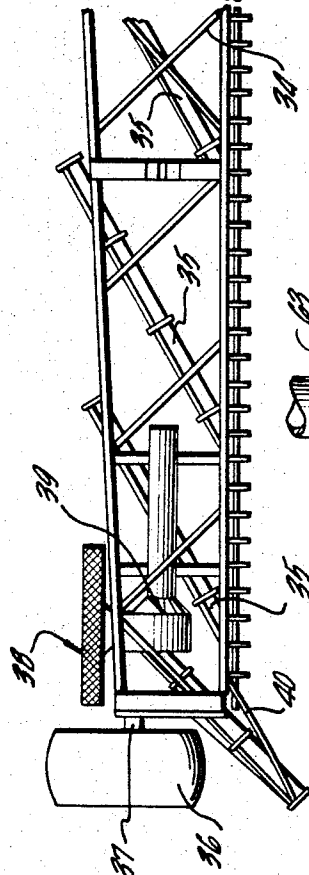


FIG. 2

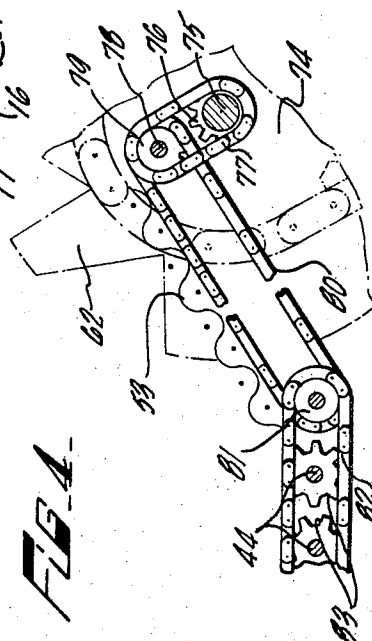


FIG. 3

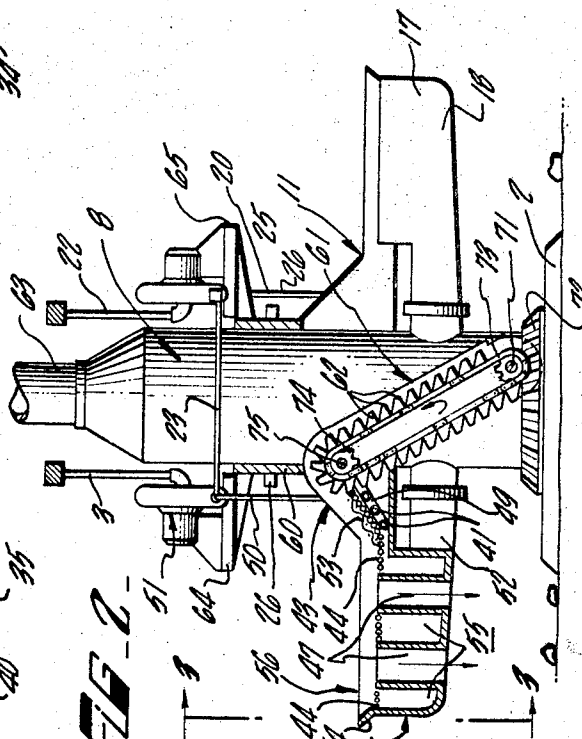


FIG. 4

INVENTORS
NICK KOOT
ROBERT W. NOLD
BY
Christie, Parker & White
ATTORNEYS

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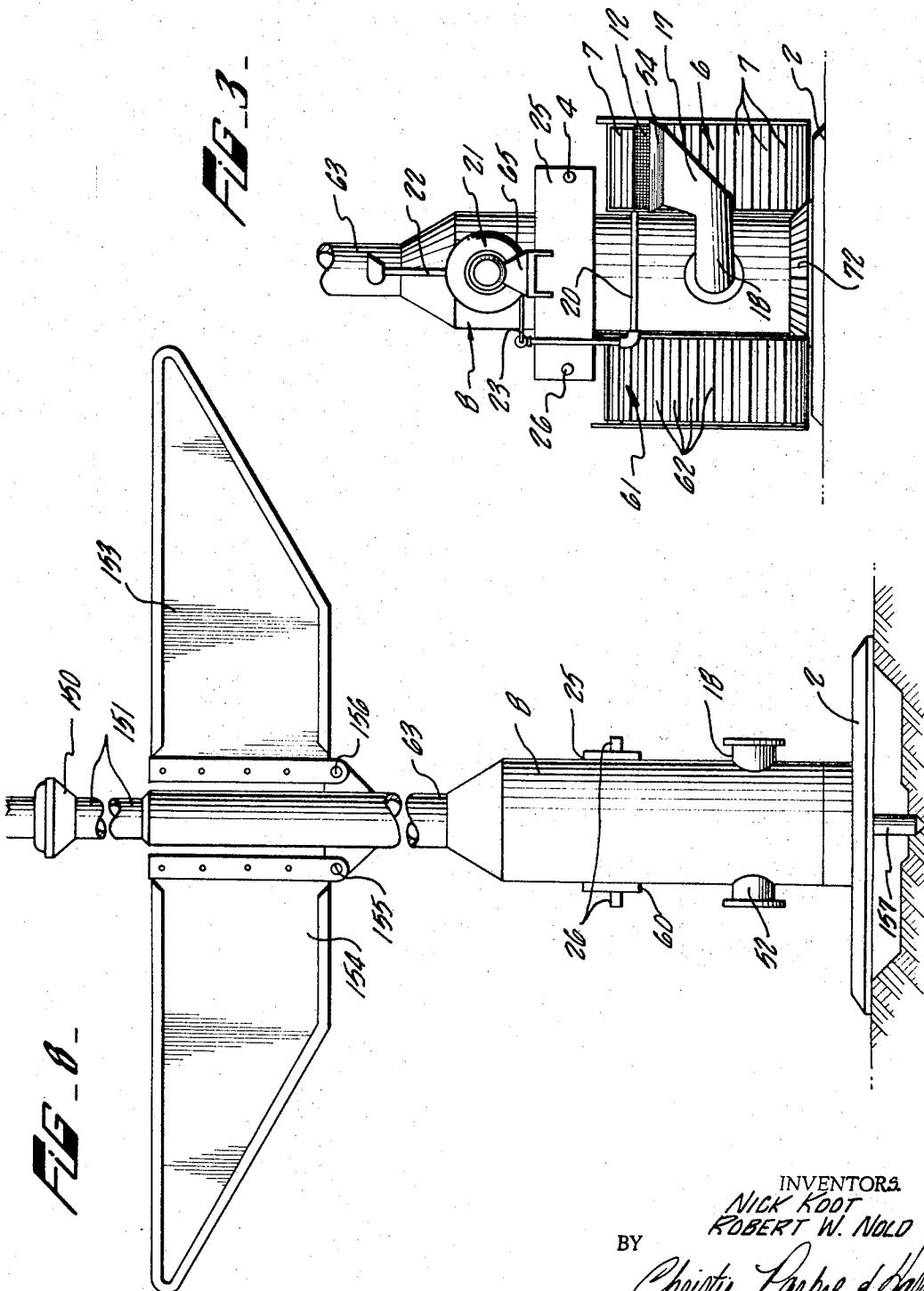
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ATTORNEYS

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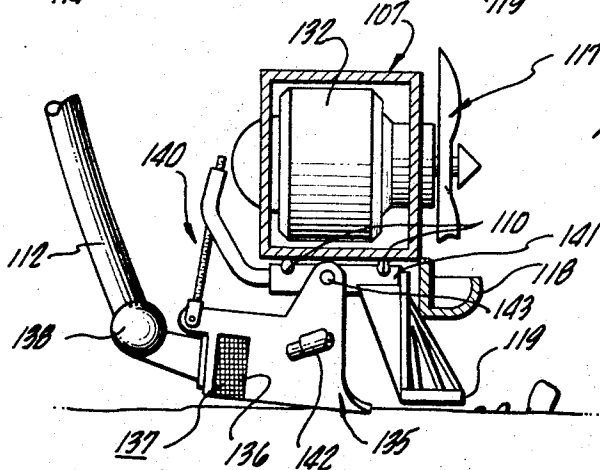
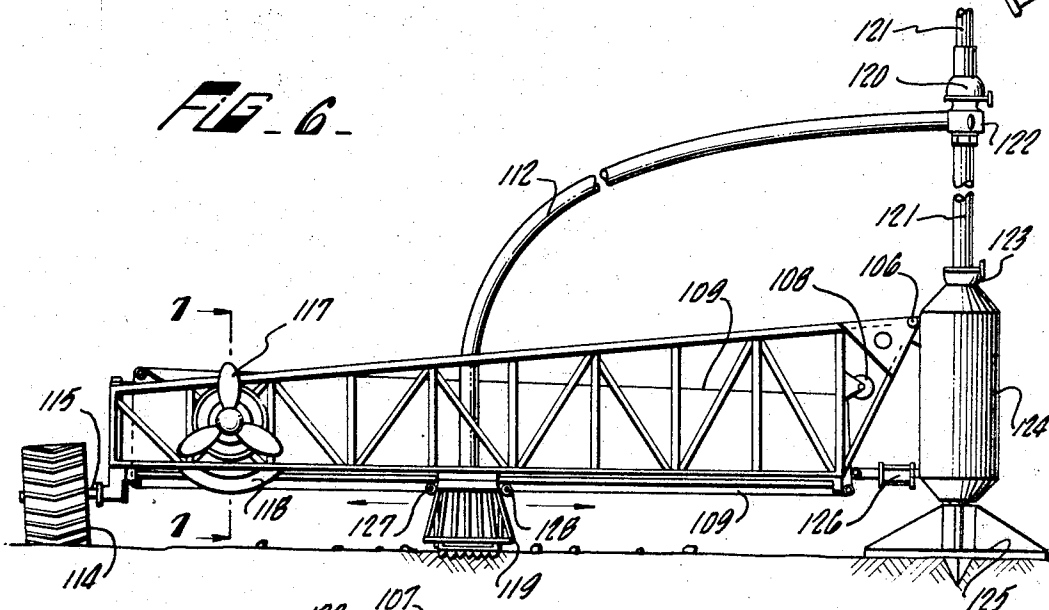
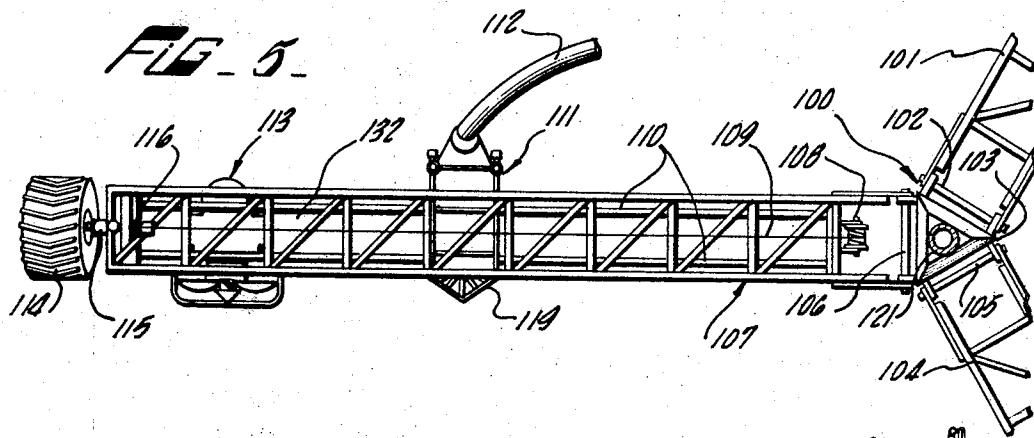
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INVENTORS
 NICK KOOT
 ROBERT W. NOLD
 BY
Christie, Pacher & White
 ATTORNEYS

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METHOD AND APPARATUS FOR UNDERSEA MINING

Nick Koot, South Laguna, and Robert W. Nold, Garden Grove, Calif., assignors to Global Marine, Inc., Los Angeles, Calif., a corporation of Delaware

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14 Claims

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ABSTRACT OF THE DISCLOSURE

At least one substantially horizontal arm is carried by a hub supported on a bearing plate. A propeller mounted on the arm is used to rotate the arm about the bearing plate. The arm carries means to gather ore deposits on the ocean floor. The gathering means may be a plurality of blades disposed to sweep ore toward a conveyor at the hub or an ore harvesting assembly capable of moving back and forth along the length of the arm to gather ore as the arm rotates. Gathered ore is cleansed of silt and sediment by water under pressure. In one embodiment activated crushers are provided to crush the ore after it is cleansed. An ore conduit and an airlift pump transport the gathered ore to the ocean's surface.

This invention relates to the art of underwater mining and, in particular, to a method and apparatus for in-place mining of ore deposits located on the floor of the ocean.

Vast reaches of the ocean floor are covered by ore deposits of significant commercial interest. These deposits often take the form of nodules and slabs lying on or loosely embedded in the surface of the ocean's floor. Many of these deposits take the form of manganese nodules containing, in addition to manganese, significant amounts of iron, aluminum, magnesium, nickel, copper, cobalt and zinc. In general, these nodules vary from one to nine inches in diameter and have a relatively low specific gravity of approximately 2.4. The concentration of the mineral content in these nodules varies from area to area, but, in general, most of the nodule deposits admit to exciting commercial potential in the amount of minerals which can be recovered in a given area. Unfortunately, most of the commercial grade deposits lie at depths in excess of 5,000 feet which presents significant engineering problems in their extraction.

One basic scheme heretofore proposed employs a support ship with a tractor deployed on the ocean's floor. The tractor is connected to the support ship by an ore conduit or line which serves as a conveyor for harvested ore. As the tractor traverses the floor of the ocean and harvests ore in its path, the ore is inducted into the conduit for deposit in the support vessel or an ancillary barge. Ore induction is provided through an air lift which is created by introducing compressed air into the conduit at some point intermediate the vessel and the ocean's floor.

The core conduit required for such a mobile undersea system presents many problems. If the support ship remains relatively stationary while the tractor moves along the ocean's floor, severe stress in the conduit occurs because of relative movement between the tractor and the support ship. Thus, means must be provided to compensate for this relative movement. One system contemplates the movement of the support ship along with the tractor. However, this scheme suffers because of the fuel costs required in the constant stationing of the support vessel and the expensive monitoring equipment required to determine the movement of the undersea tractor. Moreover, a constantly moving ship is a cumbersome method for mining the ocean's floor.

Other systems which would overcome the stress problem

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are equally unattractive because of the cost of the complex ore conduit which would be required to present a relatively stationary ship to a moving tractor.

Notwithstanding the problems of stress in the ore conduit, any system which employs a tractor or similar ore gathering means requires expensive positioning devices to insure that the ore gathering machinery does not cover ground previously mined. Such monitoring equipment would also have to be sensitive to the terrain traversed to avoid encounters which such undersea obstacles as cliffs, gorges and the like.

Moreover, the cost of mining the ocean's floor is directly related to the percentage of mineral bearing ore to the total amount of material raised from the floor. Silt and other deposits are often found encrusted on the surface of nodules and thus reduce the economy of mining if transported to the surface.

In addition, nodule size influences the power requirements for lifting ore to the surface. In general, with larger nodules more power is required to raise a given tonnage of ore. Potential clogging of the ore conduit is also increased with larger sized material being raised.

The method and apparatus of the instant invention overcomes these and associated problems by providing an undersea mining apparatus and method which harvests a relatively large area of the ocean floor without moving the apparatus, thus avoiding the necessity of constantly stationing a support vessel or providing a complex ore conduit. In preferred form, the instant invention increases the percentage of ore bearing material raised to the surface by cleansing the ore of silt and sediment at the ocean's floor. Moreover, a preferred form of this invention also reduces the chances of ore conduit clogging and increases the economy of undersea mining by reducing the average size of ore transported to the surface.

Briefly, the apparatus of the instant invention comprises a bearing plate upon which a hub is rotatably mounted. At least one substantially horizontal arm is attached to the hub. Means are also provided for rotating the arm and hub as a unit about the latter's longitudinal axis. Ore harvesting means are associated with the arm to gather the ore in the path of rotation of the arm for its transfer to the ocean's surface.

A preferred form of the mining apparatus of this invention includes means for cleansing the harvested ore of sedimentary material which is often encrusted on its surface before the ore is transported to the surface. In addition, means are also provided for crushing the ore in preparation for its lift from the floor of the ocean to the surface. The crushing and cleansing means are powered by the means for rotating the arm.

The apparatus of this invention would typically be used after a preliminary survey has indicated that the floor of the ocean is relatively smooth and sufficiently extensive in ore deposits to warrant mining. The area is then harvested by simply moving the inventive apparatus, after the segment of the floor within its reach has been mined, from place to place. In other words, all that is required for economic use of the apparatus and process of this invention is a preliminary survey which shows the extent of the undersea terrain in which commercially attractive nodules are present. This survey can be accomplished by any of several presently known methods, for example, by an undersea vehicle equipped with television cameras and flood lamps. Mining is accomplished by lowering the apparatus to the ocean's floor and sweeping a given area at time, harvesting the ore in the path of the arm's rotation, and transporting the harvested ore to the surface.

Through the use of the relatively permanent apparatus of the instant invention, ore can be mined without the constant necessity for moving the surface vessel in relation to the mining apparatus to compensate for ore conduit stress produced by relative movement between the

surface vessel in relation to the mining apparatus. This relative permanency would, of course, overcome the necessity for a complex ore conduit design which would otherwise be necessary to avoid the stress problem.

The preferred form of the instant invention is useful in increasing the economy of undersea mining and avoiding ore conduit clogging. As was previously mentioned, the cost of transporting ore from the bottom of the ocean to its surface is a function of the amount of power required to raise a given payload. The removal of non-productive materials before transporting ore to the surface thus reduces the cost of the mining operation. This removal is accomplished by the mining apparatus' cleansing means. Moreover, the crushing of nodules on the ocean's floor reduces the chances of clogging the ore conduit by avoiding the lodging of nodules in the conduit. In addition, the amount of power required to raise a given tonnage of ore to the ocean's surface is reduced by grinding the nodules and enhancing the efficiency of the air lift which would normally be used with the mining apparatus of this invention.

These and other aspects, features, and advantages of the instant invention will become more apparent from the following description, appended claims, and drawings in which:

FIGURE 1 is a partial plan view, partly in section, of a preferred embodiment of the instant invention;

FIGURE 2 is a view of the embodiment shown in FIGURE 1 taken along line 2—2;

FIGURE 3 is a view of the embodiment shown in FIGURE 1 taken along line 3—3 of FIGURE 2;

FIGURE 4 is a partial view of a preferred power train for the grinding means of the instant invention;

FIGURE 5 is a partial plan view of another embodiment of the instant invention;

FIGURE 6 is an elevational view of the embodiment shown in FIGURE 5;

FIGURE 7 is an end view of embodiment shown in FIGURE 6 taken along line 7—7;

FIGURE 8 is a partial elevational view of an ore conduit, hub, and float assembly which can be used in the illustrated embodiments of the instant invention; and

FIGURE 9 is an overall schematic view of the apparatus of this invention in its aqueous environment showing the preferred means for lifting the ore from the bottom of the ocean to the surface.

With specific reference to FIGURES 1, 2 and 3 there is shown a preferred embodiment of the undersea mining apparatus of the instant invention denoted by reference numeral 1. A mounting plate, or base 2 is capable of relatively permanent placement on the ocean's floor where it is anchored against rotation preferably by the weight it supports. Circular bevel gear 72 is secured to mounting plate 2. A hub 8 is rotatably mounted on plate 2 and has a hollow interior 9 for the passage of ore into ore conduit or line 63. Conduit 63 is rotatably coupled to the upper portion of hub 8 to provide for unencumbered rotation of the hub.

A first nodule processing and recovery assembly 16 is carried by hub 8 for a rotation about base 2. Assembly 16 comprises a cleaning assembly 11, ore conveyor assembly 6, and crushing and sorting assembly 27, as well as ore inlet duct 18 and ore distribution manifold 17. A similar and complementary ore processing and recovery assembly 56 is disposed diagonally opposite to assembly 16 and is carried by hub 8. Assembly 56 comprises a nodule crushing and sorting assembly 45, a cleaning assembly 43, a conveyor assembly 61 together with ore manifold 48 and inlet duct 52. Harvesting arms 5 and 31 are pivotally secured to arm mounting brackets 25 and 60 through trunnions 4 and 26, respectively. Mounting brackets 25 and 60 are secured to the periphery of hub 8 in order to provide for the common rotation of arms 5 and 31 with hub 8 about the latter's longitudinal axis.

Cleansing assembly 11 comprises a plurality of parallel,

angularly disposed, spaced-apart water pipes or lines 10 having nozzles 24 disposed for providing jets of water to clean ore passing over expanded metal screen 12. Each of the pipes 10 is in communication with water manifold 19 which in turn is connected to water pump 21 through connecting line 20. Water pump 21 is mounted to hub 8 by bracket 65 while its associated pump 51 is mounted on hub 8 by bracket 64. Angularly disposed to the horizontal is expanded metal screen 12 in position to receive nodules from conveyor assembly 6 and to discharge nodules onto the nodule crushing and sorting assembly 27. The nodules discharge from the buckets 7 carried by conveyor assembly 6 tumble across and down the expanded metal screen 12 to be crushed by the activated rollers or crushers 13 which form a part of the crushing and sorting assembly 27. Nodule pass-throughs 14 and 15 are in ore communication with the floor of the ocean and provide a convenient means for disposing of outsized nodules. The water which cleanses the nodules passing over expanded screen 12 is supplied through water pumps 21 and 51 which have their discharges connected through tie-line 23. Water inlets 22 and 3 for pumps 21 and 51, respectively, are disposed well above the ore processing apparatus to avoid contamination of the water through silt and the like created by the action of the ore recovery process. Cleansing assembly 43 is in all particulars similar to cleaning assembly 11. Thus a plurality of angularly disposed pipes 41 are in fluid communication with manifold 49 which in turn is in fluid communication with pumps 51 and 21 through water supply line 50 and tie-line 23. Each of the pipes 41 has a plurality of nozzles or jets 42 disposed for cleansing nodules passing across expanded metal screen 53. Ore discharged from expanded metal screen 53 passes onto the activated crushers or roller 44 of crushing and sorting assembly 45 and is retained thereon by nodule guard 54.

Ore passing off expanded metal screens 53 and 12 passes on to the activated crushers 13 and 44, respectively, where nodules are reduced in size. The size of the crushed nodules is determined by the spacing between each of the rollers. Crushed ore passing between the rollers will be inducted into ore distribution manifolds 17 and 48, into ore inlet ducts 18 and 52, and into the interior 9 of hub 8 for passage through ore conduit 63 to the surface of the ocean.

With specific reference to FIGURES 2 and 4, the nodule conveyor assembly 61, cleansing assembly 43 and crusher and sorting assembly 45, are better seen. The complementary ore processing and recovery assembly 16 is not shown in greater detail because its operation and configuration are identical to the illustrated assembly 56. Hub 8 rotates about base 2 because of the motive power supplied by propeller 38 of arm 31 as well as a similar propeller on the other arm. Driven sprocket 71 will rotate owing to a gear train (not shown) connected to the circular gear 72. As driven sprocket 71 rotates, it will drive chain 73 which carries ore buckets 62 in an endless path. Ore is loaded into buckets 62 as they traverse the lower portion of their path. Chain 73 drives idler sprocket 74 which is keyed to idler sprocket shaft 75. Idler sprocket shaft 75 in turn drives crusher drive sprocket 76 as is seen in FIGURE 4. Crusher drive sprocket 76 drives the endless crusher drive chain 77 which in turn drives crusher intermediate idler sprocket 79 keyed to crusher intermediate idler shaft 78. Crusher intermediate idler shaft 78 drives a sprocket (not shown) which drives chain 80. Endless chain 80 in turn is in power communication with crusher primary idler sprocket 81 which drives chain 82 and a plurality of power take-off sprockets 83. Each of the sprockets 83 in turn drives an individual one of the activated crushers 44.

Ore harvesting arm 31 is disposed radially of hub 8 and is carried by mounting brackets 60 and 25 through trunnions 26. Arm 34, as well as arm 5, act as beams and have reinforcing trusses 34 for added structural strength. A

plurality of blades 35 are carried by arm 31 and are disposed to sweep nodules constantly inward for collection by the conveyors 61 and 6. On the leading lower edge of arm 31 is connected a rake 33 having a plurality of tines 32 disposed to dig into the ocean's bottom to unlodge embedded nodules. The tines 32 are spaced apart to allow nodules to pass for collection by blades 35. Arm 31 is driven by a propeller assembly 38 which in turn is driven by an electric motor and drive 39. The electrical energy for the electric motor is preferably provided by a support vessel through an umbilical (not shown). Energized roller 36 is journaled on axle 37 to arm 31 to support it slightly above the ocean's bottom. Propeller assembly 38, as well as similar assemblies disposed on other arms for the undersea mining apparatus 1, provide the motive power for turning the hub 8 about base 2 and in turn the power which drives conveyor assemblies 61 and 6 together with the activated crushers 44 and 13.

An alternate embodiment for the undersea mining apparatus of the instant invention is shown in FIGURES 5 through 7 and is shown in general by reference numeral 100. Hub 124 is rotatably mounted on base 125 which is adapted to be semi-permanently fixed to the ocean's floor. Ore conduit 121 is rotatably journaled to avoid rotation in ball joint 123 which is connected to hub 124. Swivel joint 122 connects suction hose 112 to ore conduit 121 and provides ore communication between the two. Ball joint 120 provides an additional means for avoiding rotation of the ore conduit 121. Arm 101 is connected to hub 124 through trunnion 102 which is secured to mounting collar 103. In like fashion, arm 104 is connected to mounting collar 103 through trunnion 105, and arm 107 is connected to mounting collar 103 through trunnion 106. Ore harvesting assembly 111 is mounted on arm 107 for movement radially in and out along its length along parallel rails or guides 110 which are secured to arm 107. Similar ore harvesting assemblies are disposed on arms 101 and 104. Movement of harvesting assembly 111 is produced through winch 108 which drives cable 109. Cable 109 is connected to harvesting assembly 111 at points 127 and 128. The winch 108 is conventionally powered and operated. Energized roller 114 is rotatably mounted to arm 107 through axle 115. As in the previously described embodiment, each of the arms is powered for rotation, together with the hub 124, about base 125 through propeller assemblies such as shown by reference numeral 113. Propeller assembly 113 includes propeller blades 117 powered by electric motor 132, and a propeller guard or shroud 118 disposed to avoid fouling of the propellers. Shock absorber 126 is connected at one end to hub 124 and its other to arm 107 to avoid abnormal loads produced if arm 107 traverses an obstacle or uneven ground.

Harvesting assembly 11 is best shown in FIGURE 7. In general, it comprises a cow catcher 119 mounted on carriage 141 and disposed in the path of oncoming ore to sweep to one side large obstructions. Clearance is provided between the bottom of cow catcher 119 and the ocean's floor to allow nodules to be gathered by ore scoop assembly 135. Ore scoop assembly 135 is pivotally mounted on carriage 141 by pin 143. The leading edge of the ore scoop assembly 135 is disposed to contact the surface of the ocean's floor to harvest nodules in its path. In addition, tines or an irregular edge may be formed on the leading edge to mine embedded nodules. As the nodules are swept in to the ore scoop assembly 135 they are cleansed by action of laterally oriented cleansing jet 142 which is connected to a source of high pressure water (not shown) in a known manner. A complementary jet (not shown) is disposed on the opposite side of ore scoop assembly 135. The combined jets cooperate to provide laterally impinging jet streams across the induction path of nodules within scoop assembly 135. Exhaust for these jets is provided at the end of the ore scoop assembly 135. Opening 137, which is covered by an expanded metal

screen 136, provides exhaust for the complementary jet while a similarly oriented opening on the opposite side of assembly 135 provides exhaust for jet 142. Nodule outlet from the ore scoop assembly 135 is provided through suction hose 112 which is connected to the assembly by ball joint 138. The angle of attack of the ore scoop assembly 135 is adjustable through an electrically powered jack 140.

In order to compensate for excessive weight of the ore conduit, pairs of buoyant floats such as are shown in FIGURE 8 by reference numerals 153 and 154 may be attached at regular intervals along its length. Float 154 is pivotally connected to ore conduit 63 through pin 155. Similarly, float 153 is pivotally connected to ore conduit 63 through pin 156. The floats maintain their horizontal attitude by virtue of their buoyancy which also lightens the ore conduit by providing an upward force. The floats are connected at their bottom to allow raising of the ore conduit without excessive resistance by swinging downward about pins 155 and 156 when the buoyant force is exceeded by fluid resistance created by the raising of the ore conduit. A rotation compensating ball joint 150 is shown disposed above ore conduit 63; similar ball joints would be disposed at regular intervals along its entire length. These joints also provided the coupling required in assembling the ore conduit. FIGURE 8 includes skeletal view of hub 8 and some of its associated elements previously described, with exception of stake pin 157 which functions to anchor the mining apparatus in one place despite lateral forces produced by currents and the like.

FIGURE 9 shows in schematic form the preferred mode of raising mined nodules to the surface. Ore conduit 172 is in communication with support vessel 170 where it is conveniently fabricated and placed by means of a derrick assembly 171 much in the same manner as the drill strings used in ocean oil drilling. The density of the fluid in ore conduit 172 is substantially reduced through compressed air supplied through pipe 174. By reducing the density of the fluid in ore conduit 172 in this manner, the pressure of the water at the ocean's floor will substantially exceed that within the ore conduit 172. This creates a vacuum effect at the harvesting point on the bottom of the sea. Thus, in the embodiment shown in FIGURES 5 through 7, a substantial suction is present within the ore scoop assembly 135. Such suction is also felt in the initially described embodiment through ore inlet ducts 18 and 52 and their concomitant elements in which they are in fluid communication, such as the interior 9 of hub 8.

The operation of the first described embodiment is as follows: Propeller assembly 38 rotates arm 31 and a similar assembly rotates arm 5. Hub 8 follows the rotation of the arms and carries nodule processing and gathering assemblies 16 and 45 in a circular path about the longitudinal axis of hub 8 above fixed base 2. Rake 33 through its tines 32 dislodges nodules from the ocean's floor and passes them into the path of blades 35. Nodules laying loosely on the floor pass through the spaces between tines 32 to blades 35. Blades 35 sweep the nodules progressively inward towards the hub 8 and deposit them in the path of conveyors 6 and 61. As hub 8 rotates about its longitudinal axis, each of the conveyor assemblies 6 and 61 will pick up nodules in their path deposited by the blades. As is shown in FIGURE 2, nodules will be lifted by buckets 62 for discharge onto expanded metal screen 53. Ore will traverse expanded screen 53 owing to gravity and motion of subsequently discharged ore. As the nodules travel across expanded screen 53, they are cleansed by nozzles 42 of silt and sedimentary material. Ultimately, the ore will reach activated crushers 44 where it is reduced in size. Upon sufficient size reduction ore passes through the interstices between the crushers 44 and into crushed nodule passage 55, inlet duct 52, the interior 9 of hub 8, and up the ore conduit 63. Oversize nodules drop through ore pass-throughs 47 and 46 and thus are prevented from

blocking more easily crushed ore from entering nodule passage 55.

Activated crushers 44 are powered as previously described through a chain drive arrangement. Thus, each individual crusher 44 is driven by a sprocket 83 which in turn is driven by an endless chain 82 powered by sprocket 81. Sprocket 81 receives rotational energy through chain 80, sprocket 79, chain 77, sprockets 76 and 74, chain 73, sprocket 74, and, finally gear 72.

The embodiment of the invention shown in FIGURES 5, 6 and 7 operates, with minor exception, in the same manner as the embodiment previously described. Ore harvesting assembly 111 traverses back and forth for the radial length of arm 107 along rails 110 by action of winch 108, while arm 107 rotates about the longitudinal axis of hub 124 by virtue of propeller assembly 113. Ore collected in the path of ore gathering scoop 135 is cleansed by jet 142 and its complementary jet. Ore is inducted into suction hose 112 and ore conduit 121 through the vacuum effect previously described. Through direction of suction hose 112 to a plurality of crushers, as shown in the previously described embodiment, the nodules may be reduced in size if so desired.

The instant invention has been described with reference to certain preferred embodiments. However, it should be appreciated that the scope and spirit of the appended claims should not be limited thereto.

What is claimed is:

1. A mining apparatus for harvesting ore from the floor of the ocean comprising:

- (a) a bearing plate adapted to be removably anchored to the ocean's floor;
- (b) a hub rotatably mounted on said plate;
- (c) at least one substantially horizontal arm attached to the hub;
- (d) means for rotating the arm and the hub about the latter's longitudinal axis; and
- (e) means cooperating with the arm for harvesting the ore in the path of rotation of the arm and for transporting the harvested ore to the surface of the ocean.

2. A mining apparatus as claimed in claim 1, including means for cleansing the harvested ore of sediment before it is transported to the surface of the ocean.

3. A mining apparatus as claimed in claim 2, wherein the harvesting means includes an ore conduit rotatably coupled to the hub and adapted to transport harvested ore to the surface.

4. A mining apparatus as claimed in claim 3, including means for supporting the arm from the ocean's floor, and wherein the harvesting means includes an air lift pump capable of cooperating with the ore conduit to transport harvested ore to the surface of the ocean.

5. A mining apparatus as claimed in claim 2, including means for crushing the harvested ore before it is transported to the surface of the ocean.

6. A mining apparatus as claimed in claim 5, wherein the harvesting means includes:

- a plurality of blades mounted on the arm disposed to sweep ore, in the path of rotation of the arm, towards the hub;
 - a rake disposed along the lower leading edge of the arm in position to dislodge ore embedded in the surface of the ocean's floor and to allow the dislodged ore to be swept by the blades, and, wherein
- the cleansing means and the crushing means are mounted on the hub.

7. A mining apparatus as claimed in claim 6, wherein the harvesting means includes

a conveyor mounted on the hub in position to gather ore deposited by the blades; and, wherein,

the cleansing means cooperates with the conveyor to receive ore discharged therefrom and includes at least one water pump and a plurality of water pipes in communication with the outlet of the water pump, the water pipes having a plurality of nozzles in position to cleanse the ore discharged from the conveyor; and,

the crushing means cooperates with the cleansing means to receive ore discharged therefrom.

8. A mining apparatus as claimed in claim 7, wherein: the hub has at least one ore intake in ore communication with the crushing means to receive crushed ore, the hub being adapted to pass ore from the intake to the ore conduit; and

the crushing means and conveyor are powered by the means for rotating the arm.

9. A mining apparatus as claimed in claim 4, wherein the harvesting means includes an ore harvesting assembly in ore communication with the ore conduit and mounted on the arm for movement in and out along its length.

10. A mining apparatus as claimed in claim 9, wherein the ore harvesting assembly is driven in and out along the length of the arm by a winch.

11. A method for harvesting ore from the floor of the ocean comprising:

- (a) sweeping an area of the ocean's floor by rotating at least one arm about a fixed point thereon;
- (b) gathering ore deposits on the ocean's floor in the path of the rotating arm while the arm rotates by gathering means carried by the arm;
- (c) cleansing the gathered ore of sediment by pressurized water; and
- (d) transporting the cleansed ore to the surface of the ocean in an ore conduit by the introduction of compressed air into the ore conduit at an intermediate point therein.

12. A method for harvesting ore as claimed in claim 11 wherein the gathering means moves in and out along the length of the arm to gather ore as the arm rotates, the ore is cleansed in the gathering means, and the ore conduit is in direct ore communication with the cleansed ore in the gathering means.

13. A method for harvesting ore as claimed in claim 11 wherein the gathering step includes sweeping the ore toward the point of rotation.

14. A method for harvesting ore as claimed in claim 13 including the additional step of crushing the ore before transporting it to the surface.

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ERNEST R. PURSER, *Primary Examiner*.

U.S. Cl. X.R.

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