

[54] **SCRAPER BUCKET APPARATUS FOR DEEP SEA MINING SYSTEMS**

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172/393, 299/1

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37/103, 109, 122-123, 191, 192, 86-90; 172/783,
393, 311, 26.5; 73/95; 175/7; 299/1, 71; 254/172;
198/140

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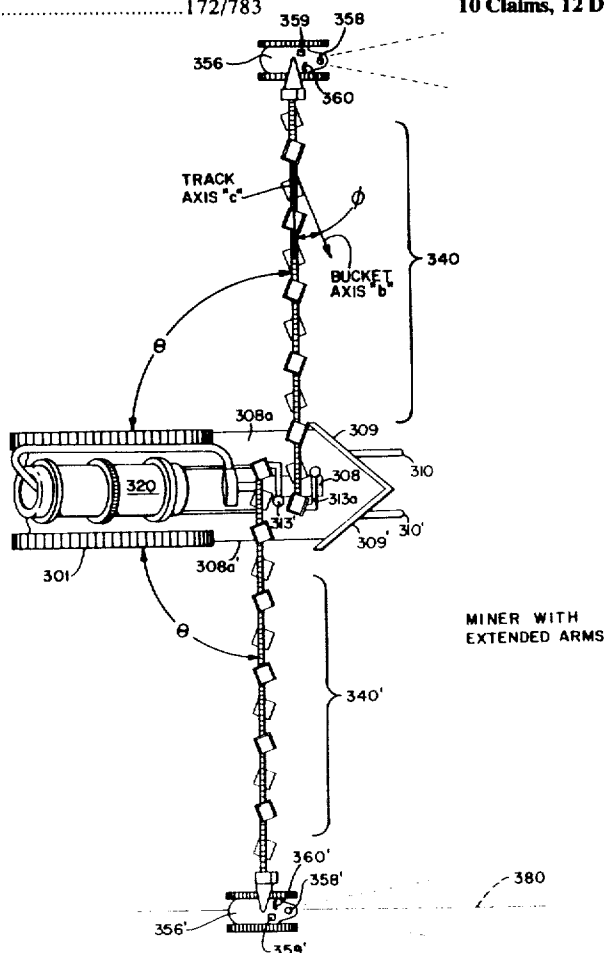
Assistant Examiner—Clifford D. Crowder

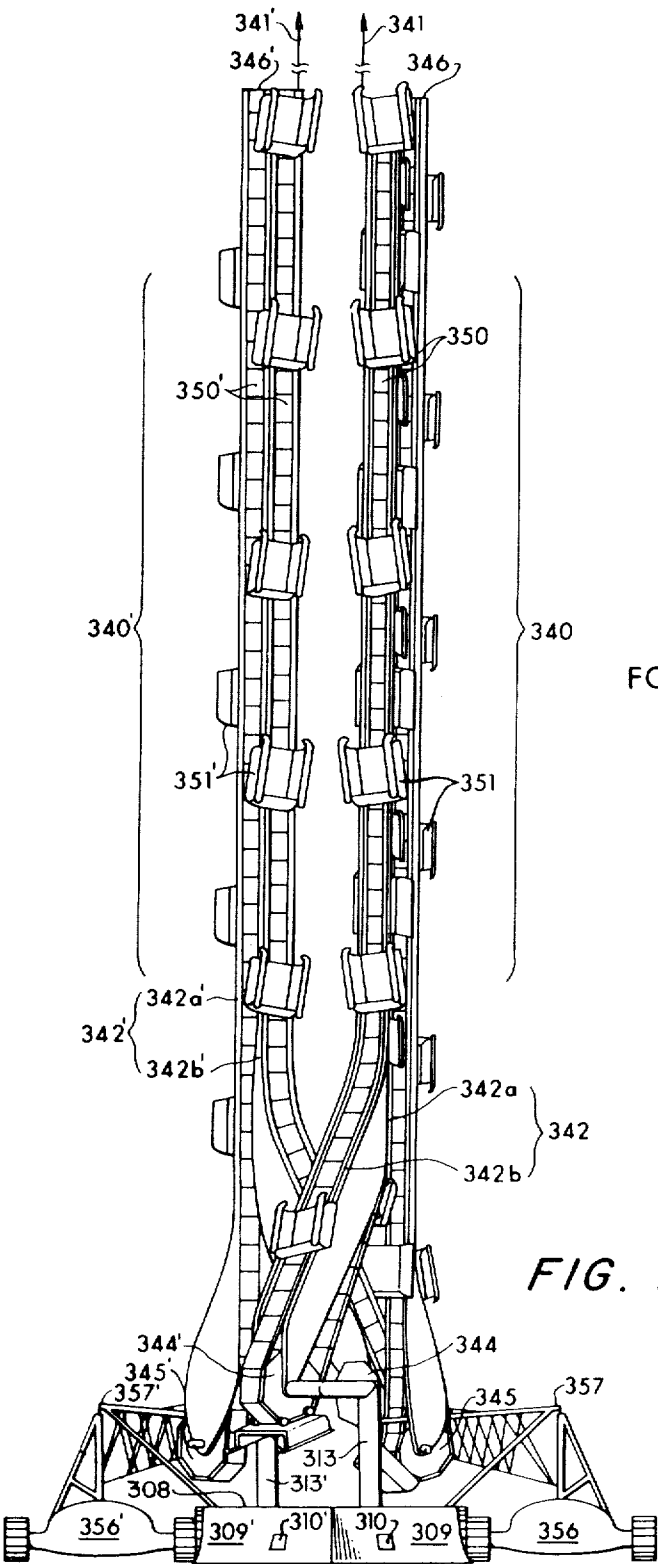
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[571] **ABSTRACT**

Scrapper bucket apparatus for scraping loose ore sediment from a deep sea bed and delivering it to an undersea mining vehicle traveling the bed. The apparatus is embodied in a vertically flexible, long and foldable double tiered track carrying an endless chain with a series of scrapper buckets attached that scrape the nodules and deliver them to the vehicle. To reduce crabbing, the buckets are skewed forward of the vehicle by an angle ϕ relative to the axis of the track. One end of the track is rotatably mounted on a tail sheave tractor driven along a course parallel to the vehicle and at a speed preferably to keep the track disposed at an angle of 90° relative to the negative of the vehicle's velocity vector.

10 Claims, 12 Drawing Figures





FOLDED ARMS

FIG. 1

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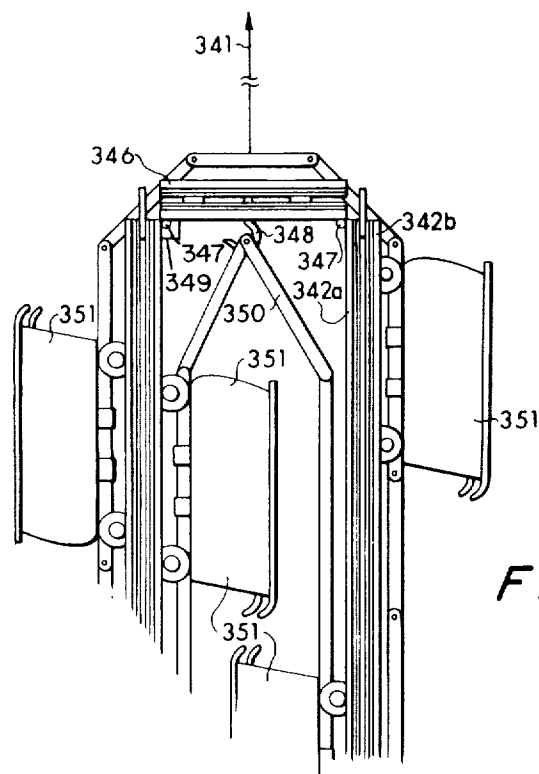


FIG. 2

DOUBLE JOINT AT MID LENGTH OF ARM
SHOWN IN FOLDED POSITION AS WHILE LOWERING

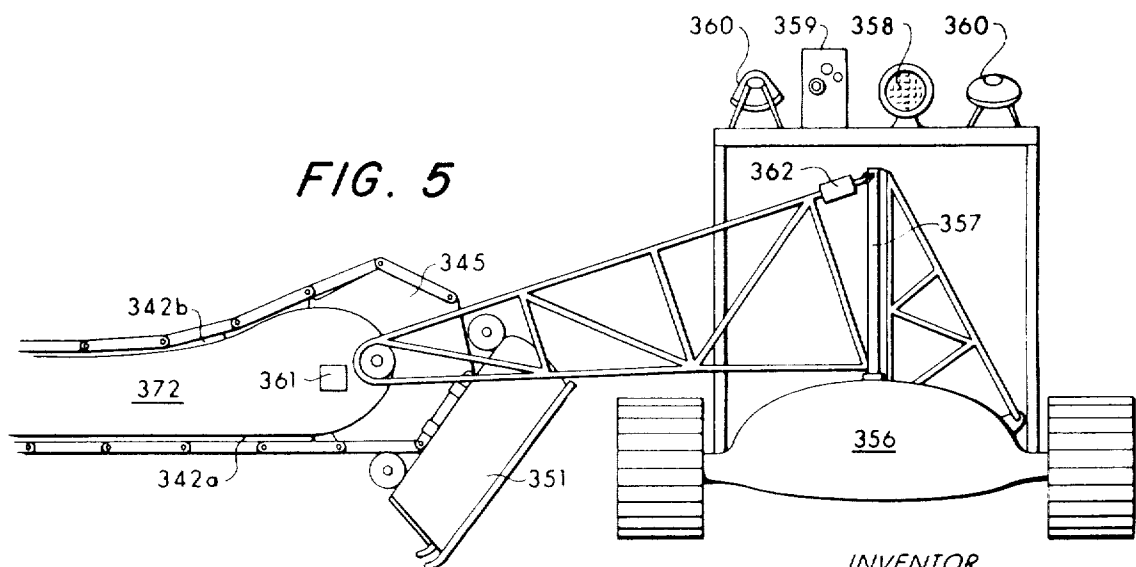


FIG. 5

FAR END TERMINAL OF ARM

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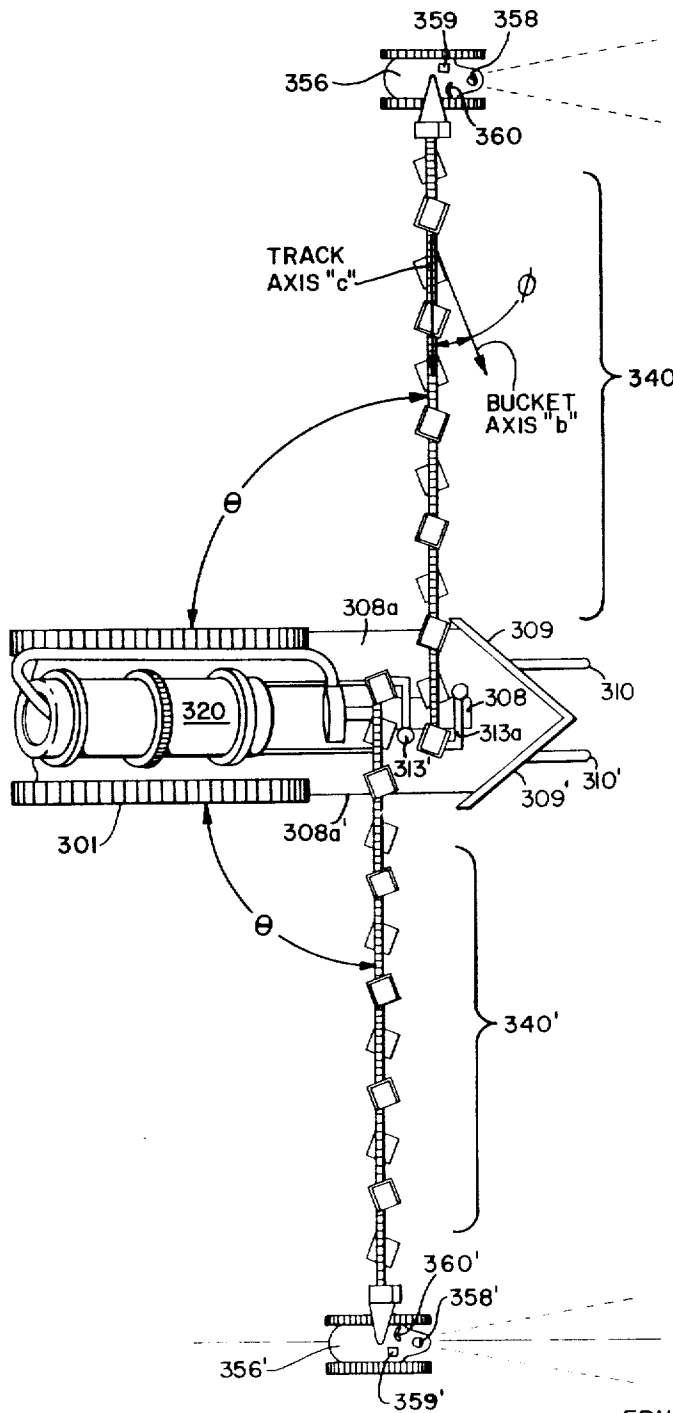


FIG. 3

MINER WITH
EXTENDED ARMS

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FIG. 4

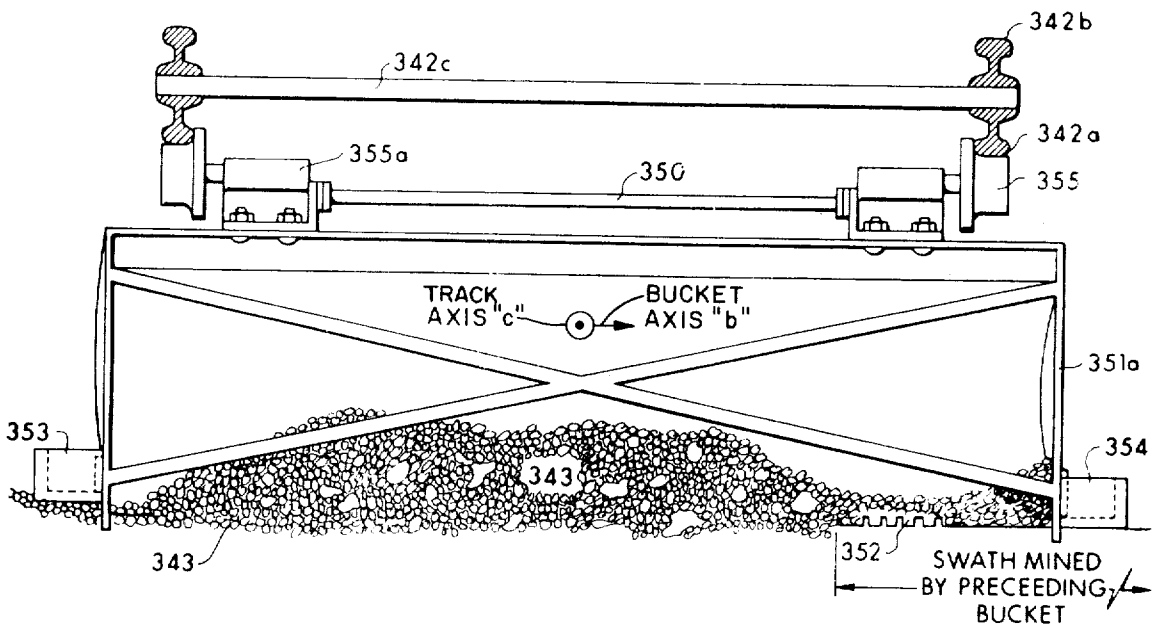
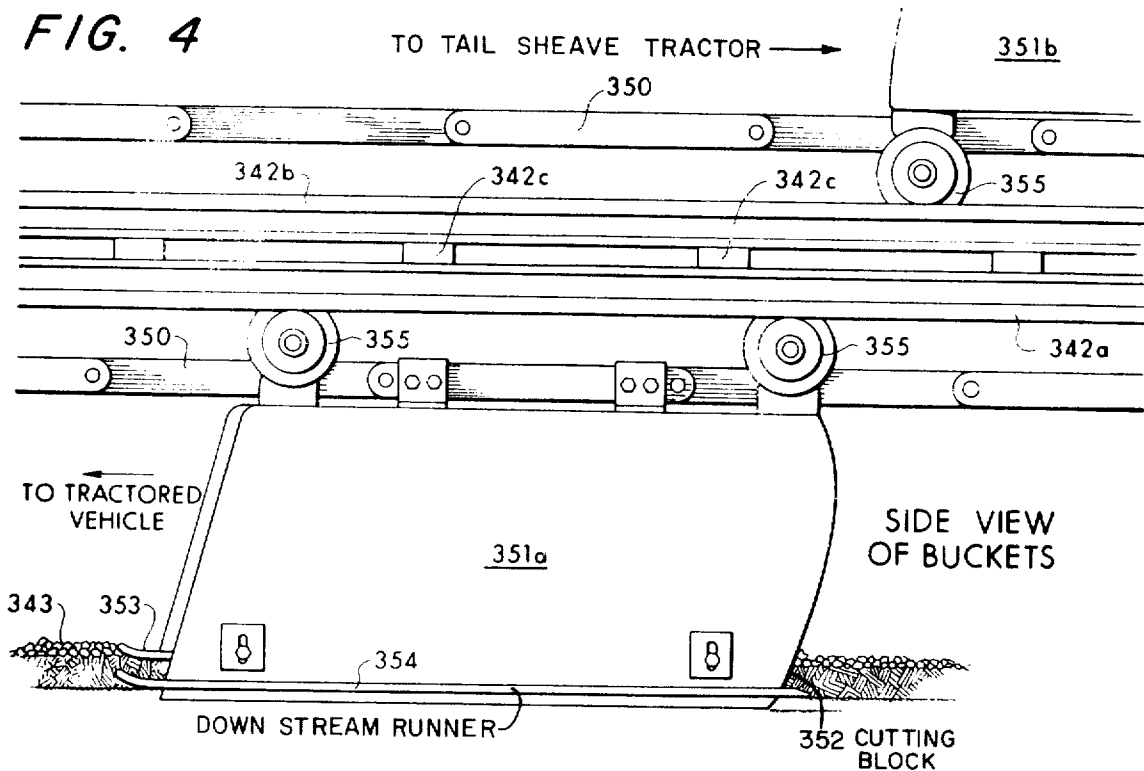


FIG. 4A

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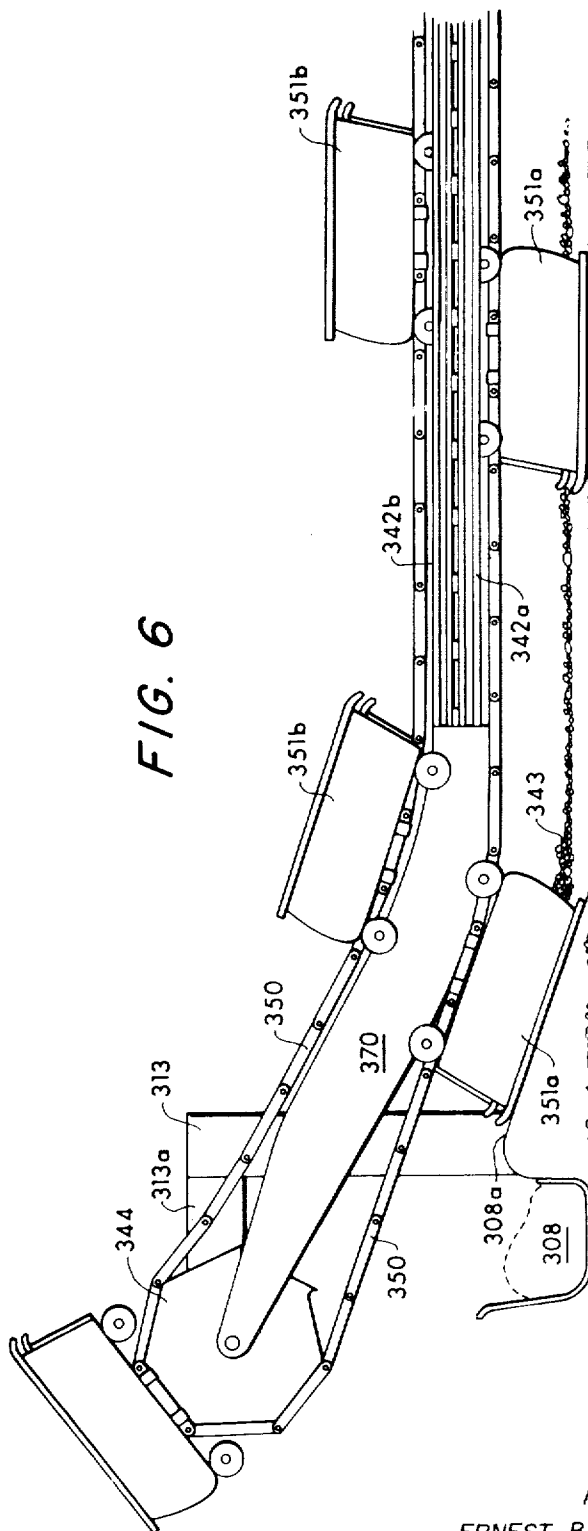
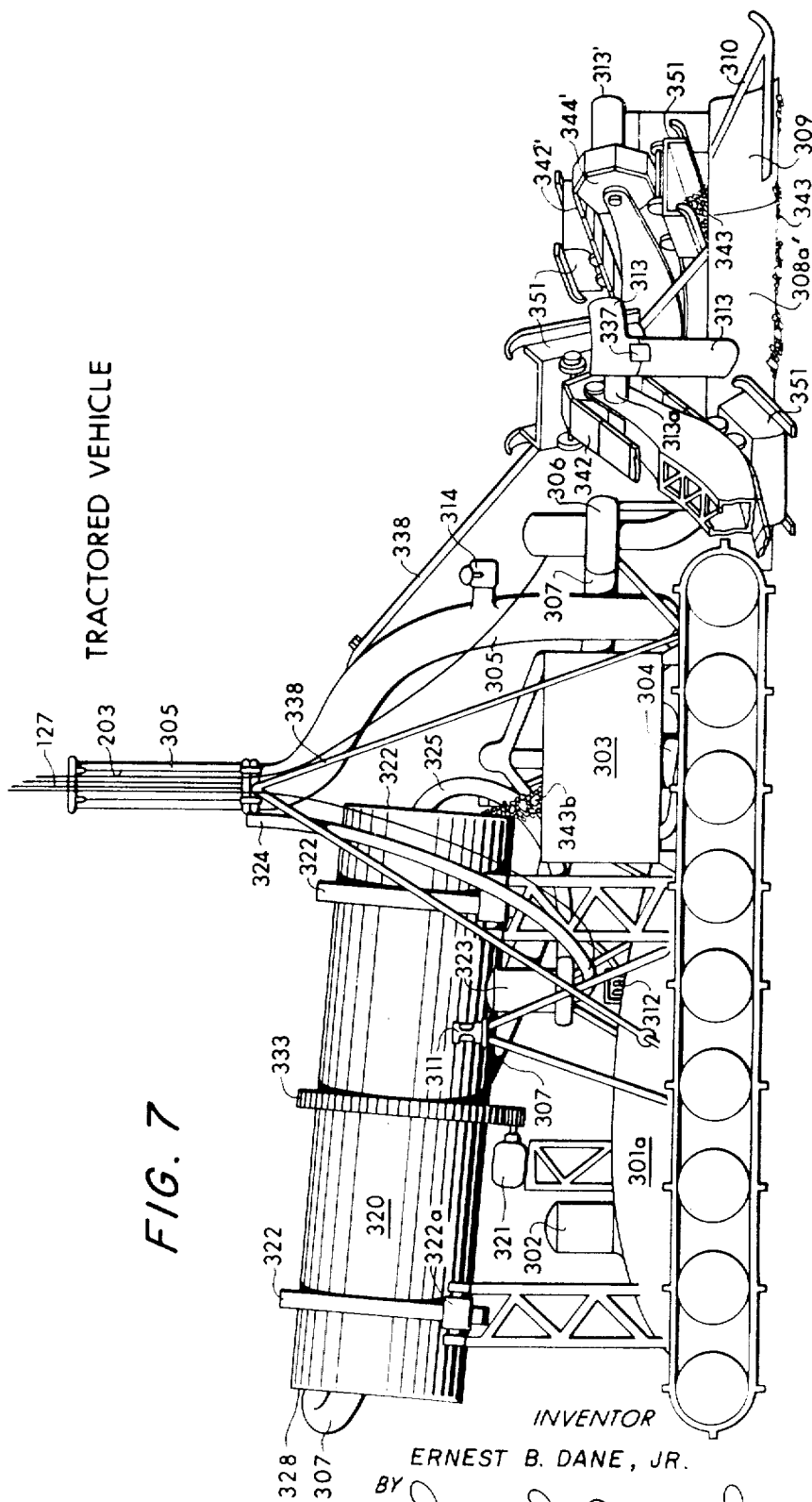


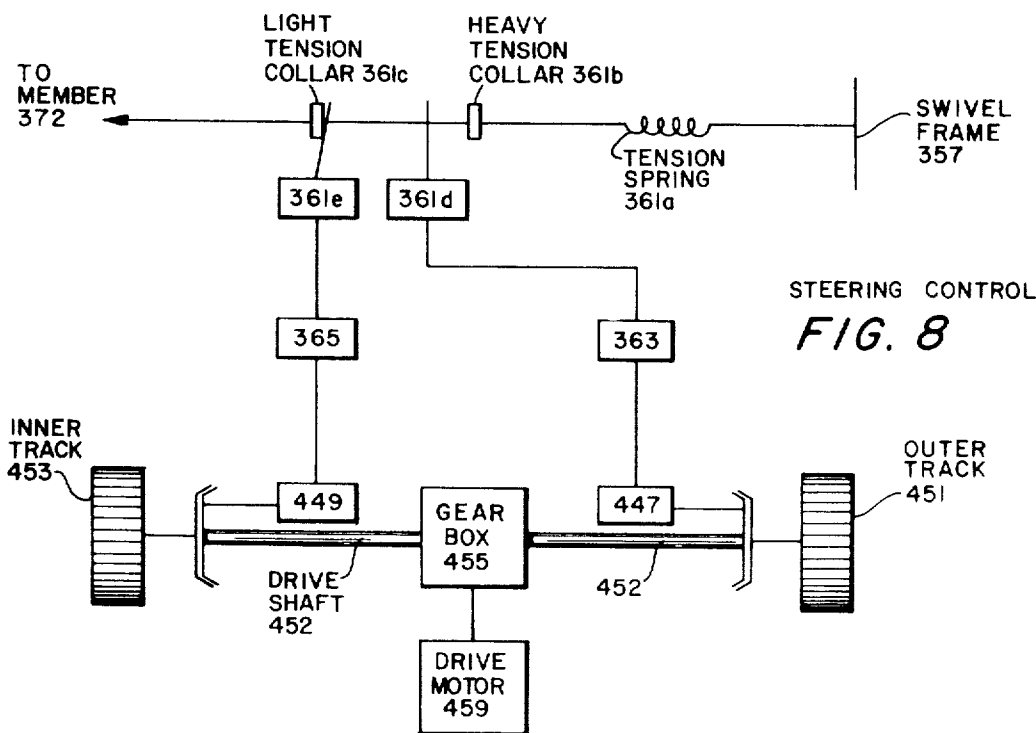
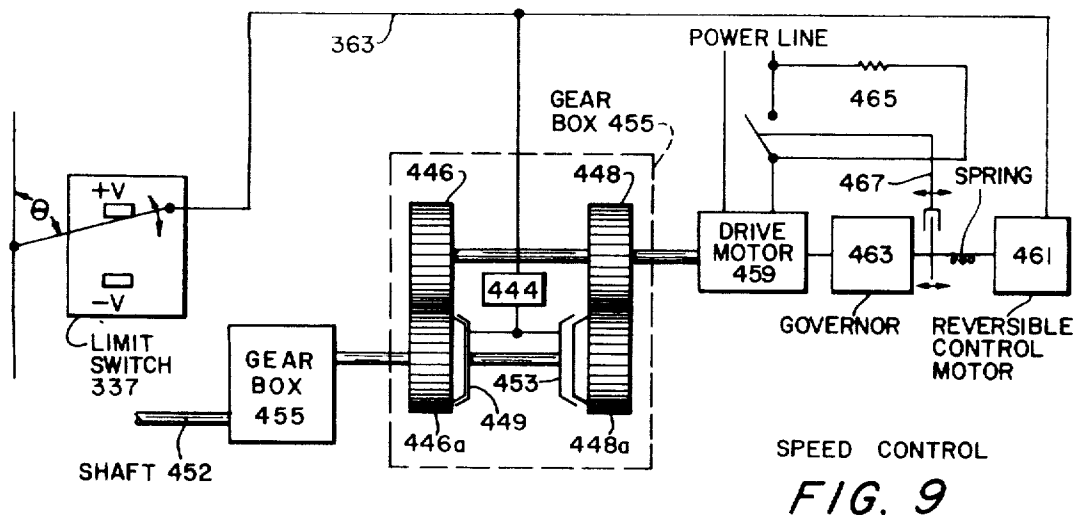
FIG. 6

NEAR END TERMINAL OF ARM

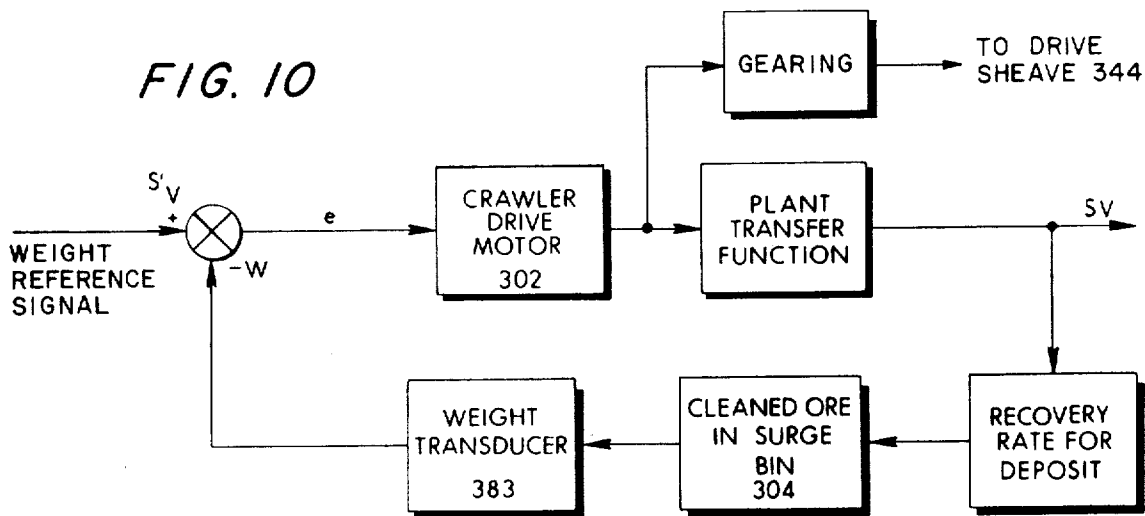
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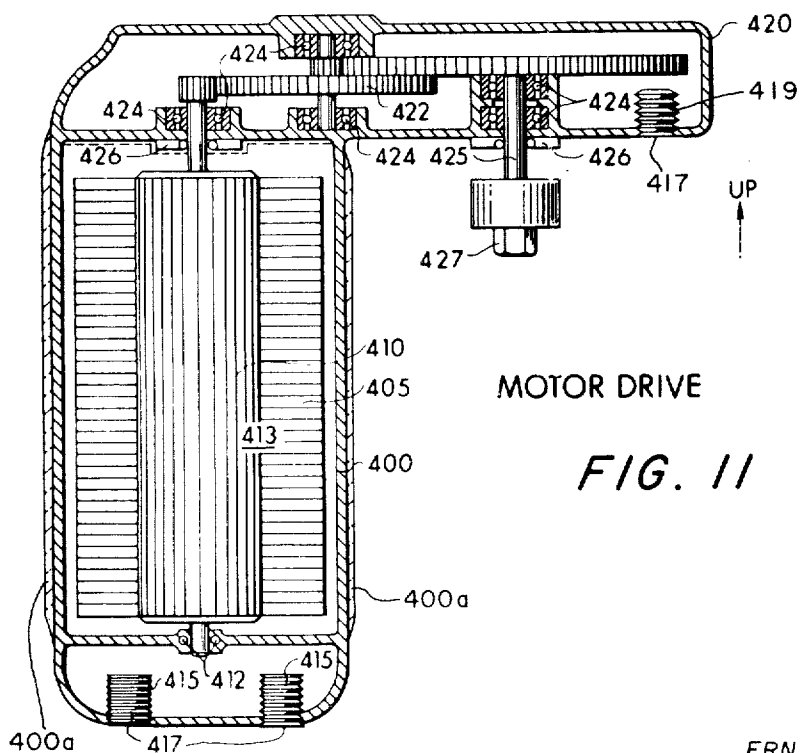




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FUNCTIONAL BLOCK DIAGRAM



MOTOR DRIVE

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SCRAPER BUCKET APPARATUS FOR DEEP SEA MINING SYSTEMS

This application is a continuation-in-part of my copending application Ser. No. 754,191 filed Aug. 21, 1968, but now abandoned and subject to a requirement for restriction.

This invention relates generally to ocean mining systems and particularly to systems for retrieving loose ore sediment from deep sea floors.

INTRODUCTION

The mineral resources of deep ocean beds though long recognized have yet to be fully exploited. Sufficient quantities of minerals lie loosely in the sediment of deep sea oozes to make their recovery in scale attractive. Of particular interest are manganese nodules that are found in ocean sediments formed under oxidizing conditions, and are especially widespread in the southeast Pacific Ocean. They are shaped like potatoes, mammilated cannon balls, marbles and also assume less identifiable forms. They range in size with diameters of between 0.5 to 25 cm, however, the majority of nodules recovered from deep sea dredging probes have not exceeded 10 cm in diameter. Numerous photographs taken of the ocean floor indicate that they average about 3 cm in diameter (See *The Mineral Resources of the Sea*, by John L. Mero, Elsevier Publishing Company (1964)).

In addition to manganese, the nodules contain a number of other minerals in adequate quantities, for example, iron, silicon, aluminum, copper and nickel to make them an attractive source of them as well. Mineral content is regional with comparatively high concentrations of iron in nodules near the western coasts of North and South America and the eastern coast of Asia, while nodules distant from Pacific islands and continental bodies possess relatively high nickel and copper content.

Most deposits are covered by between 2000 and 6000 meters of ocean. They are within the range of some deep submersible vehicles and sampling probes but the feasibility of mining them depends on the capability of recovery in scale, at the rate of many tons per day.

The above referenced parent application discloses a deep sea mining system for recovering ore from such deposits. The system comprises a mining plant connected to a Sessile ship by a series of hoist pipe sections. The plant consists of a tractored vehicle with a pair of foldable arms projecting from its sides arranged to scrape nodules from the ocean bed and deliver them to the vehicle for processing prior to delivery to the hoist pipe circuit. The system is transported to the mining site by the Sessile ship and there assembled. The plant is lowered during the construction of the lengthly hoist pipe circuit to which it is attached, the plant descending to progressive depths as the pipes are serially connected one at a time. Once on the bottom the arms are unfolded and the plant operated to travel the bed gathering and processing nodules entering the hoist pipe circuit and conveyed to the Sessile ship which follows the plant. The invention of this application resides in improvements in the active scraper bucket apparatus embodied as the arms of the vehicle.

SUMMARY OF INVENTION

Accordingly, it is a primary object of such apparatus to gather loosely embedded nodules in quantity from deep ocean beds.

It is another object of the invention to provide such apparatus adapted for transport to and operation at depths of 100 fathoms or more.

It is yet another object of invention to provide such apparatus capable of gathering nodules continuously over a wide and continuous swath for delivery to a vehicle traveling a bed.

These and other objects are met by scraper bucket apparatus embodied in a vertically flexible, long foldable double tiered track carrying an endless chain with a series of scraper buckets attached that scrape nodules and deliver them to the vehicle. To reduce crabbing, the input axes "b" of the buckets

are skewed forward of the vehicle at an angle ϕ relative to the axis "c" of the track, where

$$\phi = \theta - \tan^{-1} (S_r \sin \theta) / (S_r + S_v \cos \theta),$$

where θ is the angle at which the apparatus is disposed relative to the negative of the velocity vector of the vehicle, S_r the speed at which the chain is driven along the track, and S_v the speed of the vehicle. Angle θ preferably is maintained at 90° to maximize the width of the swath so that

$$\phi = 90^\circ - \tan^{-1} S_r / S_v.$$

One end of the track is adapted for rotatably mounting on the vehicle, while the other end is carried by a tail sheave tractor driven parallel to the vehicle. These and other features of the scraper bucket system will become apparent from the following description taken in conjunction with the drawings of which:

DRAWINGS

FIG. 1 is a front view of the mining plant with folded arms.

FIG. 2 is a side view of the double tiered joint of the folded arms of FIG. 1.

FIG. 3 is a distant vertical view of the miner of FIG. 1 illustrating the skewness in the buckets.

FIG. 4 and 4A are side and front views, respectively, of the buckets of FIG. 1.

FIG. 5 is a side view of the far end of the arm of FIG. 1.

FIG. 6 is a side view of the near end of the scraper bucket arm of FIG. 1.

FIG. 7 is a detailed side view of the tractored vehicle of FIG. 3.

FIG. 8 is a block diagram of a steering control system for the tail sheave tractor of FIG. 5.

FIG. 9 is a block diagram of a speed control system for the tail sheave tractor of FIG. 5.

FIG. 10 is a functional block diagram of a crawler drive system for controlling the advance rate of the tractored vehicle of FIG. 7.

FIG. 11 illustrates a geared motor drive for use in the deep sea apparatus described.

PREFERRED EMBODIMENT

Both arms of the mining plant have the same basic construction. Therefore in detailing structure, it suffices to describe the port-side arm for which unprimed notation applies. Referring now to FIG. 1, shown is a front view of the mining plant with arms 340 and 340' folded, as they are when the plant is first transported to the mining site, and down to the ocean bed during assembly of the system. Arm 340 comprises double tiered track 342 carrying endless sprocketed chain 350 to which skewed buckets 351 are attached. The mid section of track 342 has a double hinged joint 346 allowing the track to fold approximately 180° along its length. The joint is supported by tension in line 341 coupled between the joint and a remotely operated winch located at the top of the first pipe section attached to the outlet pipe of the tractored vehicle, the winch not being shown. The winch is controlled shipboard when the arm is first extended and folded-up again upon completion of mining operations. The inboard end of arm 340 is linked with rotatable mast 313 at the front of the vehicle. Located below mast 313 and at the turn of inbound buckets is trough 308 that receives scraped nodules. At the front of the vehicle are a pair of snow plow-like blades 309 and 309' that push nodules to either side of the vehicle when it advances along the ocean bed. Projecting from the front of the vehicle are a pair of ski-like runners 310 and 310' that extend back into the body of the vehicle.

FIG. 2 illustrates the double hinged joint 346 in better perspective. Hinges 347 are set inboard of upper and lower tracks 342b and 342a just below the head of the latter's rail. Remotely operated hook 348 engages the lower side of chain 350

when the chain is to be secured and releases it when the chain is to be operative. Once the arms are outstretched, outbound buckets of upper track 342b are inverted, while inbound buckets riding track 342a are righted and contact the ocean bed.

The arms are unfolded one at a time by coordination of the above referenced winches of the first pipe section and maneuvers performed by each tail sheave tractor 356. Tractors 356 initially are secured to the vehicle by electrically operated davits 311 of later FIG. 7 and other remotely operated catches controlled from the ship. They are released by signals conveyed through cable system 127 of FIG. 7 that run up the hoist pipe circuit to the hovering ship. Tractors 356 are slightly elevated above the base level of the vehicle by a few centimeters and are lowered prior to their release. Running gear within the tractors are tripped by relays to afford direct or manual control from the ship. Scanning sonars, lights and a closed circuit t.v. system on the tractor are turned on. Tail sheave tractors 356 and 356' turn sharply outward from the vehicle one at a time orthogonal to the vehicle and are driven outward as the arms are outstretched. Angle transducers 349 at the double hinged joints 346 indicate the angular disposition of the folds so that the tractors may be slowed down to a crawl when the arms are fully outstretched. The tractors are then rotated 90° about their centers for orientation toward the direction of the proposed swath to be cut.

FIG. 3 shows vehicle 301 with fully extended arms cutting a track bounding rim 380 of a previously cut swath. Arms 340 are disposed from rotatable masts 313 and 313' at an angle θ relative to the negative of the vehicle's velocity vector. To reduce crabbing, bucket axes "b" (co-directional with bucket sides) are preferably skewed forward in the direction of the vehicle's motion by an angle ϕ relative to axis "c" of the track. Generally, angle ϕ is in accordance with the relationship

$$\phi = \theta - \tan^{-1} (S_c \sin \theta) / (S_r + S_c \cos \theta)$$

where S_r and S_c are the speeds of the chain and vehicle, respectively. To maximize the width of the swath angle θ is maintained at 90° so that $\phi = 90^\circ - \tan^{-1} (S_c / S_r)$.

By appropriate gearing between the output of the crawler drive motor advancing vehicle 301 and drive sheave 344, the two speeds S_r and S_c are proportional so that the ratio (S_c / S_r) and the proposed skewness ϕ of bucket axes "b" are essentially constant.

Still referring to FIG. 3, lights 358 and 358' illuminate areas in front of sheave tractors 356 and television cameras 359 display the terrain on monitors in control room 125e of the ship. Camera 359 displays rim 380 of the preceeding track so that an operator in the control room may steer vehicle 301 to cut an abutting swath. Scanning sonars 360 mounted on tractors 356 scan the surface to warn of impending obstacles and hazardous terrain, penetrating cloudy water that may obscure television images.

THE BUCKETS

FIG. 4 is a close side view of two representative buckets, outbound inverted bucket 351b riding upper track 342b and inbound righted bucket 351a riding lower track 342a. FIG. 4 A is a front view of righted bucket 351a and shows the relation between bucket input axis "b" and axis "c". Buckets 351 have an open front and bottom, a partially closed top, fully closed sides and back. Mounted near the bottom of each bucket's sides is a pair of broad ski-like runners 353 and 354 whose height is adjusted by means of slotted fasteners attached to each side of a bucket. Downstream runner 354 is flush with the bottom of the back of the bucket while upstream runner 353 is adjusted to a height equal to the thickness of the layer 343 to be cut as judged by samples previously taken of the bed. The disparity in runner heights enables runner 353 to glide along the top of the layer being cut while runner 354 rides on a previously scraped surface. Both bucket sides extend slightly below the runners. Fastened to the back of the

bucket is a cutting block with a toothed edge 352. The cutting edge of the block scrapes the surface causing nodules to accumulate in the bucket and the teeth permit some of the unwanted clay and mud to escape.

The buckets have a partially closed top for attachment of four flanged wheels 355 and fasteners that link the top with the chain. As is more clearly detailed in FIG. 4, upper track 342b and lower track 342a each comprise a pair of light railway rails. Flanged wheels 355 ride along the heads of the rails. The inbound buckets support the track while outbound ones help to hold the inbound buckets in contact with the sea bed even when crossing slight depressions.

THE TRACK

The track structure is thin to make it limber in the vertical plane so that the system of buckets can follow gentle irregularities in the bottom topography. Stiffness to keep the buckets in line is supplied by a series of ties and cross bars 342c shown in FIGS. 4 and 4A that extend orthogonal and diagonally between the rail pair of each track.

The two ends of the track are illustrated in FIGS. 5 and 6. Track rails terminate into rigid supporting members at both ends. At the near end of FIG. 6, lower track 342a bends upward so that incoming buckets may be elevated to deposit their load in trough 308. The upward bend starts over the point where inclined plate 308a of the vehicle of later FIG. 7 emerges from the clay. Upper and lower tracks 342a and 342b terminate into supporting member 370 which bends upward over the point where buckets 351 meet plate 308a.

The far end of the track is shown in FIG. 5. Upper track 342b bends upward while lower track 342a remains horizontal and in close proximity with the chain. Both tracks terminate into support member 372 rigidly connected by swivel frame structure 357 to tractor 356. The terminal points of the tracks are close to tail sheave 345. The terminal point for lower track 342a is as close as possible to where the rounding buckets assume a righted position. Cylinder 362 is provided in structure 357 to raise the outer end of the track when tractors 356 are maneuvering into position or the miner is moving to a new area.

To provide stability at its center, each arm is provided with a pair of wheels (not shown) that are wide enough to avoid sinking into the clay. These are mounted in the vicinity of the midpoint of the arm, one to the front of the track and the other to its rear. They are separated by about three or four meters and prevent the arms from tipping.

THE CHAIN AND ITS TERMINALS

Endless chain 350 is composed of many long links that mate with the flats of drive sprocket 344 and tail sheave 345. Drive sprocket 344 is coupled by gearing to the output of the crawler drive motor of vehicle 301. Buckets 351 are mounted at points on the chain of each arm so that there is no interference between the two sets of buckets over trough 308.

Servo units in the miner maintain angle θ at 90°. Limit switch 337 linked to each mast 313, as shown in FIG. 7, senses angle θ and issues appropriate speed adjustment command signals to sheave tractors 356 and 356'. As is discussed again subsequently, a decreasing angle θ causes switch 337 to provide a signal for increasing the speed of tail sheave tractors 356 and 356', whereas an increasing θ causes switch 337 to slow down the tail sheave tractors. Tension transducer 361 of earlier FIG. 5 measures the tension of each track along its longitudinal axis. It generates steering signals for constraining the movement of tractor 356 along a path parallel to tractor 301. If tail sheave tractor 356 deviates from a parallel course, corrective commands are sent to a steering mechanism in tractor 356. Both control systems are described in conjunction with later FIGS. 8 and 9.

SUGGESTED PARAMETERS OF THE ARMS

To utilize the buckets efficiently, they should be spaced so that the swath by any bucket overlaps that made by a preceeding one. The following specifications are proposed for the arms and suppose an average advance rate S_a of 0.2 m/sec which should be reasonably sufficient to mine ore over a typical deposit at a rate of 500 tons/hr. Suggested specifications are:

Extended length of each arm - 50 meters

Height of the arms including mounted buckets and two tiers of tracks - 1.05 meters.

Scraper chain speed, S_c , - 1 meter/sec.

Length of each chain line - 0.5 meters.

Bucket capacity - 0.5 meters³.

Bucket width - 1 meter.

Width over outside of bucket runners - 1.7 meters.

Angle θ of 90° and angle ϕ of 11°.

THE TRACTORED VEHICLE

Referring again to FIG. 7, tractored vehicle 301 comprises an ore delivery component followed by cleaning and crushing apparatus mounted on a tractored chassis. With the aid of FIG. 3, it is observed that plow blades 309 and 309' are followed by inclined plates 308a and 308a'. The blades push ore directly in front of the vehicle to its sides where it is gathered up by the incoming buckets. The inclined plates terminate sharply into trough 308. The plow and inclined plates ride on a pair of flat runners 310 and 301' that, though only partly shown, extend back and end just short of the vehicle's tracks. The runners control the cutting depth of the plow blades. Mounted on each inclined plate is a telescoping rotary mast 313 or 313' for supporting the near end of each track. The masts are located at points on the inclined plates to permit them to swing about 180° without interference. As better shown in FIGS. 3 and 6, the masts are connected to the drive sprockets through an inward pointing member 313a so as to reduce the slope at which the buckets must climb the plates to permit them before depositing their loads in trough 308. Masts 313 and 313' telescope and swivel by operation of motors mounted under plates 308a and 308a'.

Base 301a of the vehicle houses the mechanisms that drive the tractored wheels. The mechanisms are actuated by crawler drive motor 302. Because of the softness of the bed, the tracks are sufficiently wide to support the vehicle. The necessary width for the tracks is determined from samplings taken of the bed prior to the lowering of the plant.

Mounted on base 301a is cylindrical nodule cleaner 320 and ore crusher 303. Cleaner 320 is slightly inclined with its output end tipped toward the inlet of crusher 303. Nestled in the base underneath ore crusher 303 is surge bin 304. This bin rests on a weighing transducer, illustrated in later FIG. 10, that provides electrical feedback signals to the servo loop that controls crawler drive motor 302 and the advance rate of the vehicle. At its bottom, surge bin 304 is emptied by outlet pipe 305 which was rigidly coupled to the first hoist pipe at the beginning of the lowering sequence. Rods 338 support the outlying portions of the miner during the long trip to the bottom, when all its weight is supported by outlet pipe 305.

Cylindrical cleaner 320 slowly rotates about its longitudinal axis. The rotary drive is provided by interaction of gear 333 installed on the outer rim of the cylinder and drive motor 321. The cylinder is supported by a pair of trunnion rings 322 which ride on rollers 322a fixed to the base.

Feedline 307 extends from the bottom of trough 308 through pump 306 and freely projects into cleaner 320 through a large aperture in its elevated input end 328. Feedline 307 has a tap-off valve that couples into a large ballast bin with a capacity of at least 20 tons and a bottom dumping hatch (all of which are not shown). The initial load of sediment composed of mud and nodules deposited in trough 308 is fed into the ballast bin until it is filled whereupon the valve is

shut and the rest of the sediment is fed into the cleaner. After the removal of clay and mud, cleaned ore 343b escapes from the cleaner at output end 322 and falls into crusher 303 where it is reduced to particles of 1 cm or less in diameter. Ore processed by the crusher falls from its bottom into outlet pipe 305 where, by action of a pump in outlet pipe 305 or the pump of the first hoist pipe, it is transported into the hoist pipe circuit up to the hovering Sessile ship. Servo controlled valve 314 admits sea water to mix with the rising slurry to keep the concentration constant. Manifold 312 mounted on the base distributes clean water to the many water lubricated bearings used in vehicle 301.

SERVO CONTROLS

Illustrated in FIGS. 8 and 9 are two systems for controlling the direction and speed of tail sheave tractors 356. FIG. 8 illustrates a steering control system functioning with the command signals of tension transducer 361 of FIG. 5, and FIG. 9 shows a proposed speed control system utilizing the command signals of limit switch 337 of FIG. 7. Referring first to the steering control system of FIG. 8, tension transducer 361 comprising spring 361a in series with a pair of collars 361b, 361c, is connected between the frame of mast 357 and structural member 372. Collars 361b and 361c cooperate respectively with heavy and light tension switches 361d and 361e. When triggered by movement of the collars, switches 361d and 361e activate re-cycling timers 363 and 365, respectively. The timers engage one of clutch solenoids 447 or 449 to disengage momentarily one track from drive shaft 452 for purposes of turning the tail sheave tractor in the appropriate direction by a small angle, say 1°. If the turn is insufficient to release the switch the timers re-cycle after say 30 seconds to cause successive small turns in the same direction. Thus, an inward deviation of tractor 356 compresses spring 361a and declutches the drive to outer track 451, while, elongation of the spring declutches track 453. The corrective action of the steering control to unwanted deviations of tractors 356 and 356' keeps them within maximum and minimum angular limits and on an average course essentially parallel to the travel of tractored vehicle 301.

A speed control system for maintaining angle θ approximately constant on the average is illustrated in FIG. 9. Limit switch 337 coupled to mast 313 is connected electrically by line 363 to gearbox 455. The gearbox has two sets of gears, one set of which is operative at any time to couple drive motor 459 of tail sheave tractor 356 to drive shaft 452. The two gear sets provide an incremental step in the drive speed, say a 1 percent change, of shaft 452. For example, gear set 446—446a may have a tooth ratio of 201/200, and gear set 448—448a the inverse of the ratio. The gears are coupled to shaft 452 by action of bi-state solenoid 444 which operates clutches 449 and 453. The state of solenoid 444 depends on which of the two limiting signals of switch 337 is carried by line 363. When angle θ exceeds 90° by a specified maximum limit, solenoid 444 is energized to engage step-up gear pair 446—446a to decrease the speed of the tractor by 1 percent. Similarly, when angle θ reaches a minimum specified limit, step-down gear pair 448—448a is engaged with Shaft 452 imposing a 1 percent increase in speed.

While gearbox 455 provides an immediate but small adjustment in speed, a requirement for gradual and greater variations is satisfied by adjusting a governor regulating the speed of drive motor 459. Still referring to FIG. 9, limit switch 337 is parallel connected to reversible control motor 461, which is coupled to governor 463 through a large step-down gearbox (not shown). The step-down gearing affords a slow adjustment in the governor's setting, say 1 percent per minute, in response to signals from switch 337. Governor 463 regulates motor speed in the usual way with spring actuated switch 467 shorting series winding resistor 465 when motor speed is less than that ordered by the governor, and reinserting the resistor when the motor speed is excessive. Thus, when angle θ of the

scraper bucket arm attains its maximum specified limit, reversible motor 461 gradually increases the governor setting, and conversely, it decreases the setting when angle θ reaches its minimum specified limit.

The effect of such variations in the operating speed of motor 459 extends step speed changes produced by gearbox 455. If the speed required of the tail sheave tractor is not within the 1 percent adjustment capability of the gear change, one of the contacts of switch 337 is operative for a longer period than the other and the net change in governor setting is in the direction required to achieve orthogonality in the scraper bucket arm. The speed adjustment continues at a slow rate until the tractor is running at a speed very close to that desired. The intervals of high and low speed operation of the gearbox become equal and no further net change in governor setting occurs.

The advance rate of the plant is regulated by the speed control for the crawler drive motor 302 of vehicle 301 appearing in the functional block diagram of FIG. 10. Surge bin 304 of earlier FIG. 7 offers a measure of the difference of the flow rate of ore processed by the vehicle and the rate of ore hoisted by the pipe circuit. Controls, including servo control valve 314 maintain the desired flow rate and ore concentration in the pipe circuit, here about 500 tons/hr. The crawler speed control of FIG. 10 adjusts the advance rate S_r to keep the two rates equal. The initial rate of speed for the control is set according to the ore density of the field previously determined from a sampling tube. However, as the field is mined, weight transducer 383 under surge bin 304 serves as the controller. Weight reference signal S_r' transmitted from the control room of the Sessile ship corresponds with a specified quantity or weight of ore to be maintained in bin 304, preferably the weight of the bin when half-filled with ore. Output W of transducer 383 is compared with weight reference signal S_r' and error signal "e" results to vary the speed of crawler drive motor 302 appropriately until the vehicle's speed S_r is such to hold the reservoir of ore in bin 304 as specified (half-filled). A scraper bucket chain drive proportional to speed S_r is derived through gearing between the output of crawler drive motor 302 and drive sheave 344. This coupling allows a chain speed S_c proportional to vehicular speed S_r and the ratio (S_c/S_r) to be maintained reasonably constant, as was discussed earlier.

MOTOR DRIVES

The several motor drives used throughout the lower portion of the system and miner 300 are specially designed to avoid the need for tightly sealed and expensive casings ordinarily required in a high pressure ocean environment. Referring now to FIG. 11, a typical motor drive comprises a motor housed in casing 400 located below gear box 420. The chamber of casing 400 is filled with distilled water 413 that is electrically insulating and immiscible with oil in gear box 420, and has a specific gravity greater than that of the oil. Water 413 fills casing 400 down from "O" ring seal 426 at the junction of the casing and gear box 420 to the bottom of the casing where it envelops the closed surfaces of expansion bellows 415. As with a similar bellow 419 located in the shell of gear box 420, bellows 415 have outward facing openings that receive sea water. Immersed in the distilled water is motor stator 405 and rotor 410 that is mounted on shaft 409. The bottom of shaft 409 rests on rubber-lined, fluid-lubricated bearing 412, while the top of the shaft is mounted on ball bearings 424. The drive of shaft 409 is coupled to the motor's output shaft 425 and its rubber-lined, water-lubricated bearing 427 through meshed gearing 422 in box 420. Gear box 420 is filled with lubricating oil of light density and high viscosity, say with a specific gravity of 0.89 and a viscosity of about 90cs. The gearbox is sealed from the sea by "O" ring seal 426. The outer surface of casing 400 has a thin layer of insulation 400a but with enough leakage to allow some of the heat generated inside the motor to dissipate. Solid material, such as alumina, high melting point wax paints or plastics, are suitable insulators.

Functionally, the chilling temperature of the deep sea environment contracts the oil and water inside the motor causing bellows 415 and 419 to adjust in volume until the pressure differential across the motor's housing is substantially reduced. Through action of "O" seal 426, the pressures of distilled water 413 and the lubricating oil tend to equalize. These adjustments in the pressure differentials both internal and external, and the natural floatation of the oil away from the distilled water are effects that simplify the sealing problem and allow the use of "O" seals 426 instead of more expensive and lossy tighter ones at the mechanical junctions.

Having thus described a preferred embodiment of his scraper bucket apparatus, applicant now defines his invention in the appended claims.

What is claimed is:

1. Scraper bucket apparatus for use with a deep sea mining vehicle adapted to travel an ocean bed at a speed S_r for scraping ore nodules said apparatus comprising, in combination:

a vertically flexible, long, foldable track having a longitudinal axis "c" and with a first end adapted for rotatably mounting on said vehicle,

an endless chain adapted to circulate along said track with means for driving said chain at a speed S_c proportional to said speed S_r ,

a series of scraper buckets attached along points of said chain adapted to ride said track and scrape nodules from said bed and deposit them near said first end of said track, said buckets having an input axis "b" which, when said buckets are scraping nodules, are skewed forward of said track axis "c" in the direction of said vehicle's motion, and

a driven tail sheave tractor carrying a second end of said track adapted to travel parallel to said vehicle,

whereby said scraper bucket apparatus is adapted for scraping ore nodules along an angle θ which said track may make with the negative of the velocity vector of said vehicle.

2. Scraper bucket apparatus as set forth in claim 1 wherein said track has a double hinged joint allowing said track to fold approximately 180° along its length.

3. Scraper bucket apparatus as set forth in claim 2 wherein said track is at least 25 meters in length.

4. Scraper bucket apparatus as set out in claim 3 wherein said forward skewness of said input axis "b" of said buckets when scraping nodules is by an angle ϕ relative to said track axis "c", where ϕ is substantially according to the relation,

$$\phi = \theta - \tan^{-1} (S_r \sin \theta) / (S_r + S_c \cos \theta).$$

5. Scraper bucket apparatus as set out in claim 4 wherein said angle θ is essentially 90° and said angle ϕ substantially according to the relationship $\phi = 90^\circ - \tan^{-1} (S_r/S_c)$.

6. Scraper bucket apparatus as set forth in claim 5 further comprising,

a speed control system adapted to vary the speed of said tail sheave tractor, and

a limit switch for coupling between said vehicle and said track for measuring said angle θ and cooperating with said speed control system to maintain variations in said angle θ between specified maximum and minimum limits.

7. Scraper bucket apparatus as set forth in claim 6 further comprising a steering control system for steering said tail sheave tractor, and a transducer in said track for measuring the tension in said track cooperating with said steering control to maintain said tension essentially constant.

8. Scraper bucket apparatus as set out in claim 7 wherein said double hinged joint comprises an intermediate section of upper and lower pairs of rails adapted to align with corresponding pairs of upper and lower rails of said track when said track is outstretched, and with the ends of said lower rails of said intermediate section connected by hinges with said lower rails of said track, and said intermediate section has a hook adapted to engage and disengage said endless chain.

9. Scraper bucket apparatus as set forth in claim 8 wherein each of said scraper buckets comprises,

a box with a closed back carrying a bottom cutting block, closed sides and an open bottom and an open front and has a member across its top holding wheels for riding said track and means for fastening said member to said chain, first and second ski-like runners mounted on said sides slightly displaced from the bottom of said sides, said second runner flush with the bottom of said back, the height of said first runner exceeding the height of said second runner by the thickness of said layer to be scraped.

10. A scraper bucket for use with scraper bucket apparatus for scraping a layer of loose ore sediment from the ocean floor and having a track and a circulating endless chain, said bucket

comprising:

a box with a closed back carrying a bottom cutting block, closed sides and an open bottom and an open front and having a member across its top holding wheels for riding said track and means for fastening said member to said chain, first and second ski-like runners mounted on said sides slightly displaced from the bottom of said sides, said second runner flush with the bottom of said back, the height of said first runner exceeding the height of said second runner by the thickness of said layer to be scraped.

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