US 20210214916A1

(19) **United States**

(12) **Patent Application Publication**

KODAIRA et al.

(10) **Pub. No.: US 2021/0214916 A1**

(43) **Pub. Date: Jul. 15, 2021**

(54) **SEABED RESOURCE LIFTING APPARATUS**

(71) Applicant: **Lakshmi Co., Ltd.**, Tokyo (JP)

(72) Inventors: **Takatoshi KODAIRA**, Tokyo (JP); **Ichiro NAKATANI**, Tokyo (JP)

(21) Appl. No.: **17/159,776**

(22) Filed: **Jan. 27, 2021**

Related U.S. Application Data

(63) Continuation-in-part of application No. PCT/JP2019/029712, filed on Jul. 29, 2019.

(30) **Foreign Application Priority Data**

Jul. 30, 2018 (JP) 2018-143015

Publication Classification

(51) **Int. Cl.**

E02F 7/00	(2006.01)
B63C 11/52	(2006.01)
E02F 3/88	(2006.01)
B63G 8/24	(2006.01)

(52) **U.S. Cl.**

CPC ***E02F 7/005*** (2013.01); ***B63C 11/52*** (2013.01); *B63G 8/001* (2013.01); ***B63G 8/24*** (2013.01); ***E02F 3/8858*** (2013.01)

(57) **ABSTRACT**

The present invention relates to a system and its equipments to collect mineral ores on the seabed and to float them up to the sea surface by utilizing the buoyancy of a liquid having a specific gravity less than that of water at room temperature. It is an underwater navigator capable of autonomous navigation that descends at a specific gravity of around 1.0 with a ballast that cancels buoyancy when descending from the sea surface, and ascends at a specific gravity of around 1.0 by exchanging mineral ores with the ballast on the seabed. On the seafloor, it is accompanied by a device that collects seabed mineral ores for the underwater vehicle.

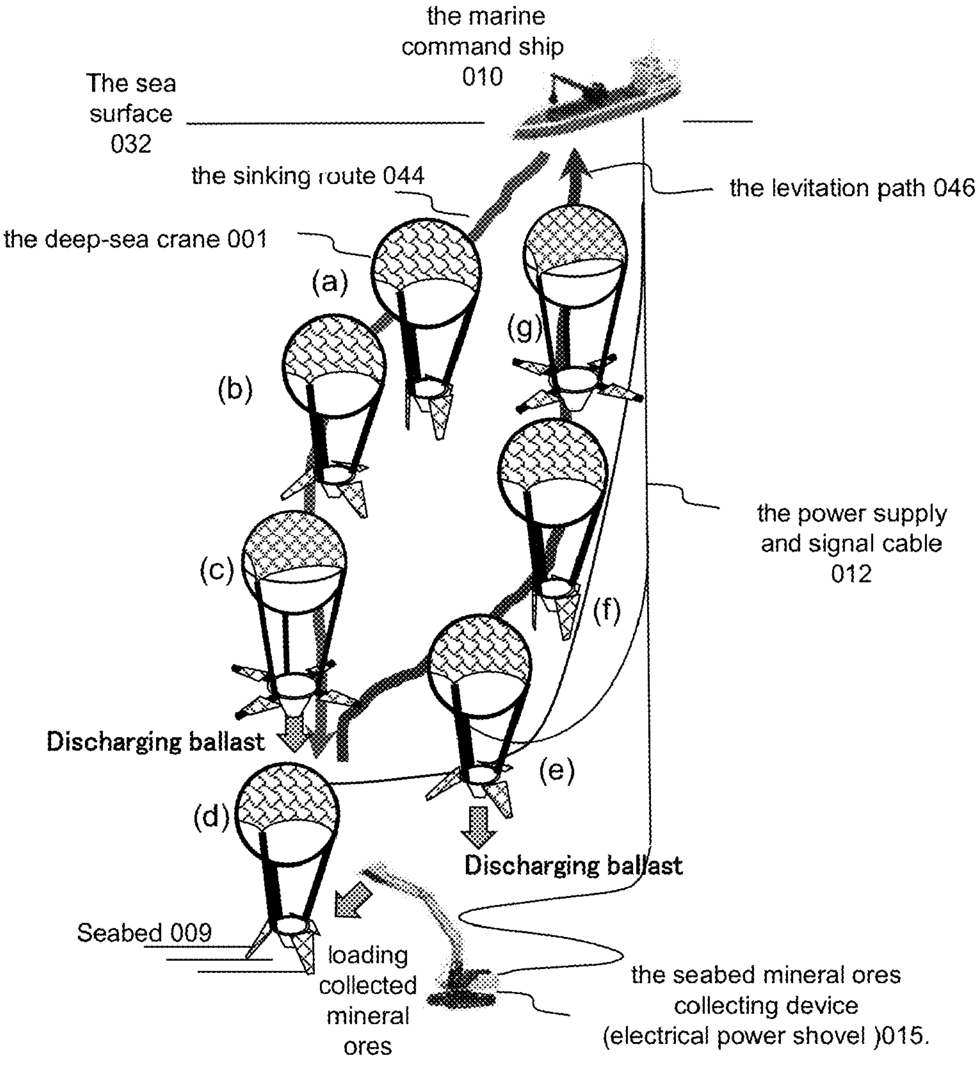


Fig.1A

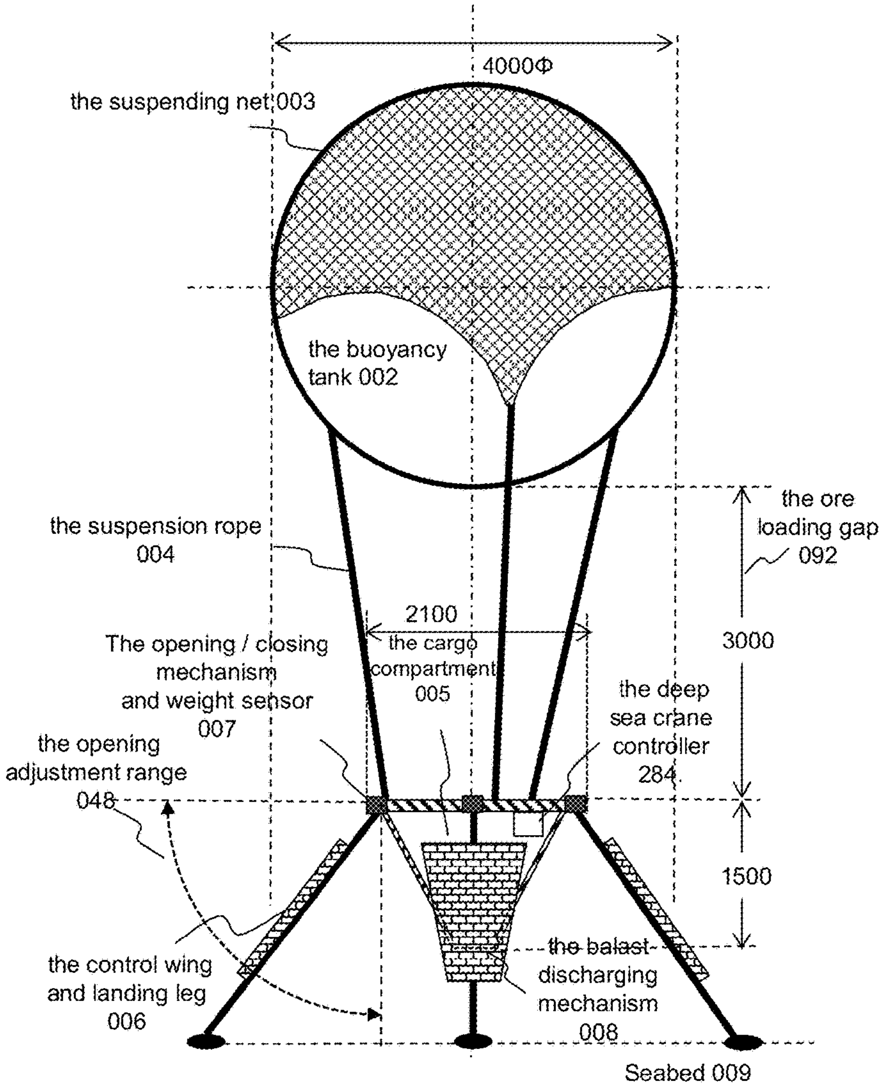


Fig.1B

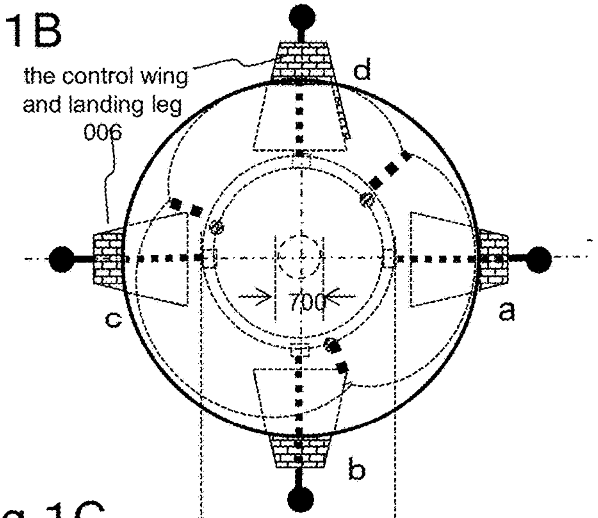


Fig.1C

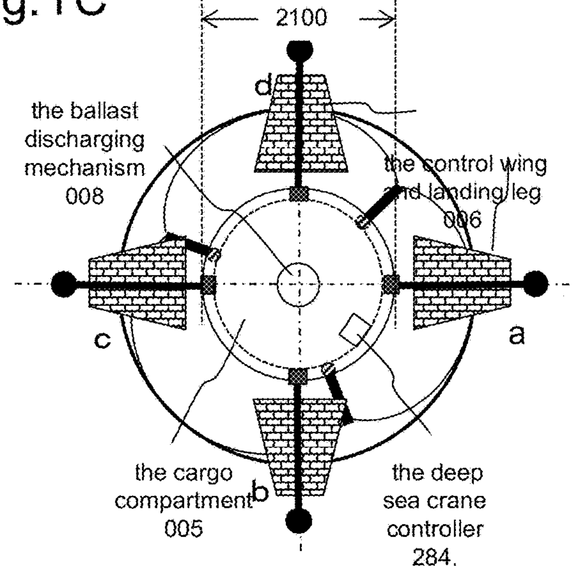


Fig. 2

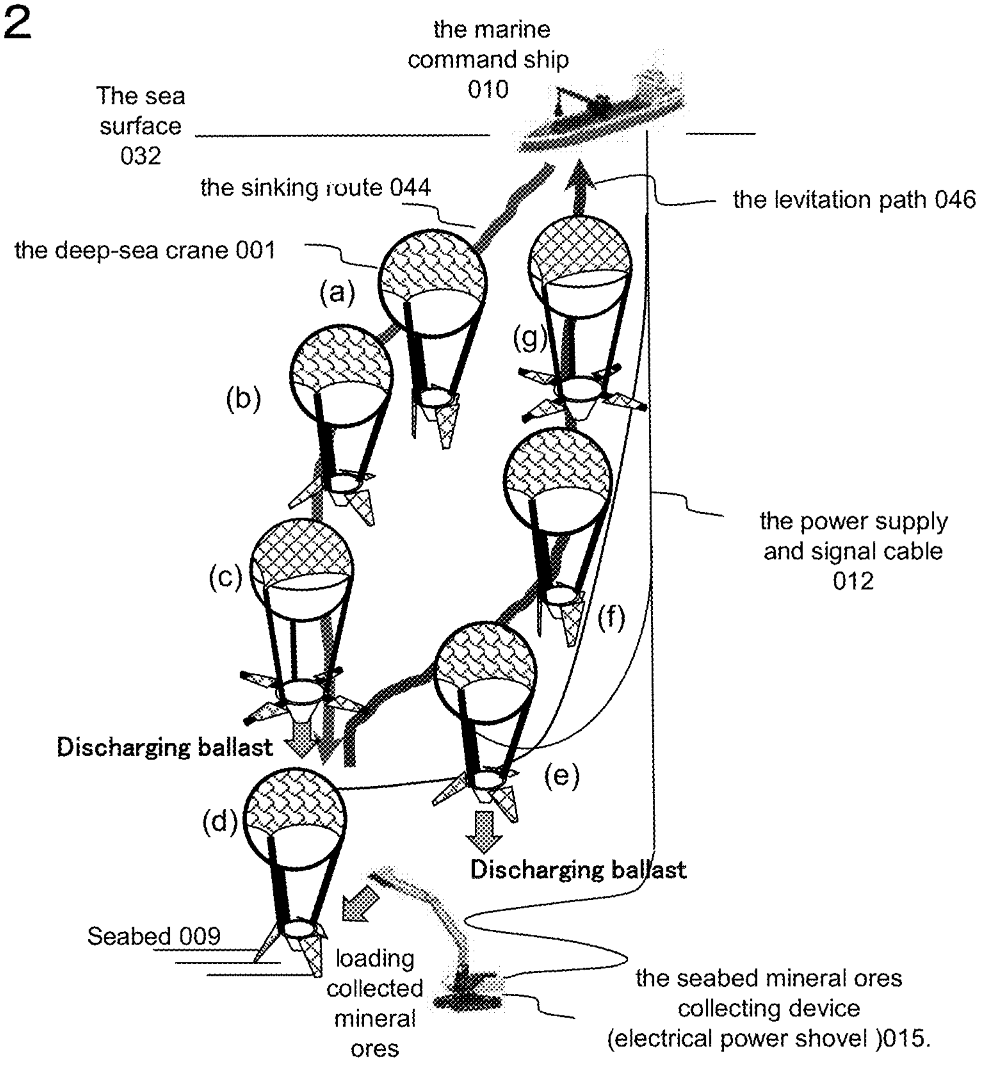

the marine
command ship
010
The sea
surface
032
the sinking route 044
the levitation path 046
the deep-sea crane 001
(a)
(g)
(b)
the power supply
and signal cable
012
(c)
(f)
Discharging ballast
(e)
(d)
Discharging ballast
Seabed 009
loading
collected
mineral
ores
the seabed mineral ores
collecting device
(electrical power shovel)015.

Fig. 3A

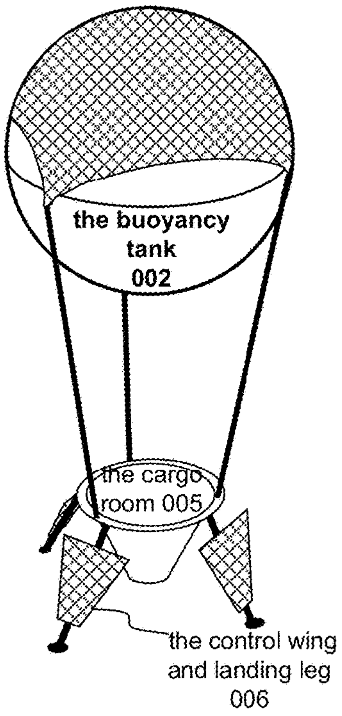


Fig.3B

radius m	diameter m	volume m3	buoyancy(Ton)		cost
			gasoline	n-pentane	Gasoline M¥
1.20	2.40	7.24	2.17	2.73	0.72
1.30	2.60	9.20	2.76	3.47	0.92
1.40	2.80	11.49	3.45	4.33	1.15
1.50	3.00	14.14	4.24	5.33	1.41
1.60	3.20	17.16	5.15	6.47	1.72
1.70	3.40	20.58	6.17	7.76	2.06
1.80	3.60	24.43	7.33	9.21	2.44
1.90	3.80	28.73	8.62	10.83	2.87
2.00	4.00	33.51	10.05	12.63	3.35
2.10	4.20	38.79	11.64	14.62	3.88
2.20	4.40	44.60	13.38	16.82	4.46
2.30	4.60	50.97	15.29	19.21	5.10
2.40	4.80	57.91	17.37	21.83	5.79
2.50	5.00	65.45	19.63	24.67	6.54
2.60	5.20	73.62	22.09	27.76	7.36
2.70	5.40	82.45	24.73	31.08	8.24
2.80	5.60	91.95	27.59	34.67	9.20
2.90	5.80	102.16	30.65	38.51	10.22
3.00	6.00	113.10	33.93	42.64	11.31
3.10	6.20	124.79	37.44	47.05	12.48
3.20	6.40	137.26	41.18	51.75	13.73
3.30	6.60	150.53	45.16	56.75	15.05
3.40	6.80	164.64	49.39	62.07	16.46
3.50	7.00	179.59	53.88	67.71	17.96
3.60	7.20	195.43	58.63	73.68	19.54
3.70	7.40	212.17	63.65	79.99	21.22
3.80	7.60	229.85	68.95	86.65	22.98
3.90	7.80	248.47	74.54	93.68	24.85
4.00	8.00	268.08	80.42	101.07	26.81
4.10	8.20	288.70	86.61	108.84	28.87
4.20	8.40	310.34	93.10	117.00	31.03
4.30	8.60	333.04	99.91	125.56	33.30
4.40	8.80	356.82	107.05	134.52	35.68
4.50	9.00	381.70	114.51	143.90	38.17

gasoline price ¥100/litter

Fig. 4

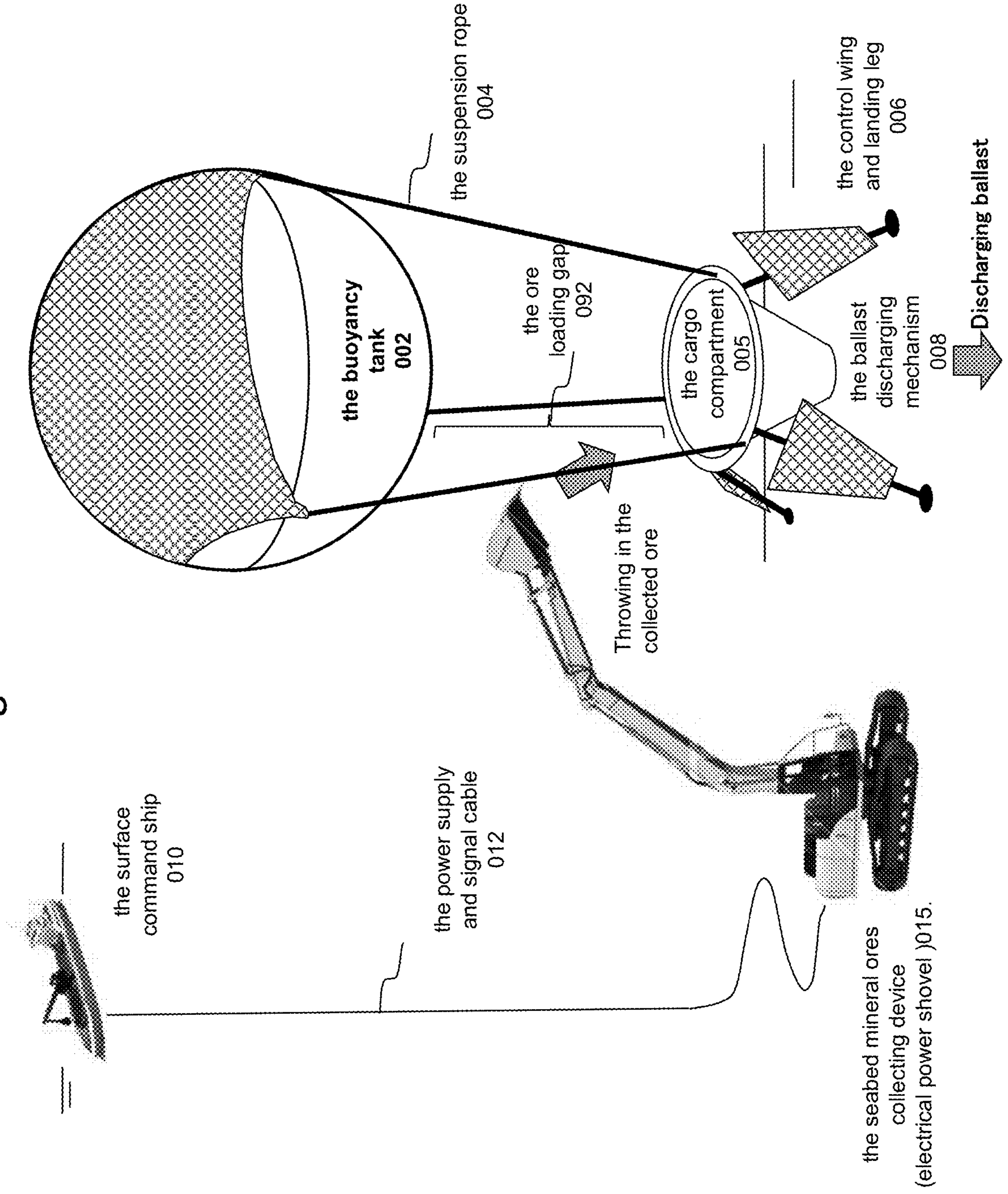

the surface command ship 010
the power supply and signal cable 012
the seabed mineral ores collecting device (electrical power shovel)015.
Throwing in the collected ore
the buoyancy tank 002
the ore loading gap 092
the suspension rope 004
the cargo compartment 005
the ballast discharging mechanism 008
Discharging ballast
the control wing and landing leg 006

Fig. 5A

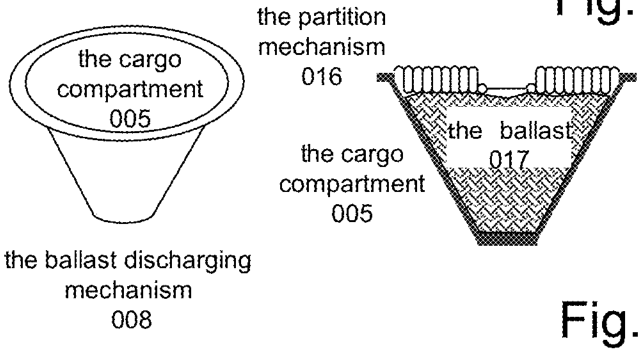


Fig. 5B

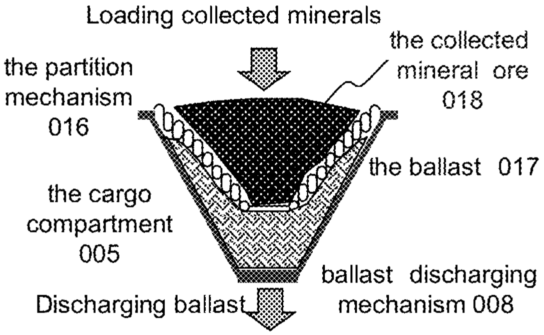


Fig. 5C

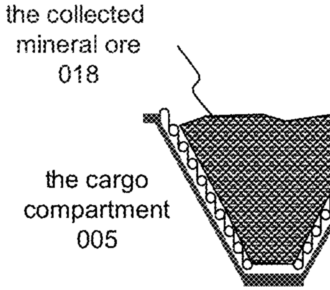


Fig. 5D

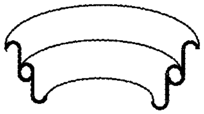


Fig. 5E

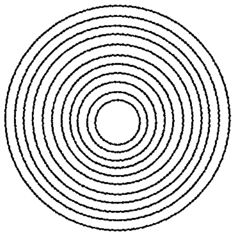


Fig. 6A

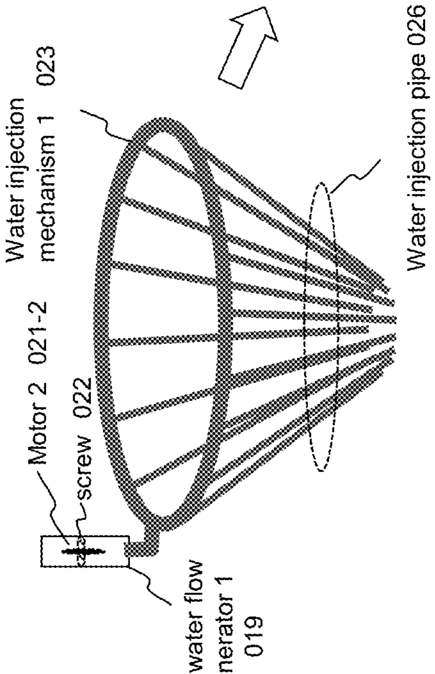


Fig. 6B

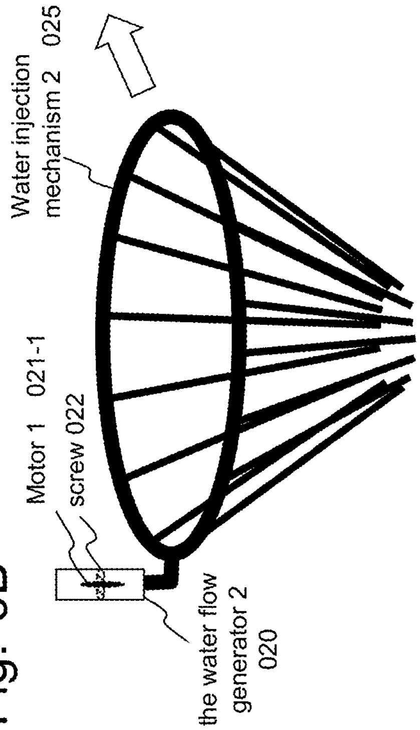


Fig. 6C

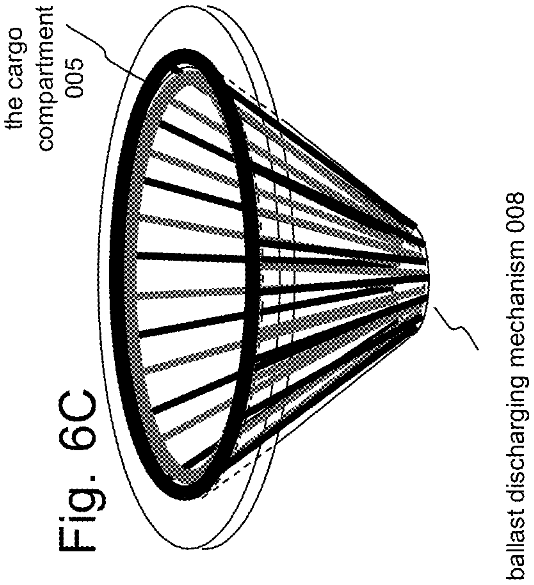


Fig. 6D

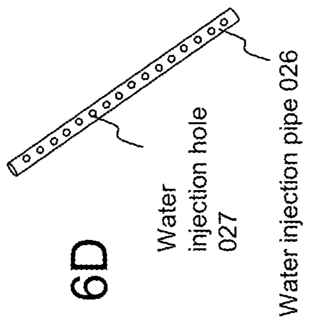
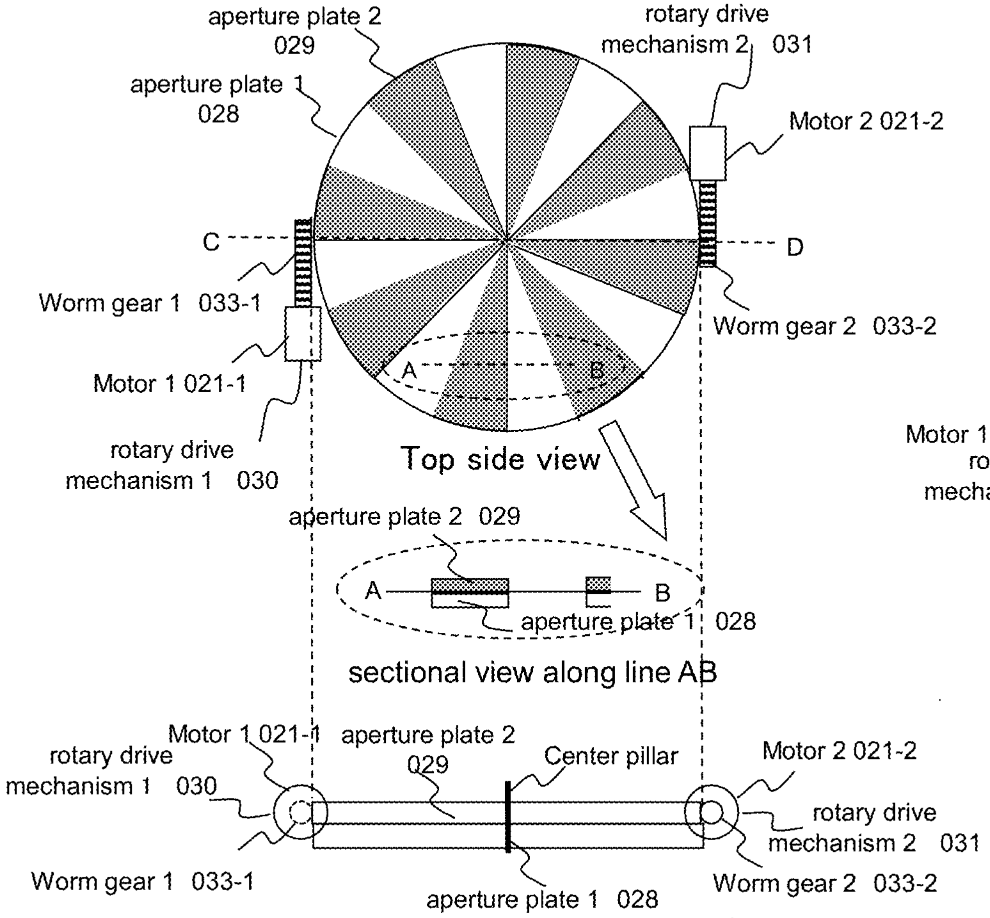
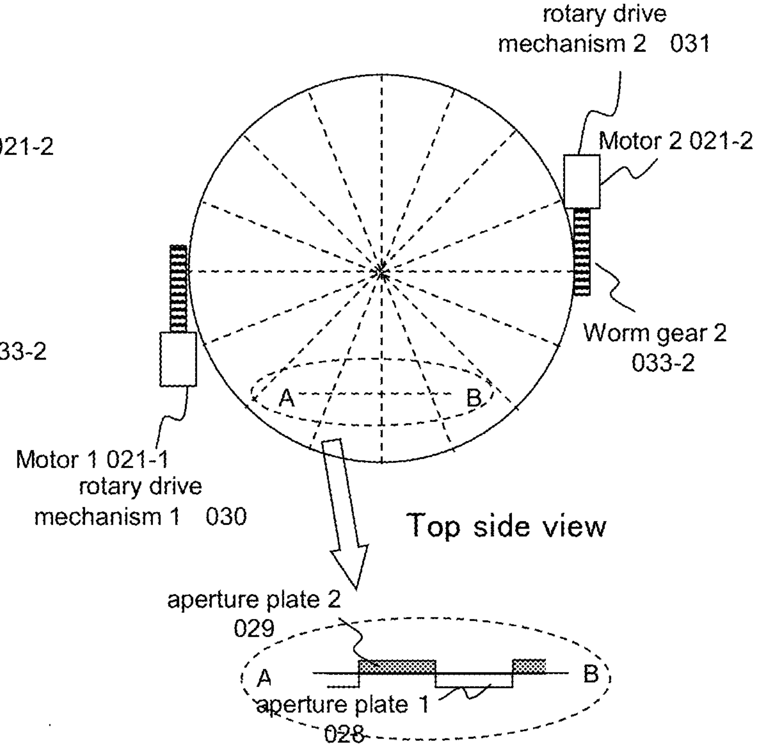


Fig. 7A



sectional view along line CD

Fig. 7B



sectional view along line AB

Fig. 8

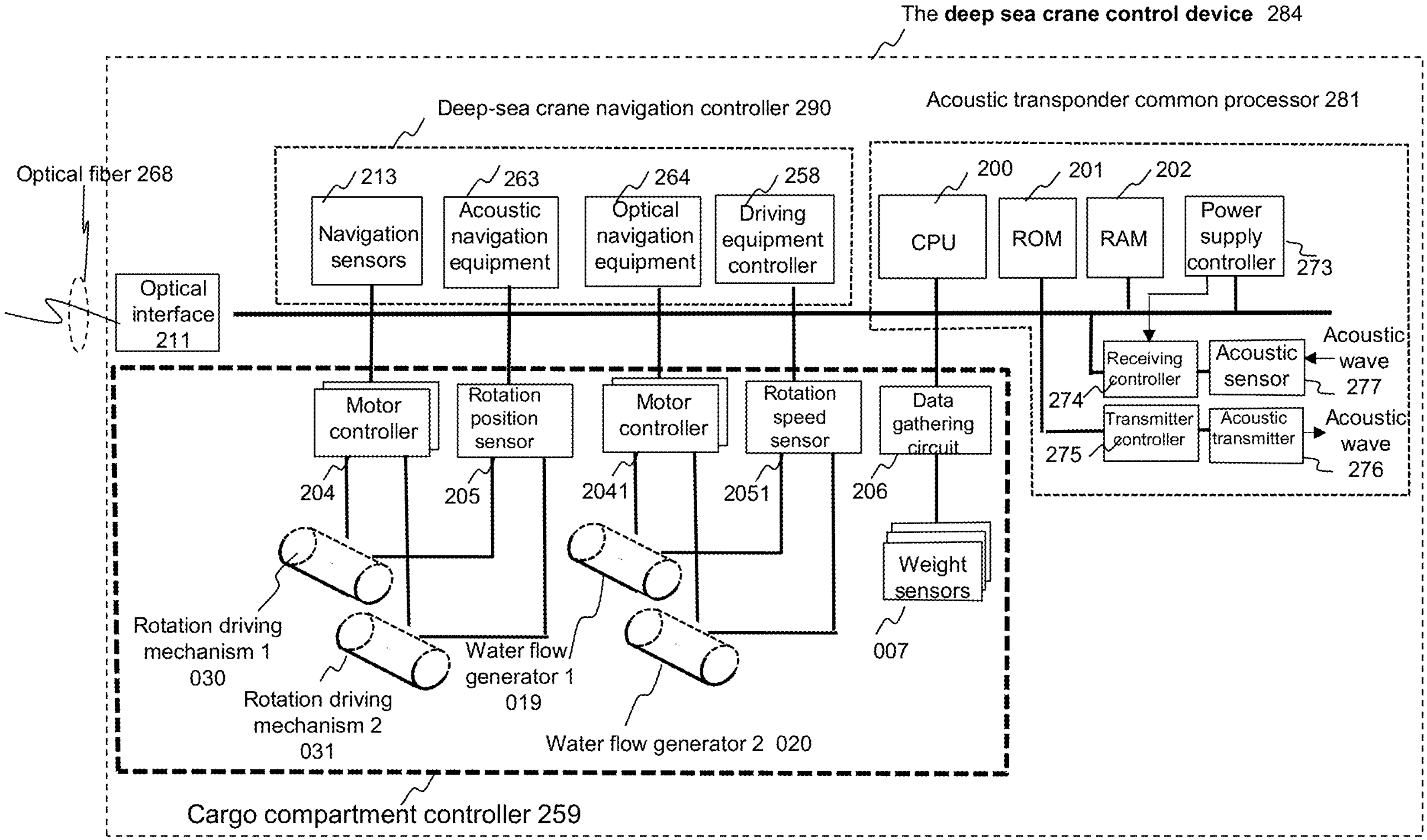
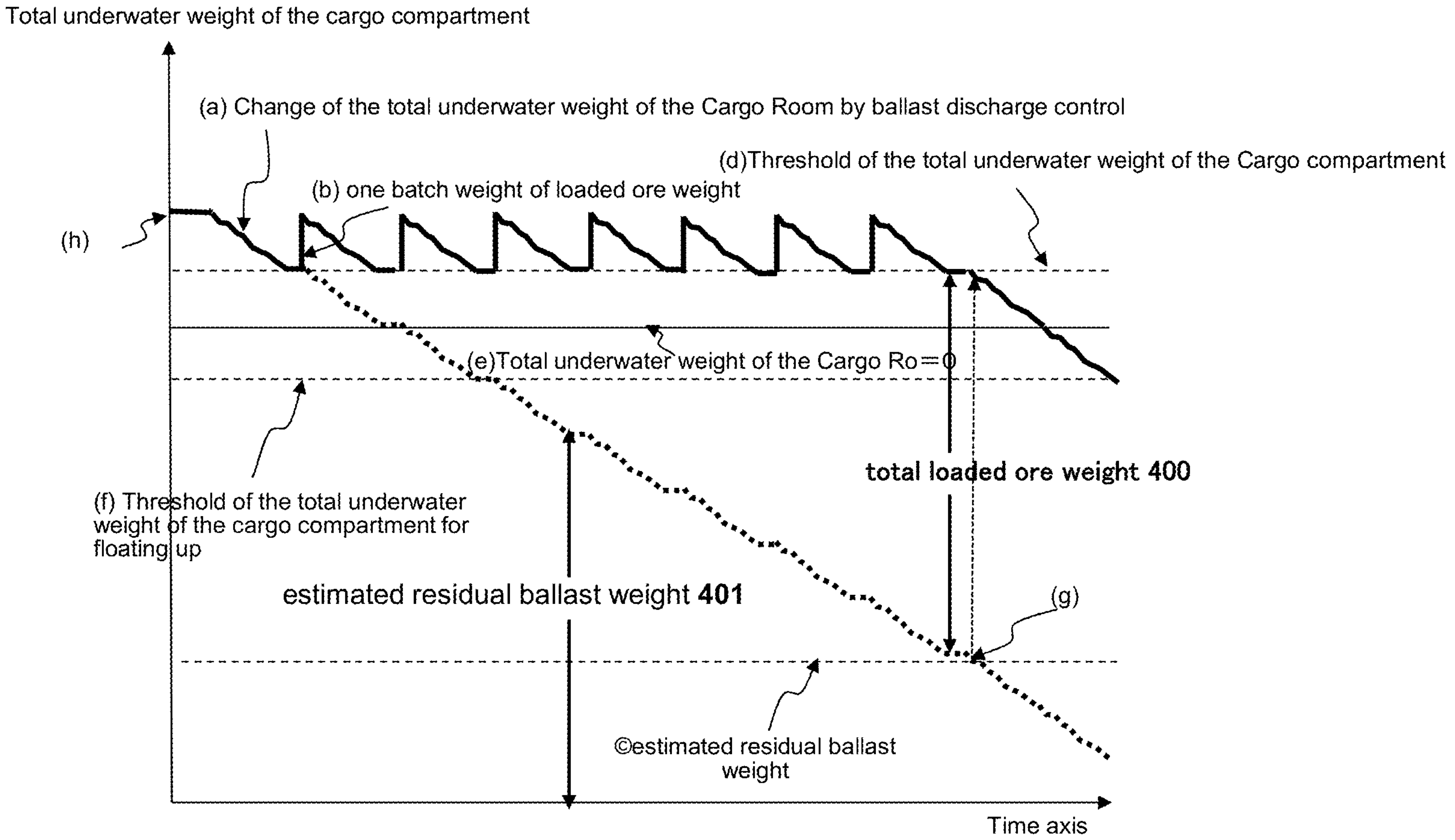

The **deep sea crane control device** 284
Deep-sea crane navigation controller 290
Acoustic transponder common processor 281
Optical fiber 268
Optical interface 211
213
Navigation sensors
263
Acoustic navigation equipment
264
Optical navigation equipment
258
Driving equipment controller
200
CPU
201
ROM
202
RAM
Power supply controller
273
Receiving controller
274
Acoustic sensor
Acoustic wave 277
Transmitter controller
275
Acoustic transmitter
Acoustic wave 276
Motor controller
204
Rotation position sensor
205
Motor controller
2041
Rotation speed sensor
2051
Data gathering circuit
206
Weight sensors
007
Rotation driving mechanism 1 030
Rotation driving mechanism 2 031
Water flow generator 1 019
Water flow generator 2 020
Cargo compartment controller 259

Fig. 9


Total underwater weight of the cargo compartment
(a) Change of the total underwater weight of the Cargo Room by ballast discharge control
(d)Threshold of the total underwater weight of the Cargo compartment
(b) one batch weight of loaded ore weight
(h)
(e)Total underwater weight of the Cargo Ro=0
total loaded ore weight 400
(f) Threshold of the total underwater weight of the cargo compartment for floating up
estimated residual ballast weight 401
(g)
©estimated residual ballast weight
Time axis

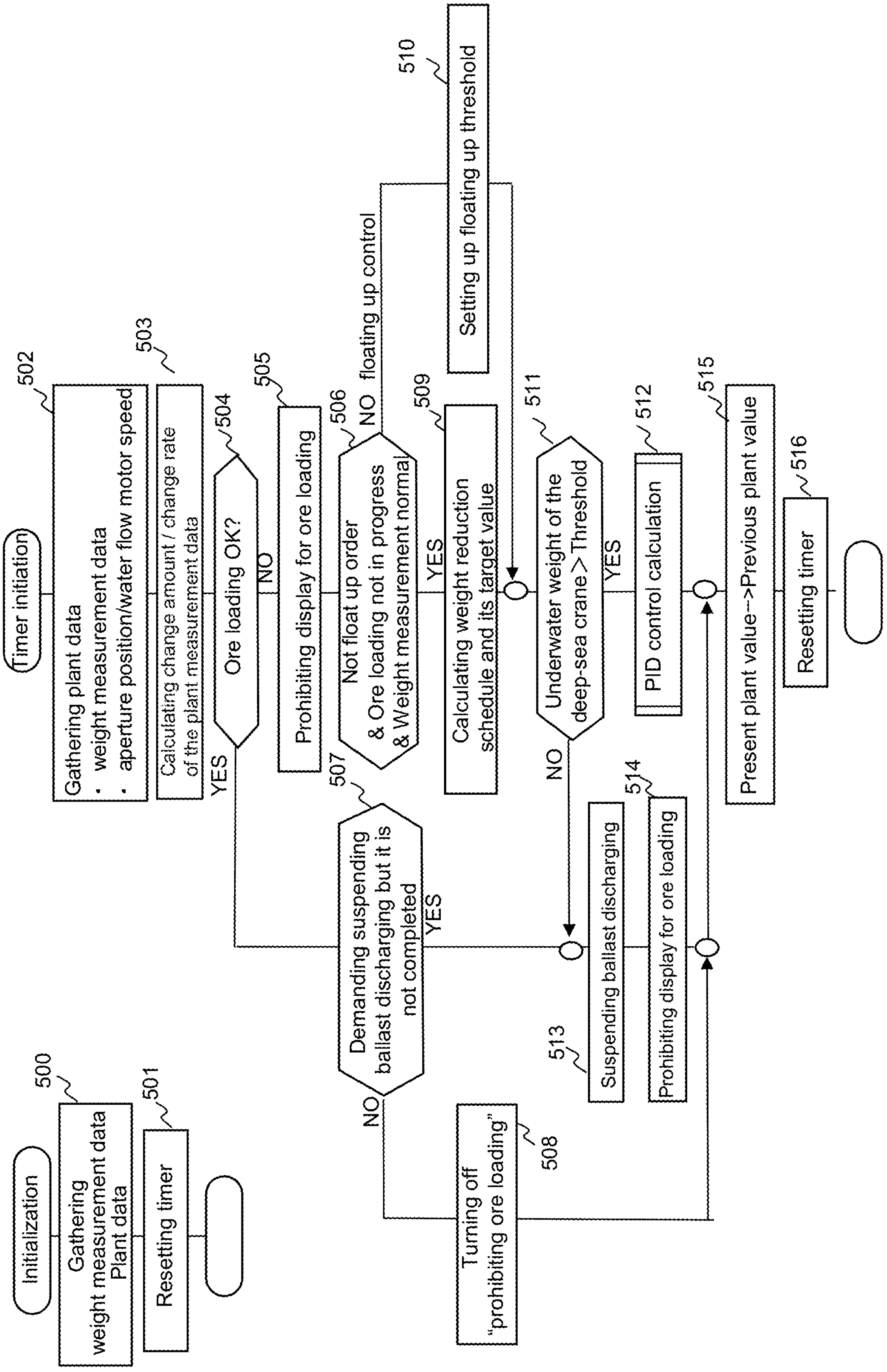


Fig. 10A

Fig. 10B

Fig. 11A

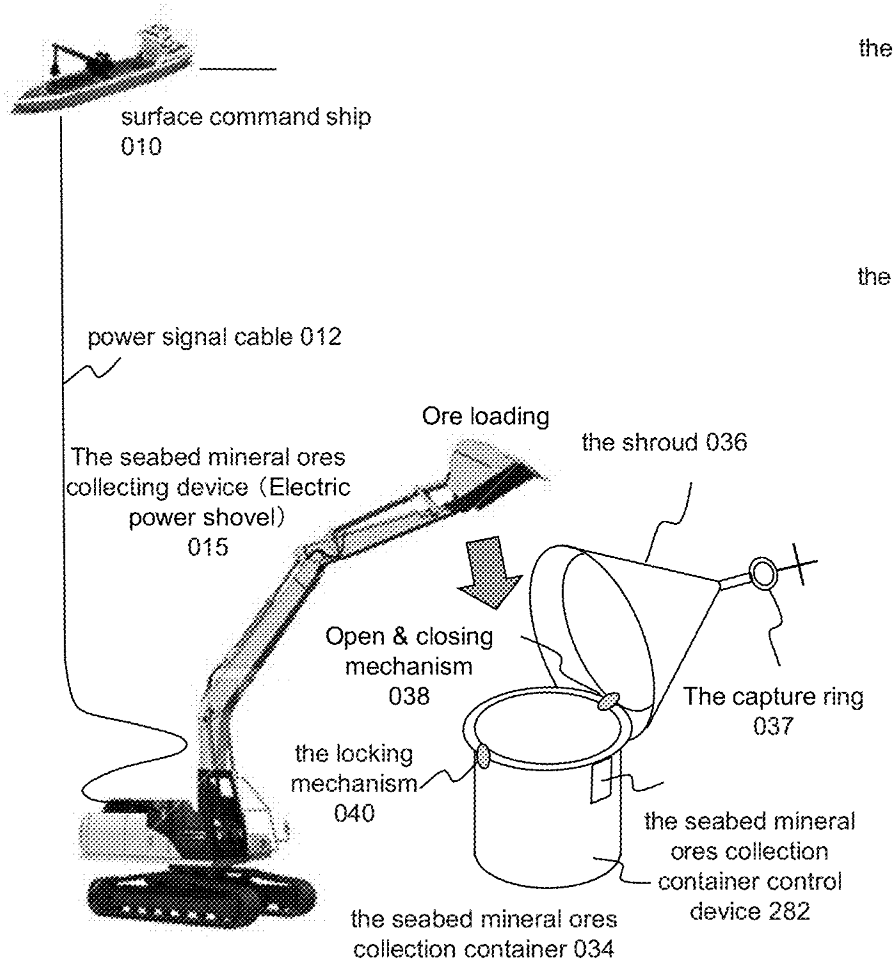


Fig. 11B

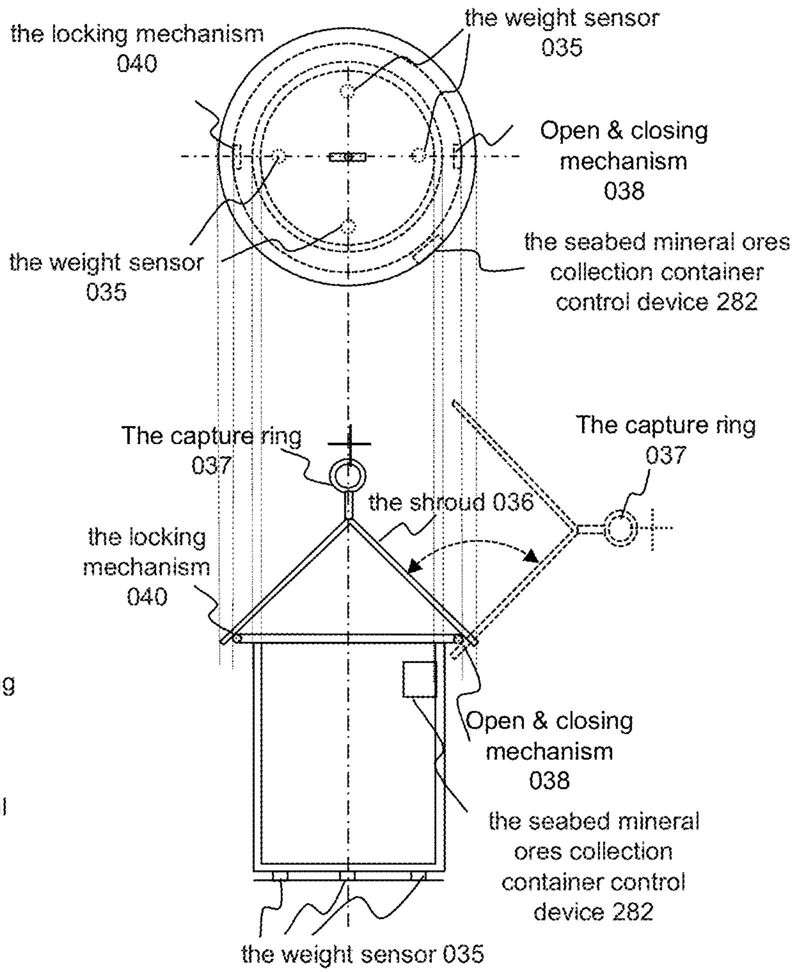


Fig. 12

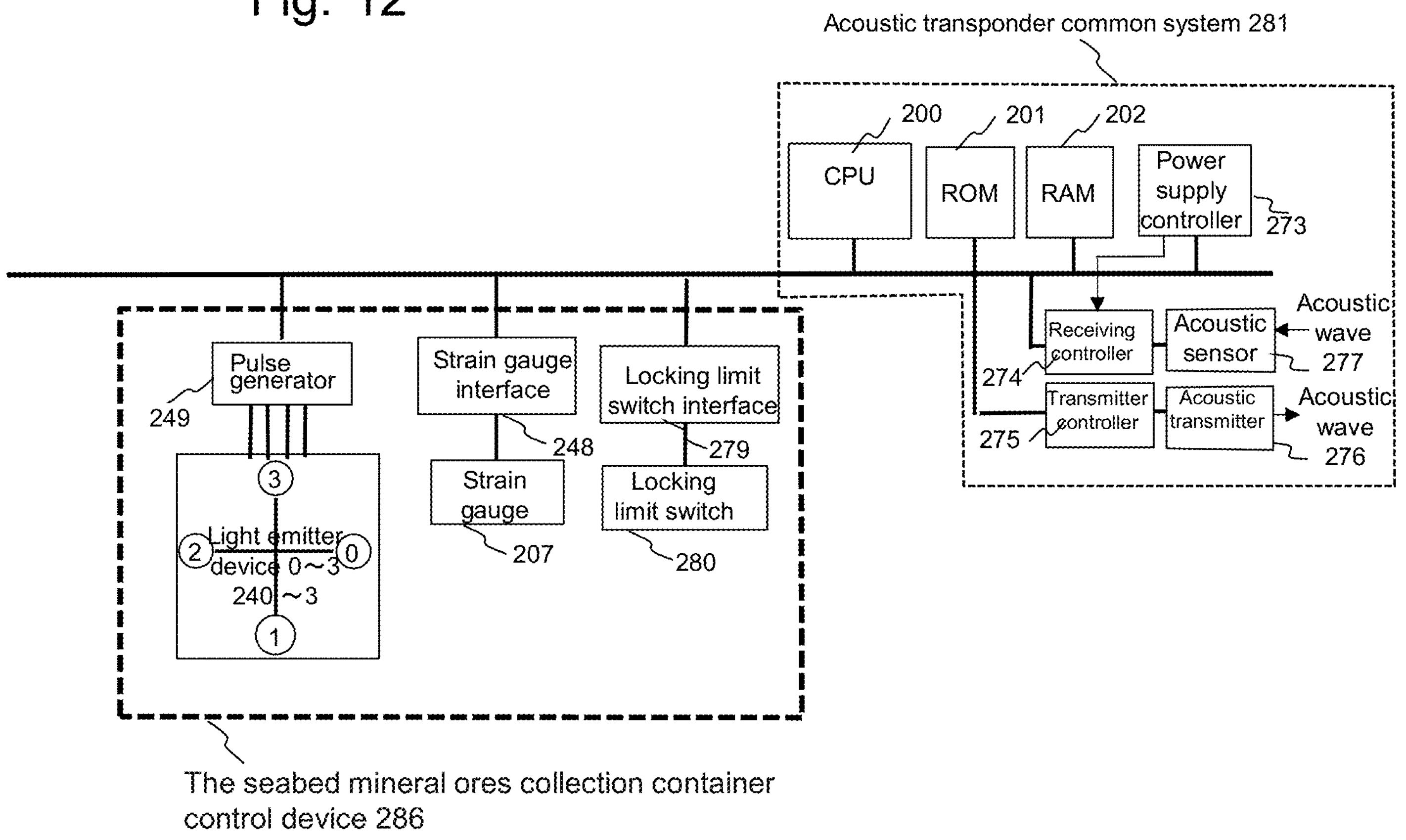
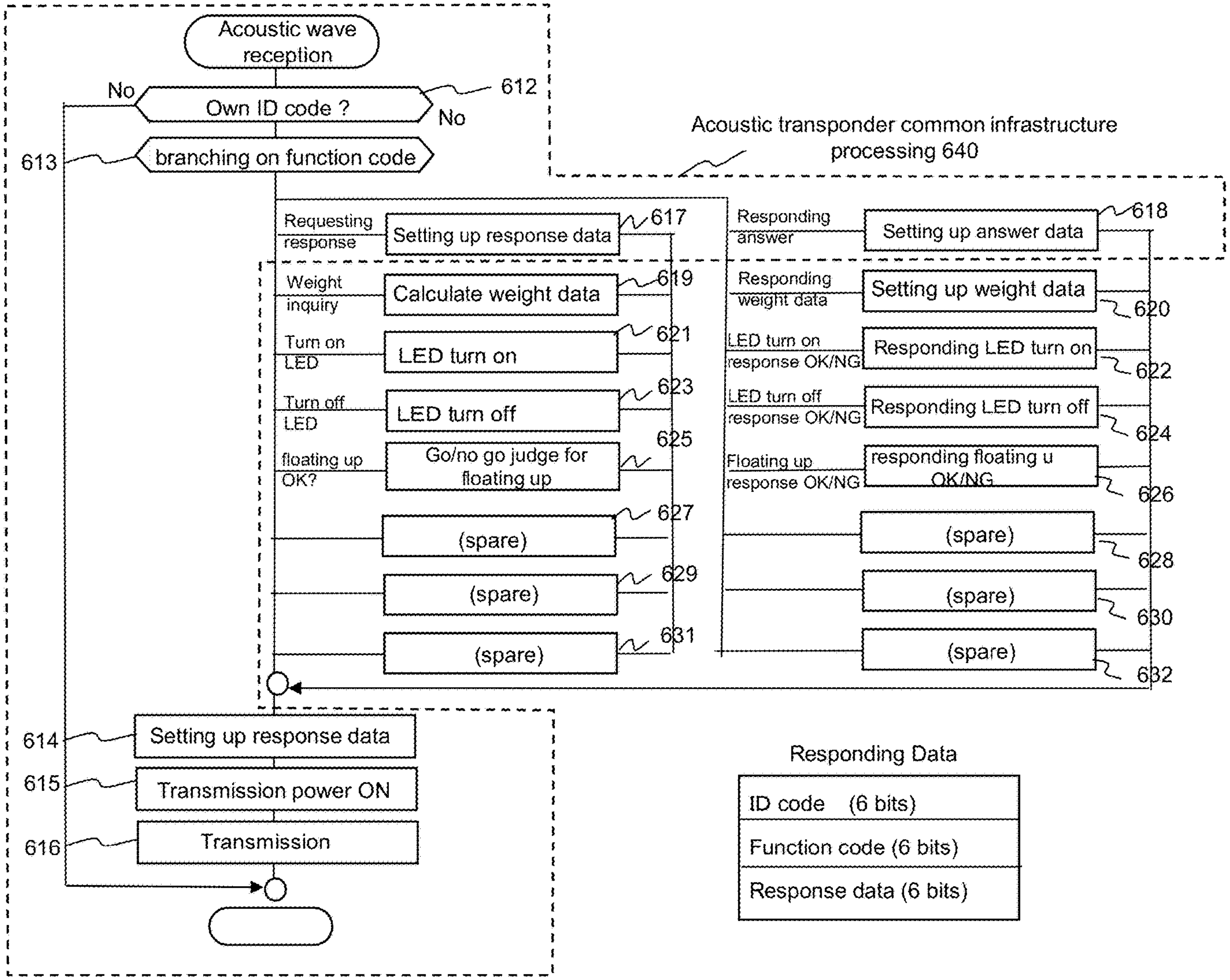

Acoustic transponder common system 281
200
201
202
CPU
ROM
RAM
Power supply controller
273
Receiving controller
274
Acoustic sensor
Acoustic wave
277
Transmitter controller
275
Acoustic transmitter
Acoustic wave
276
Pulse generator
249
Light emitter device 0~3
240 ~3
3
2
0
1
Strain gauge interface
248
Strain gauge
207
Locking limit switch interface
279
Locking limit switch
280
The seabed mineral ores collection container control device 286

Fig. 13



Responding Data

ID code (6 bits)
Function code (6 bits)
Response data (6 bits)

Fig. 14

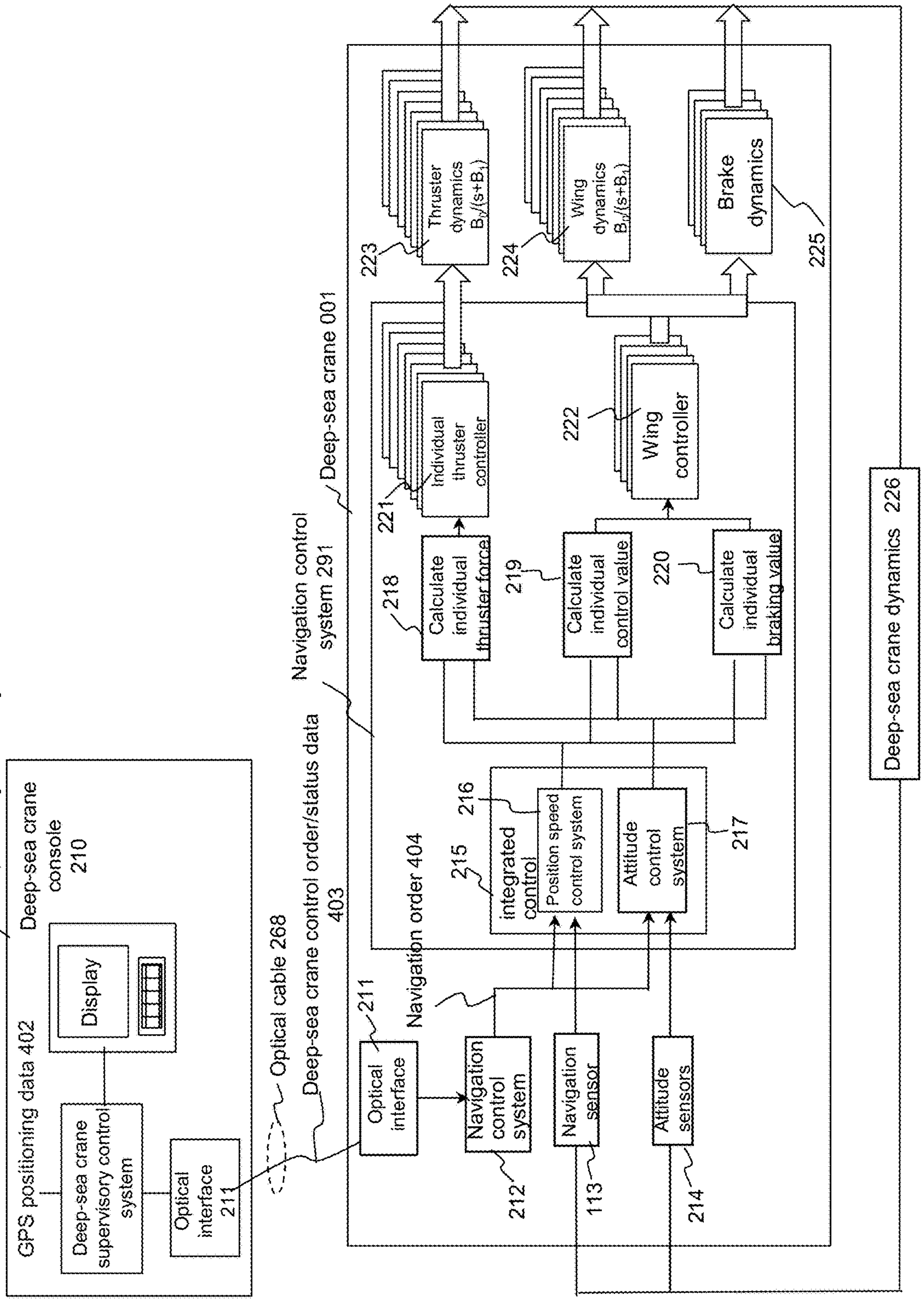

Supervisory control system 287
GPS positioning data 402
Deep-sea crane console 210
Display
Deep-sea crane supervisory control system
Optical interface 211
Optical cable 268
Deep-sea crane control order/status data 403
Optical interface
211
Navigation control system
212
Navigation sensor
113
Attitude sensors
214
Navigation order 404
Navigation control system 291
Deep-sea crane 001
integrated control
215
Position speed control system
216
Attitude control system
217
Calculate individual thruster force
218
Calculate individual control value
219
Calculate individual braking value
220
Individual thruster controller
221
Wing controller
222
Thruster dynamics $B_0/(s+B_1)$
223
Wing dynamics $B_0/(s+B_1)$
224
Brake dynamics
225
Deep-sea crane dynamics 226

Fig. 15

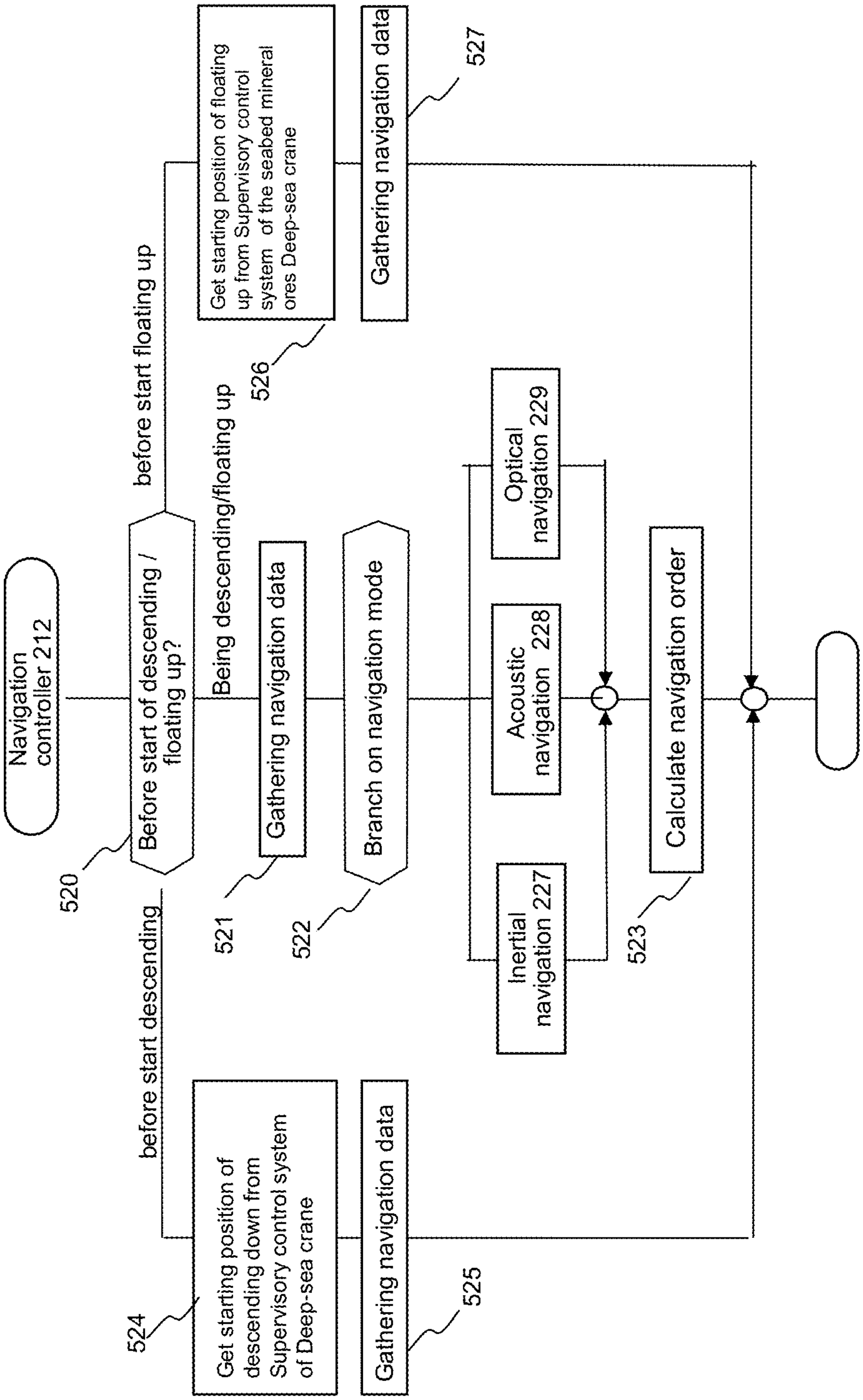
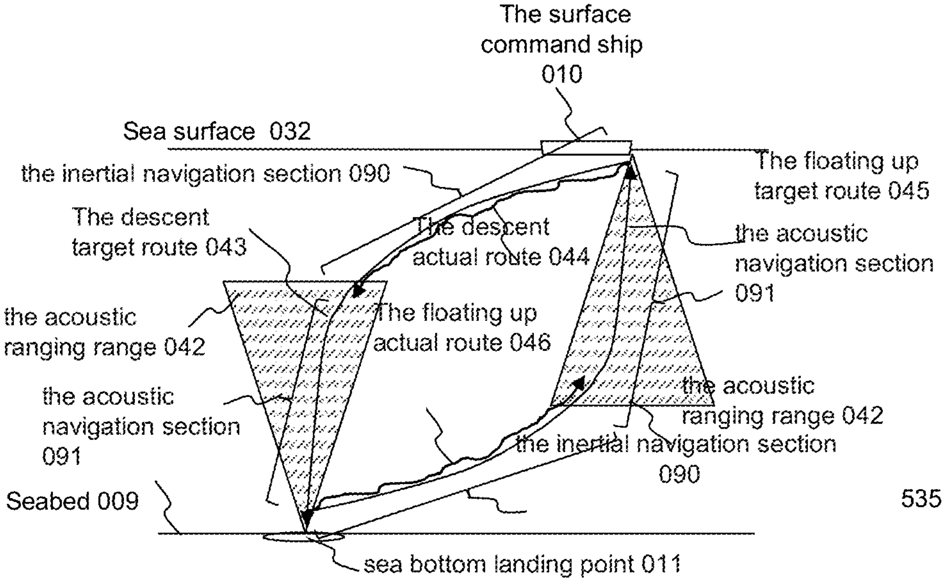

Navigation controller 212
520
Before start of descending / floating up?
before start descending
Being descending/floating up
before start floating up
524
Get starting position of descending down from Supervisory control system of Deep-sea crane
525
Gathering navigation data
521
Gathering navigation data
522
Branch on navigation mode
Inertial navigation 227
Acoustic navigation 228
Optical navigation 229
523
Calculate navigation order
526
Get starting position of floating up from Supervisory control system of the seabed mineral ores Deep-sea crane
527
Gathering navigation data

Fig. 16A



(a)

Fig. 16B

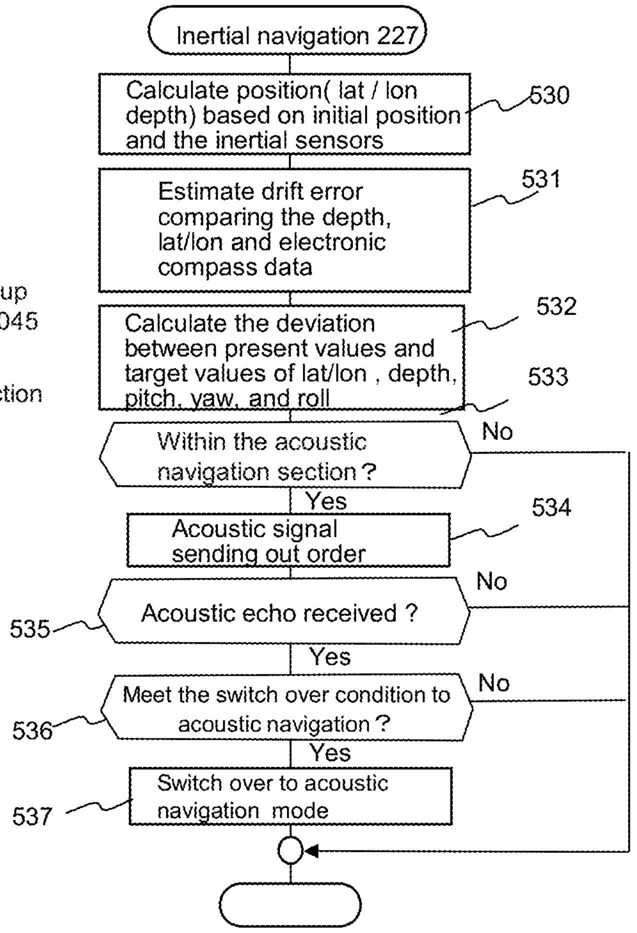


Fig. 17A

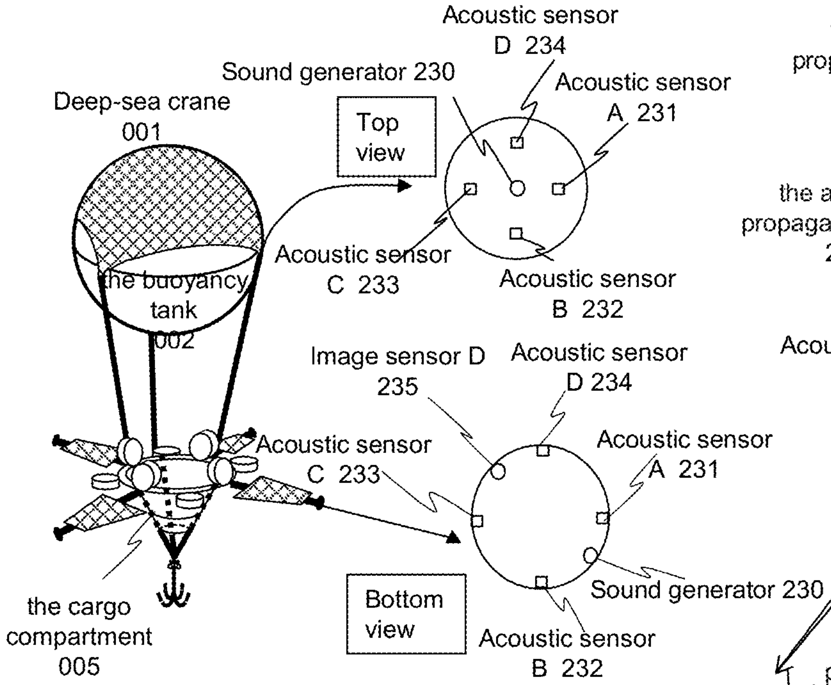


Fig. 17B

Fig. 17C

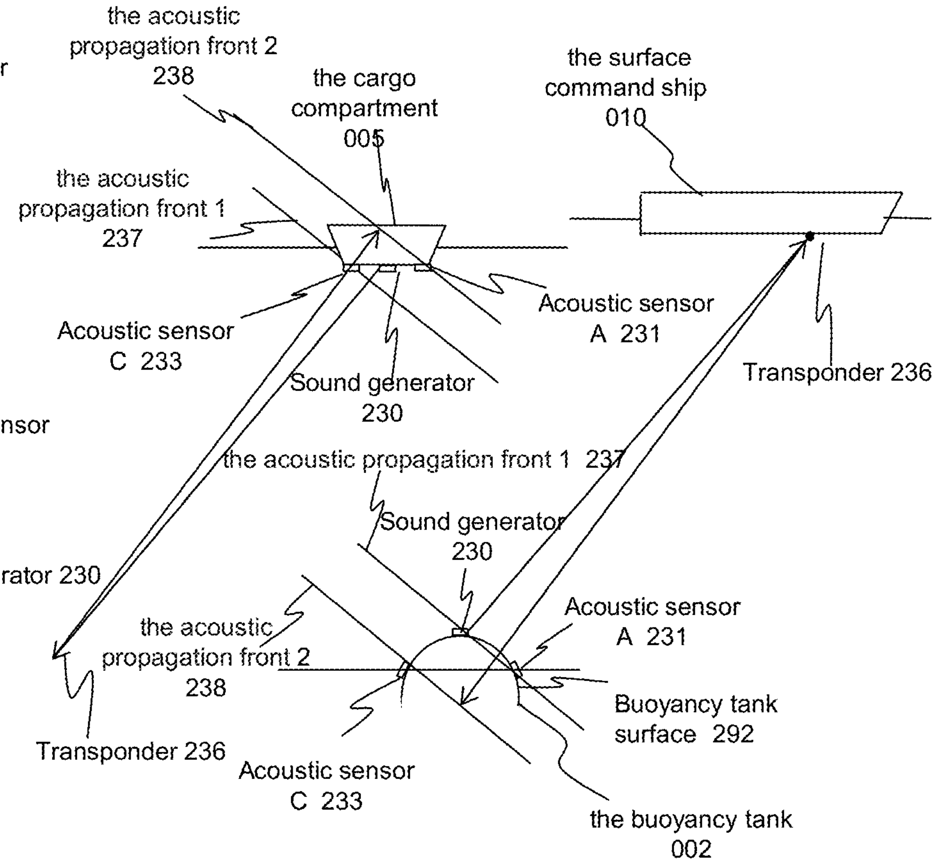


Fig. 18A

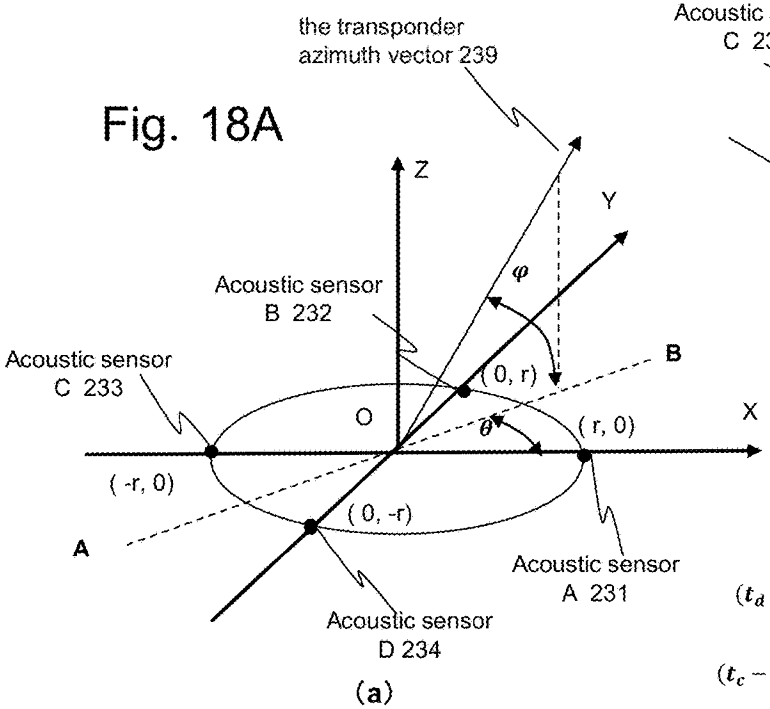


Fig. 18B

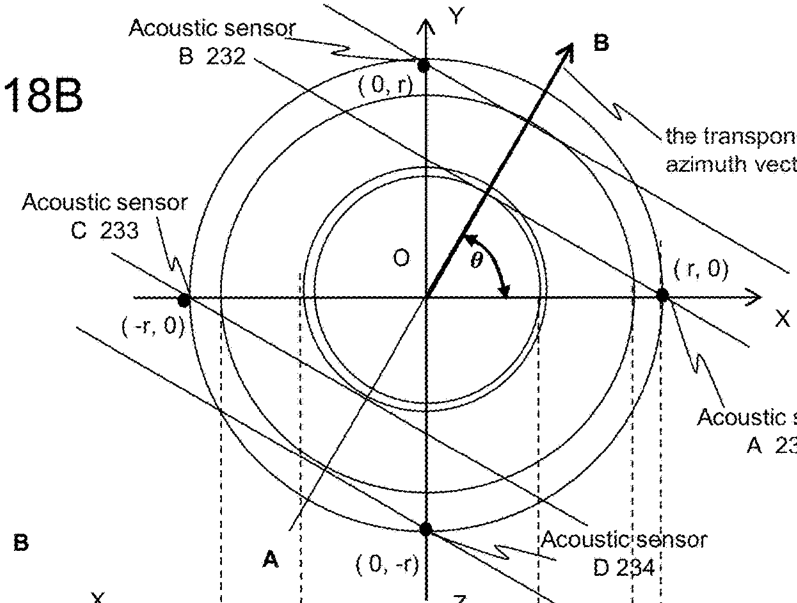


Fig. 18C

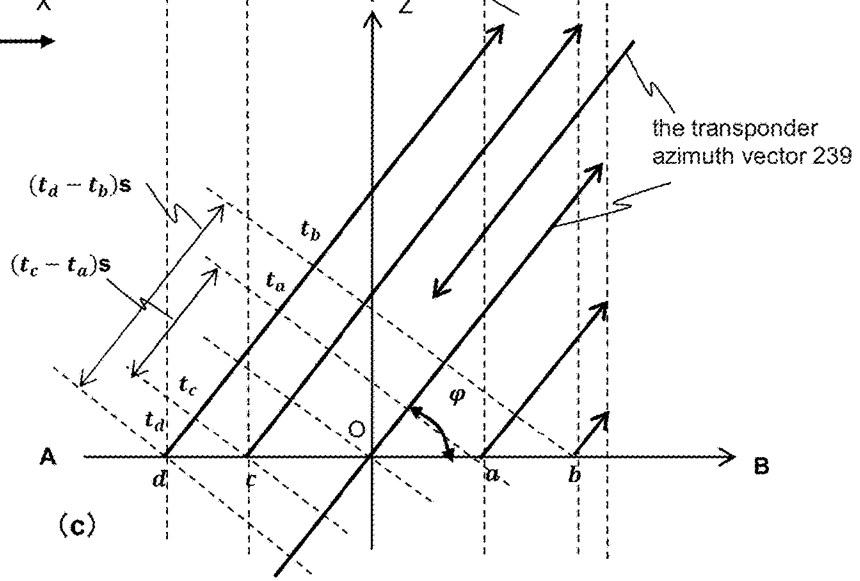


Fig. 19

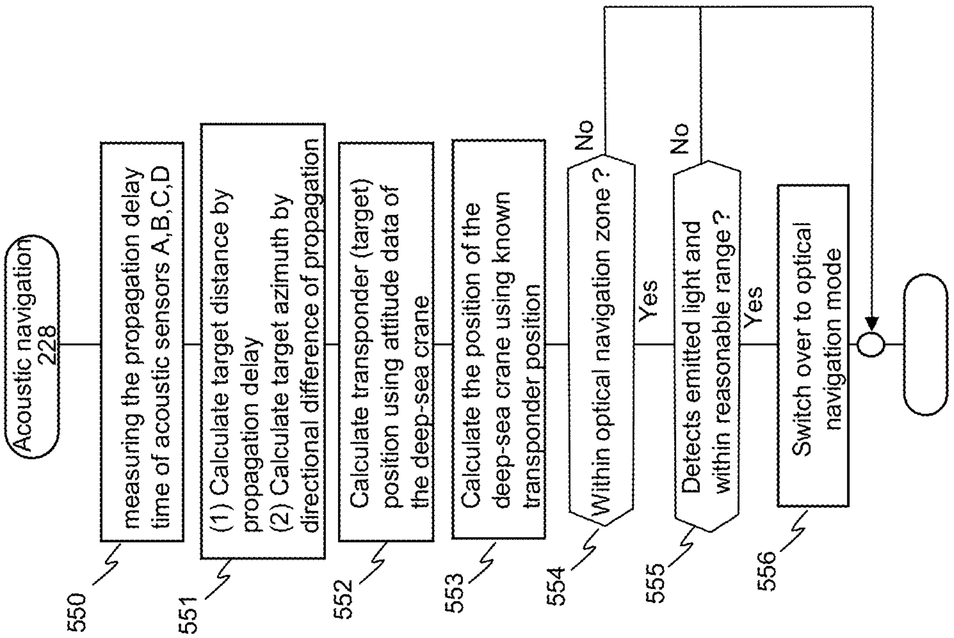

Acoustic navigation
228
measuring the propagation delay time of acoustic sensors A,B,C,D
550
(1) Calculate target distance by propagation delay
(2) Calculate target azimuth by directional difference of propagation
551
Calculate transponder (target) position using attitude data of the deep-sea crane
552
Calculate the position of the deep-sea crane using known transponder position
553
Within optical navigation zone ?
554
No
Yes
Detects emitted light and within reasonable range ?
555
No
Yes
Switch over to optical navigation mode
556

Fig. 20A

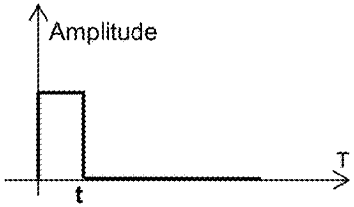


Fig. 20C

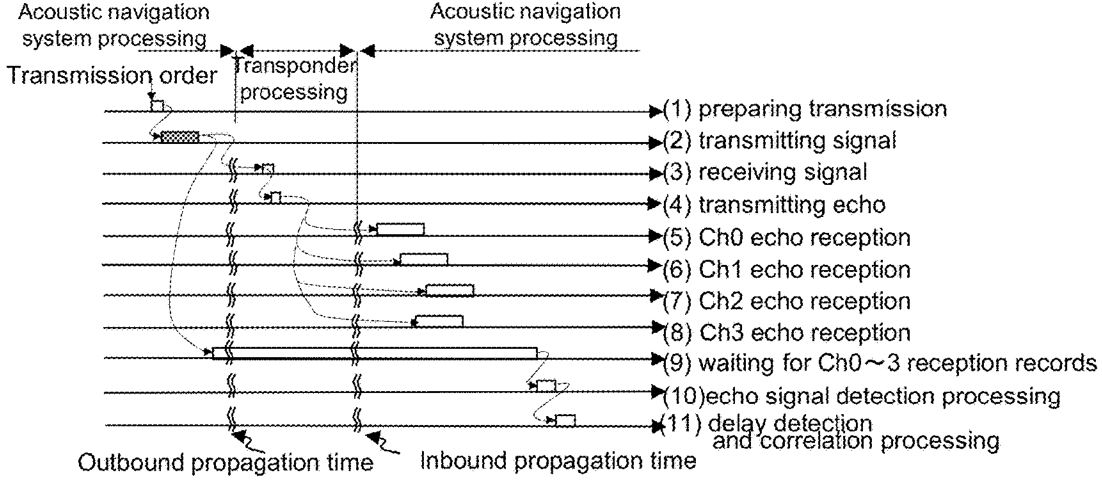


Fig. 20B

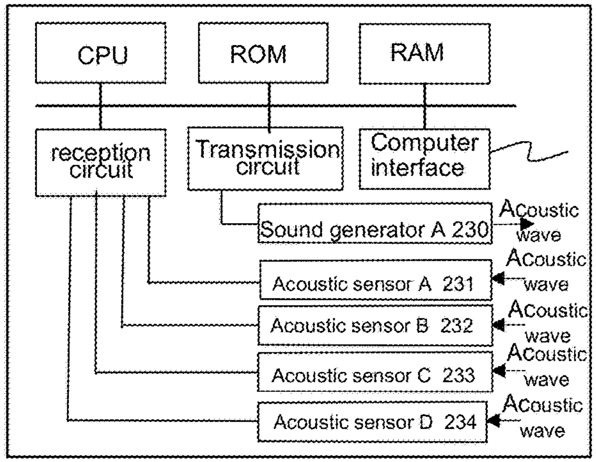


Fig. 20D

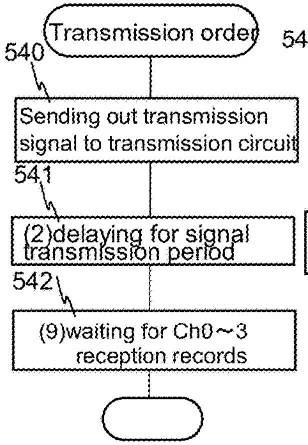


Fig. 20E

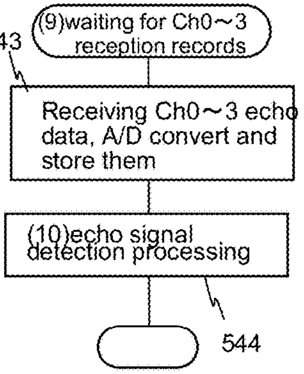


Fig. 20F

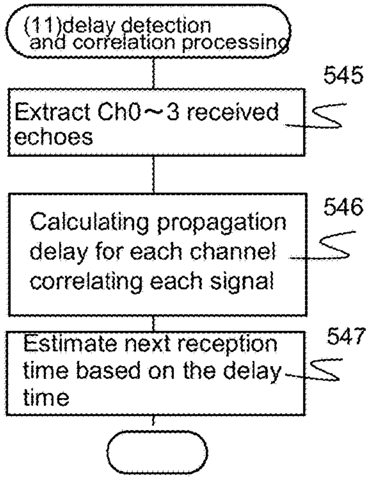


Fig. 21A

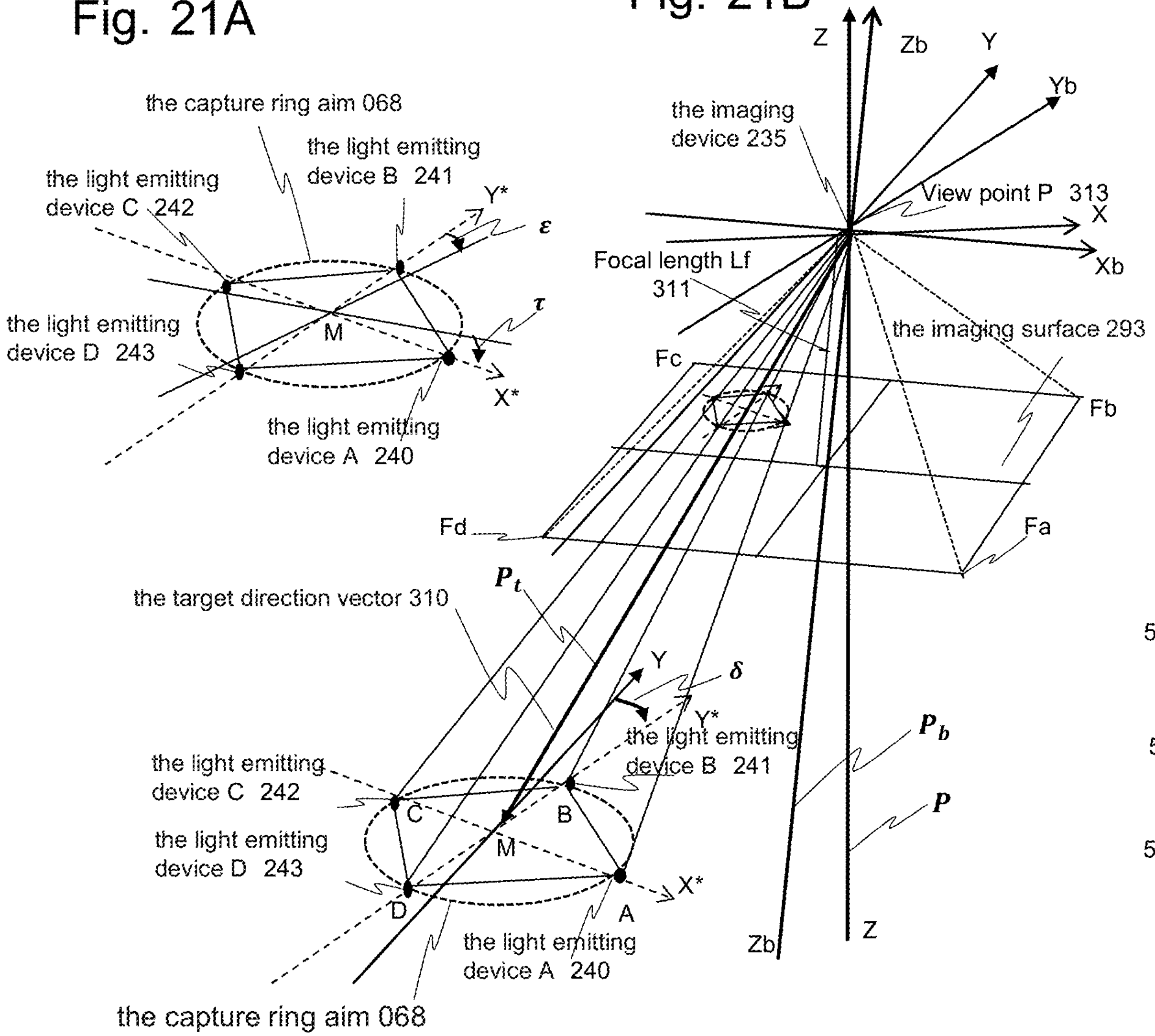


Fig. 21B

Fig. 21C

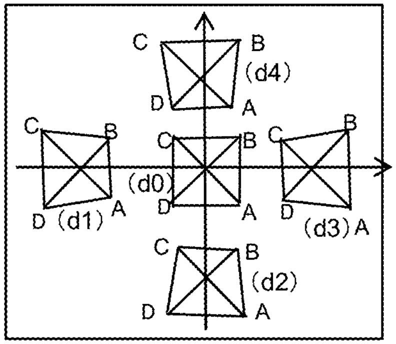
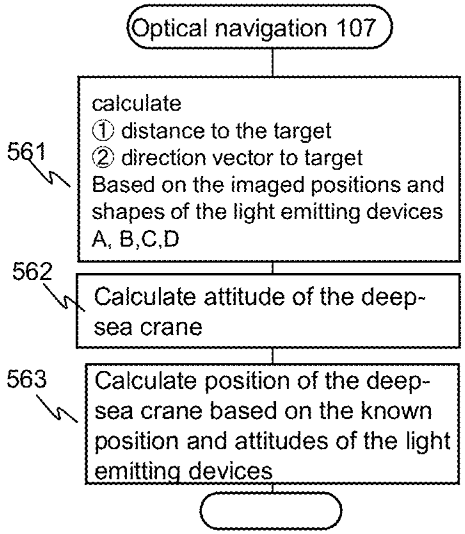


Fig. 21D



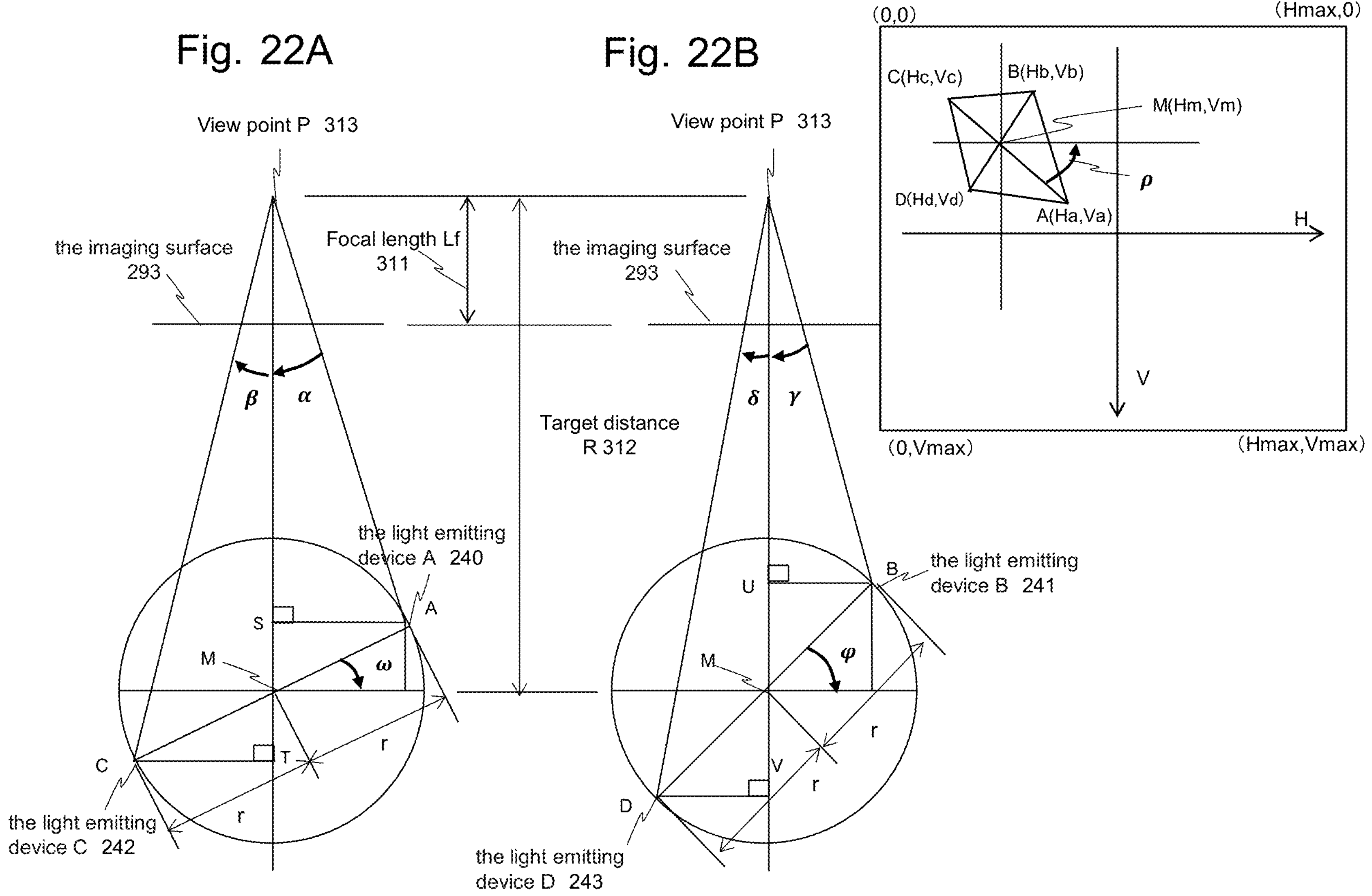


Fig. 22A

Fig. 22B

Fig. 22C

Fig. 23A

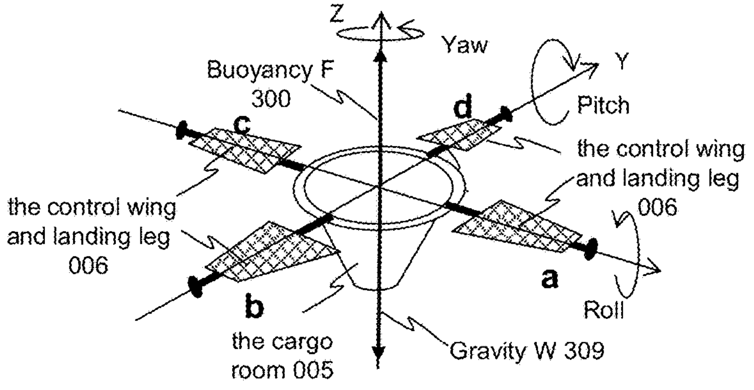


Fig. 23C

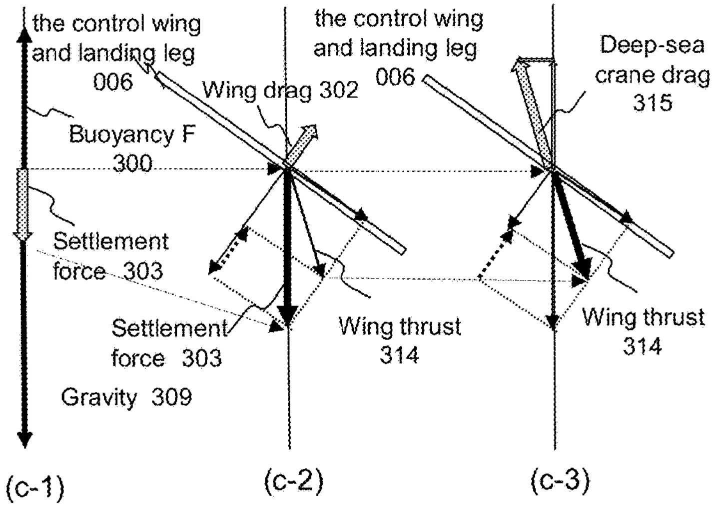


Fig. 23B

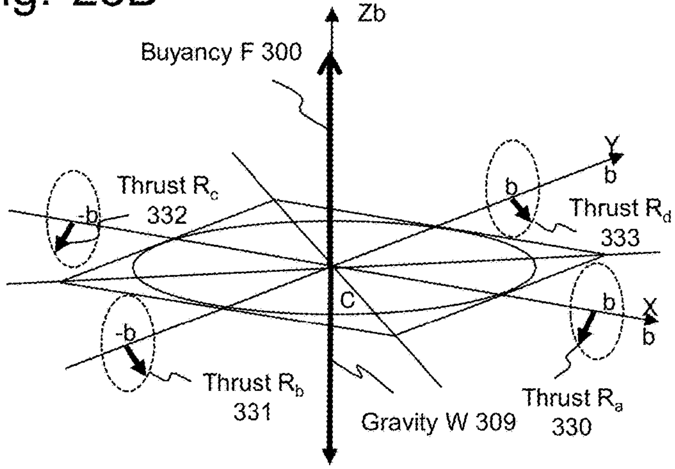


Fig. 23D

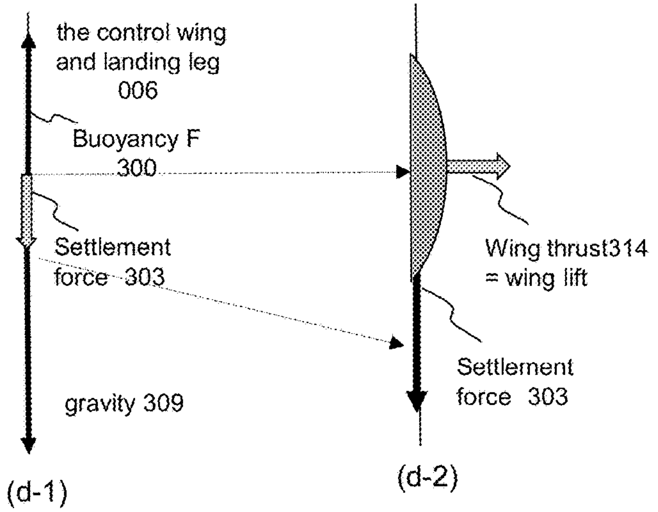
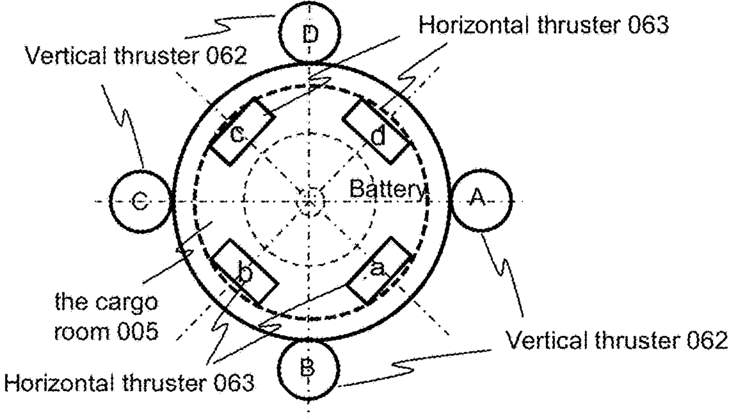


Fig. 24A



(a) Top view of attachment for precision control

Fig. 24C

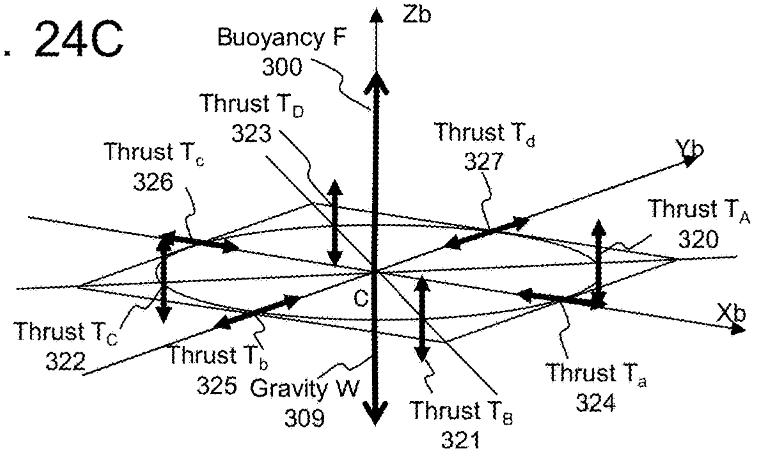


Fig. 24B

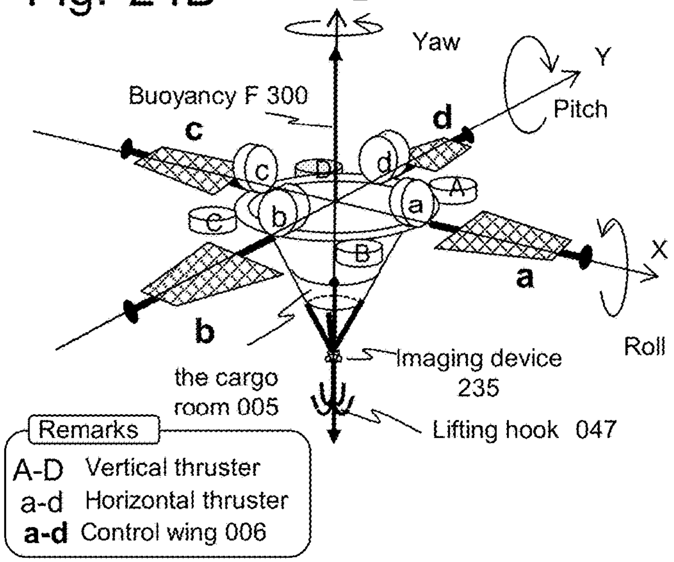


Fig. 24D

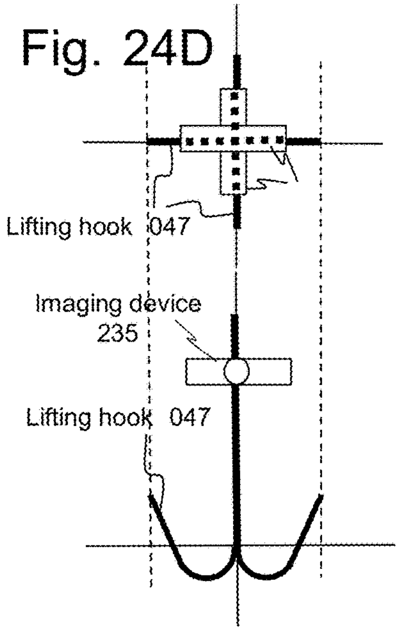


Fig. 24E

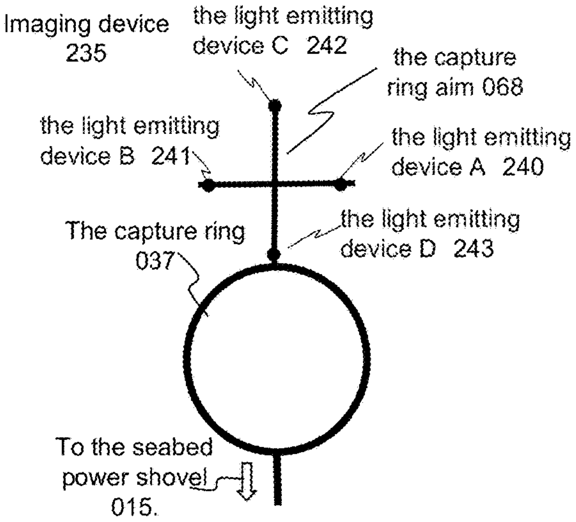


Fig. 25A

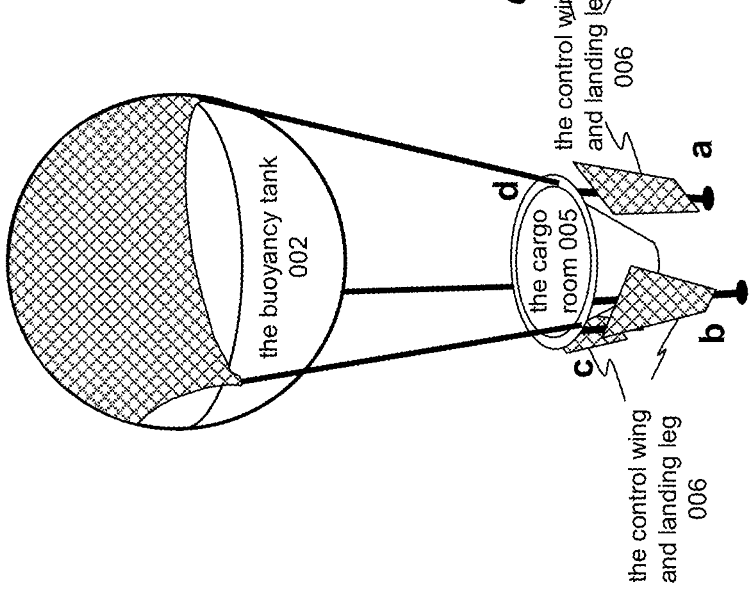


Fig. 25B

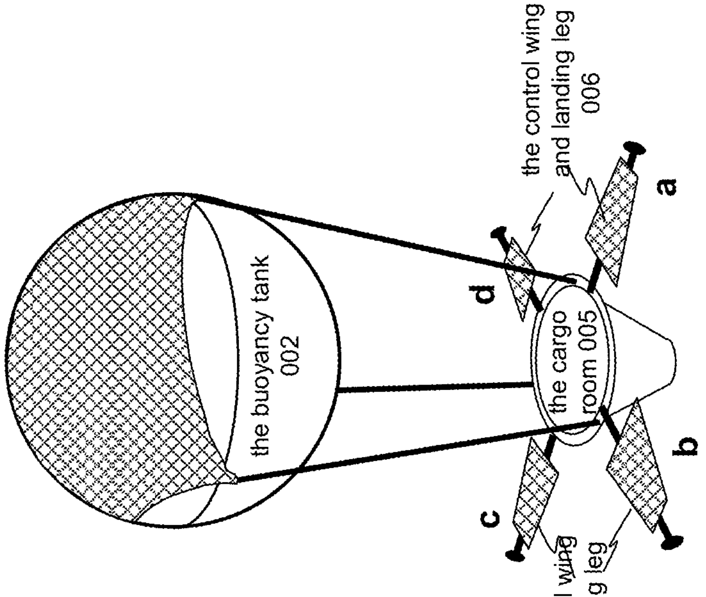


Fig. 26A

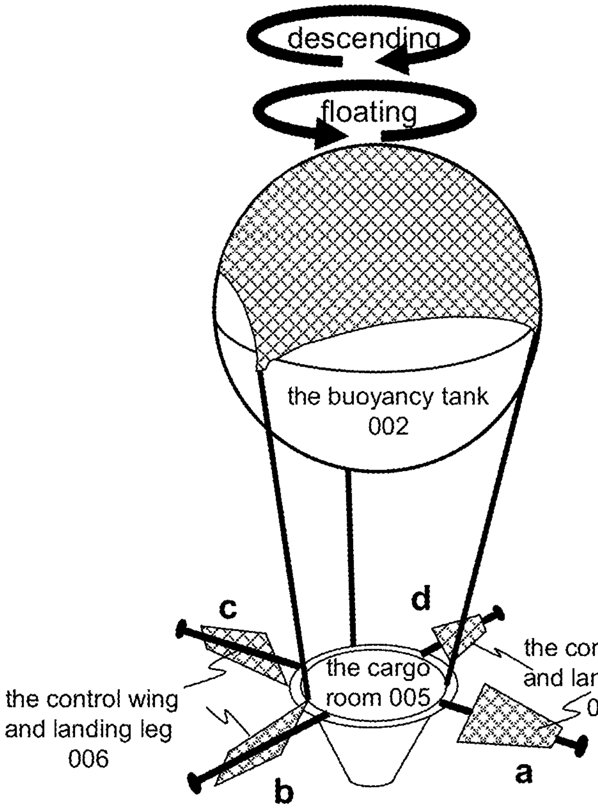


Fig. 26B

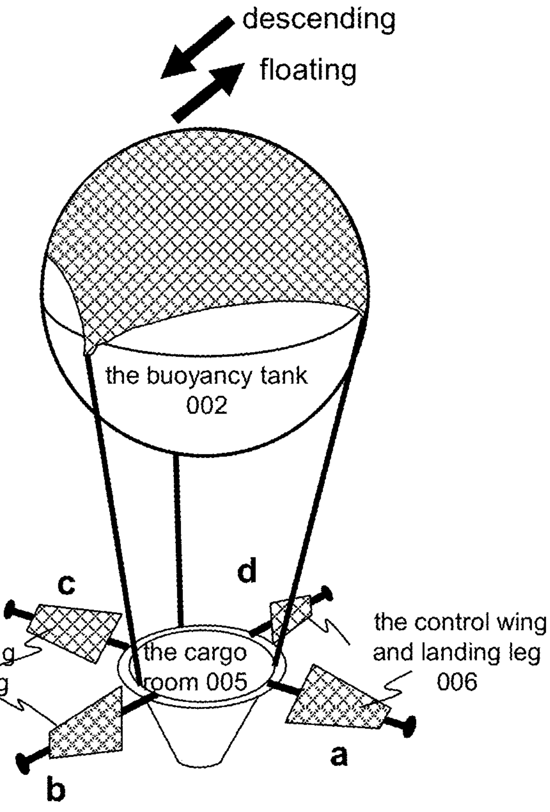


Fig. 26C

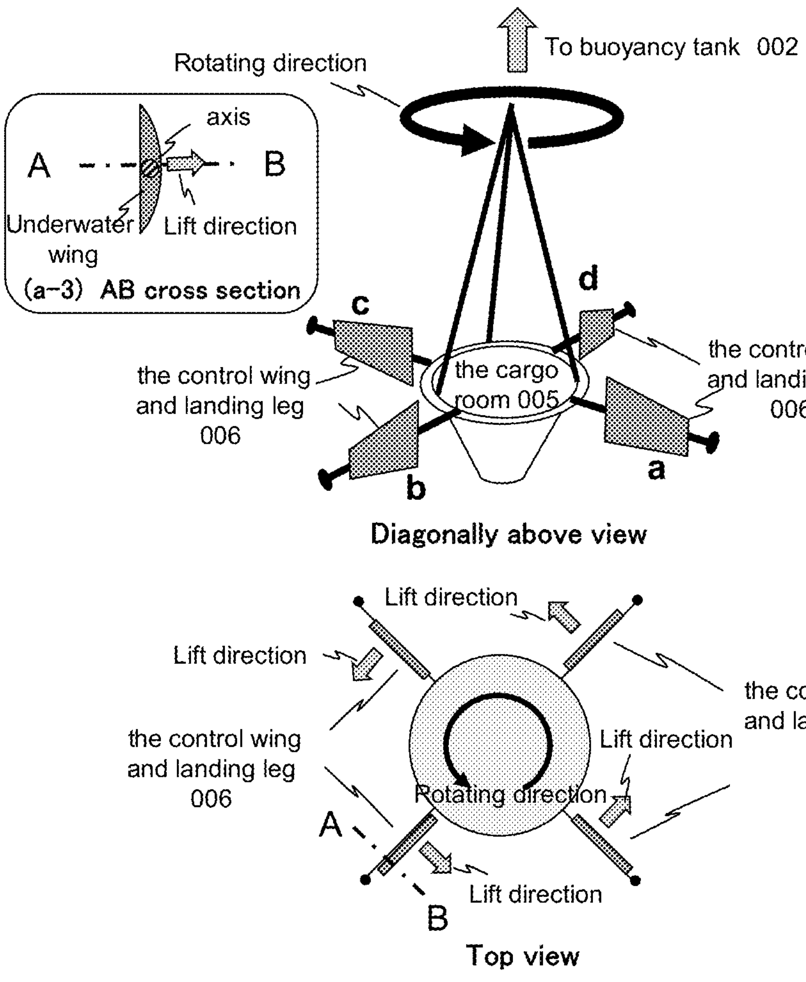


Fig. 26D

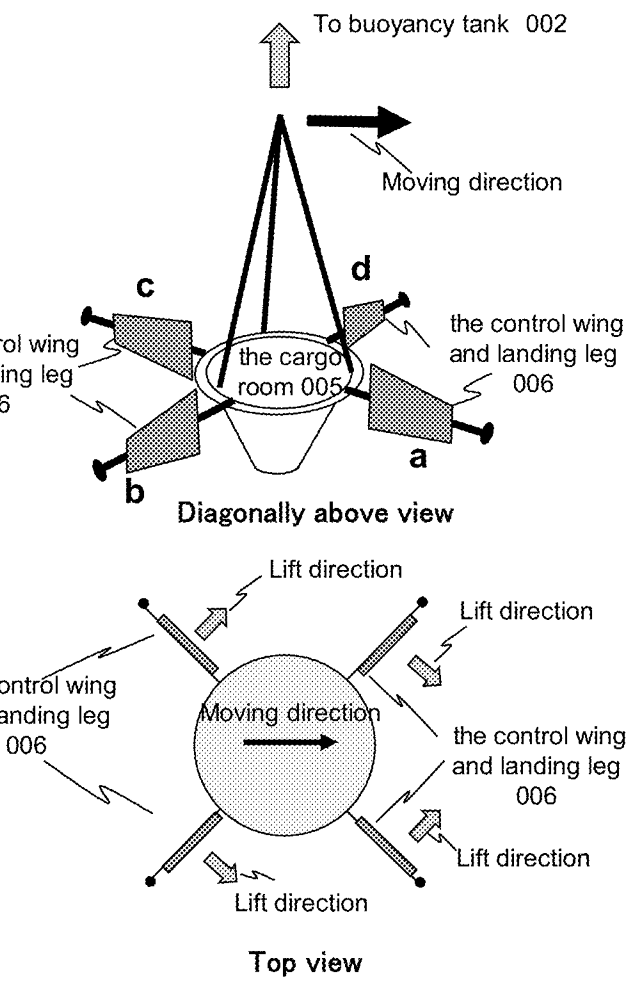


Fig. 27A

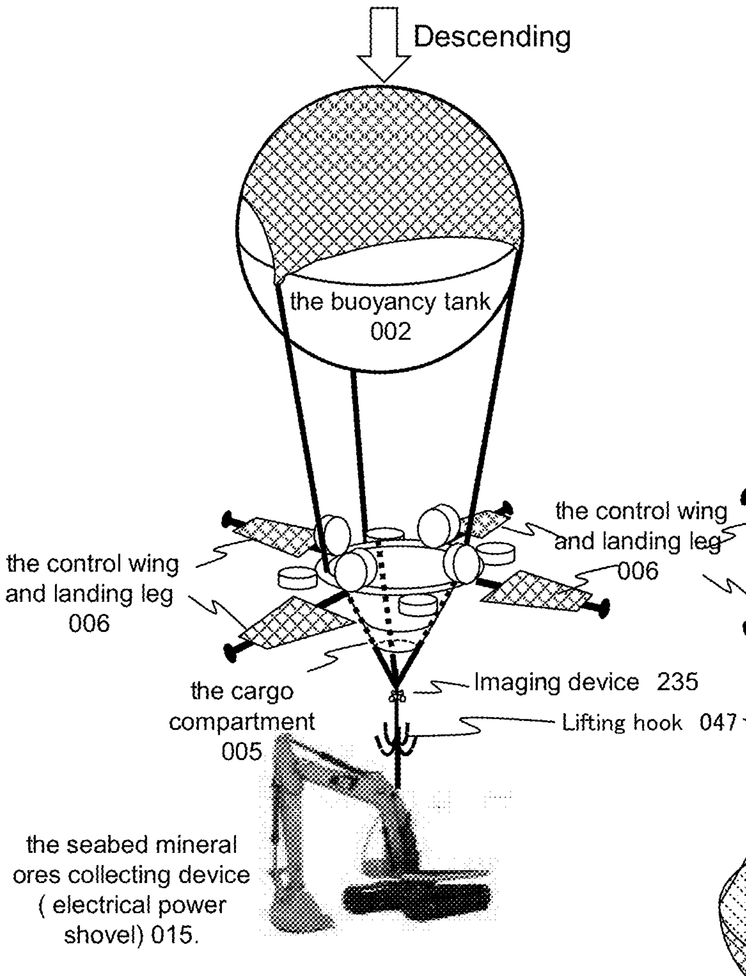
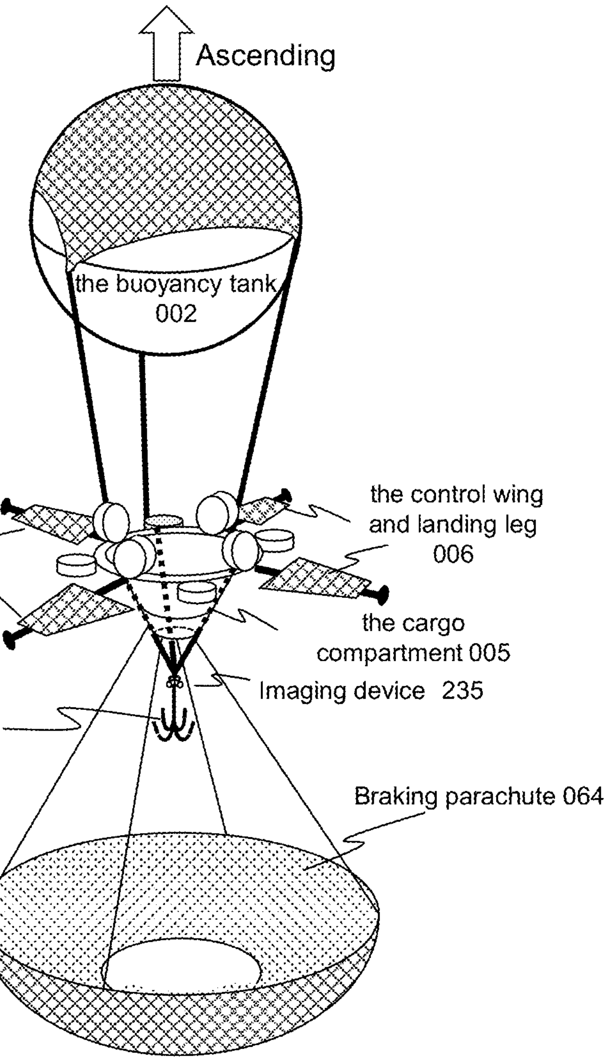


Fig. 27B



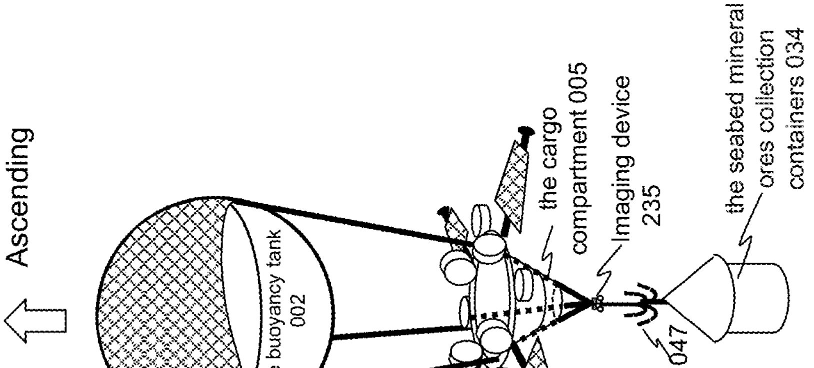


Fig. 28D

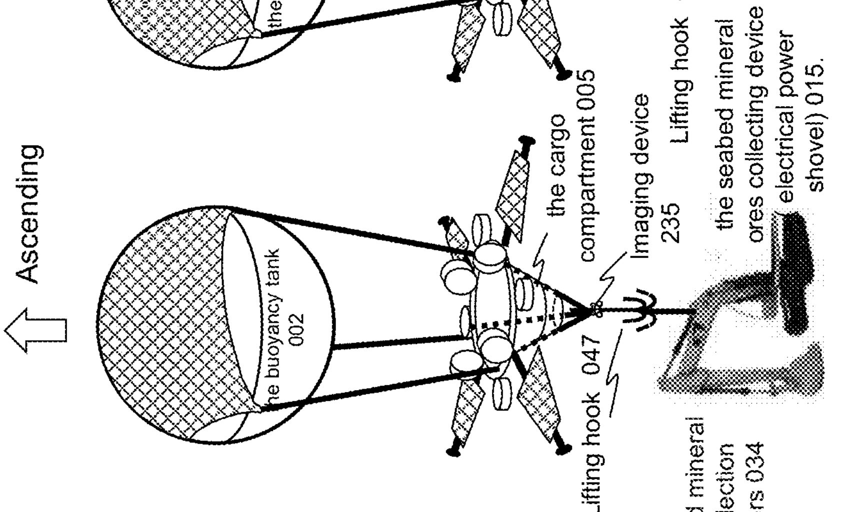


Fig. 28C

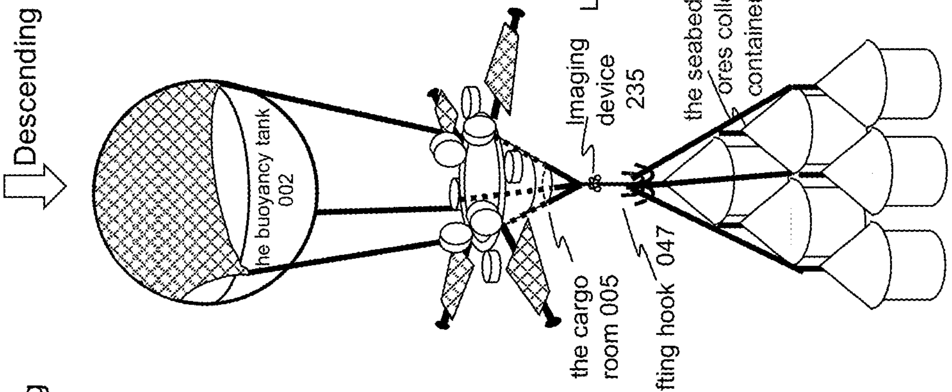


Fig. 28B

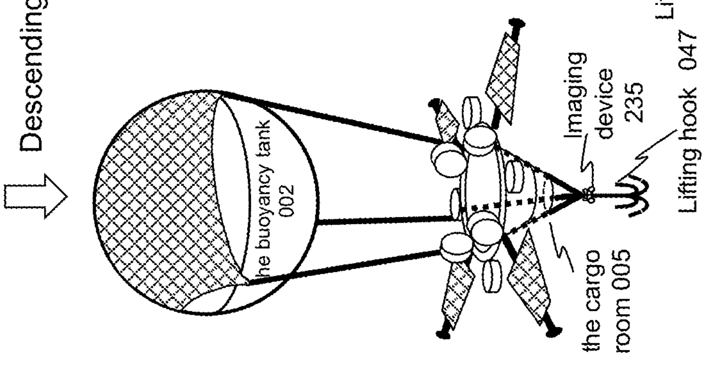


Fig. 28A

Fig. 29A

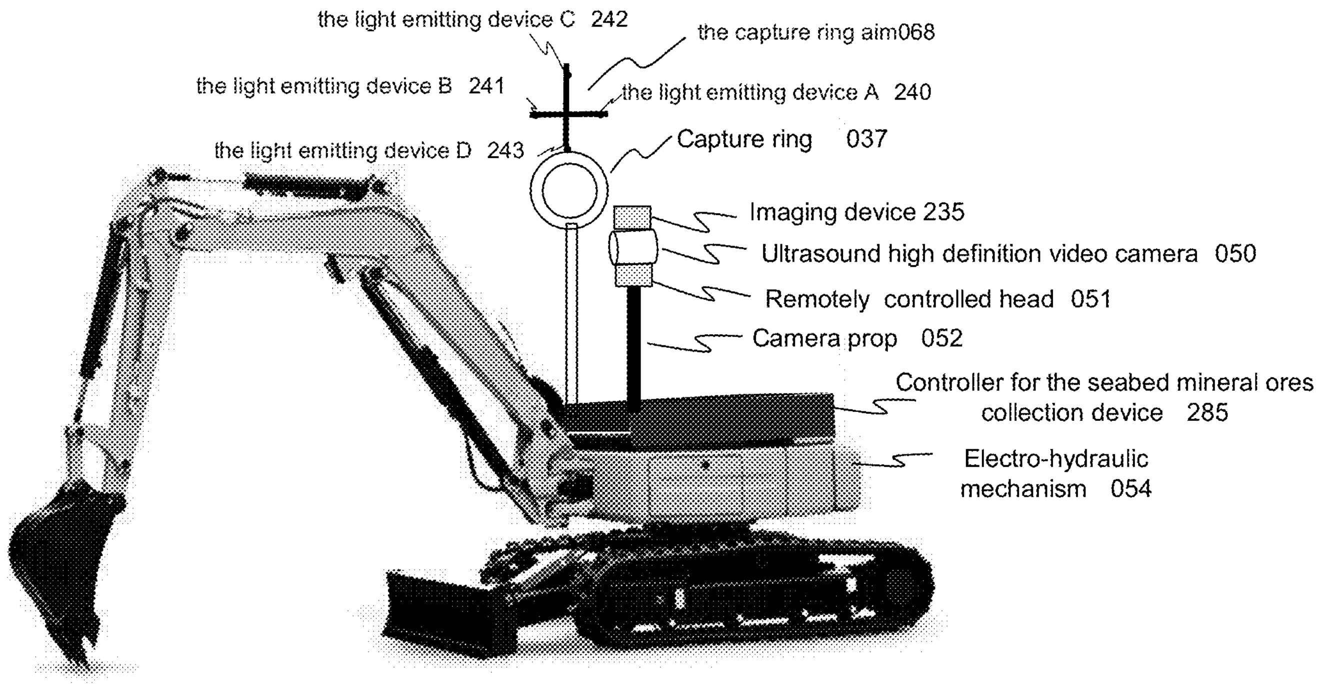


Fig. 29B

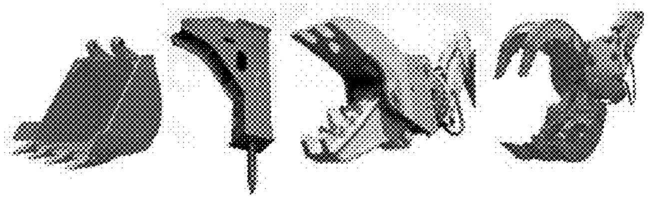


Fig. 30

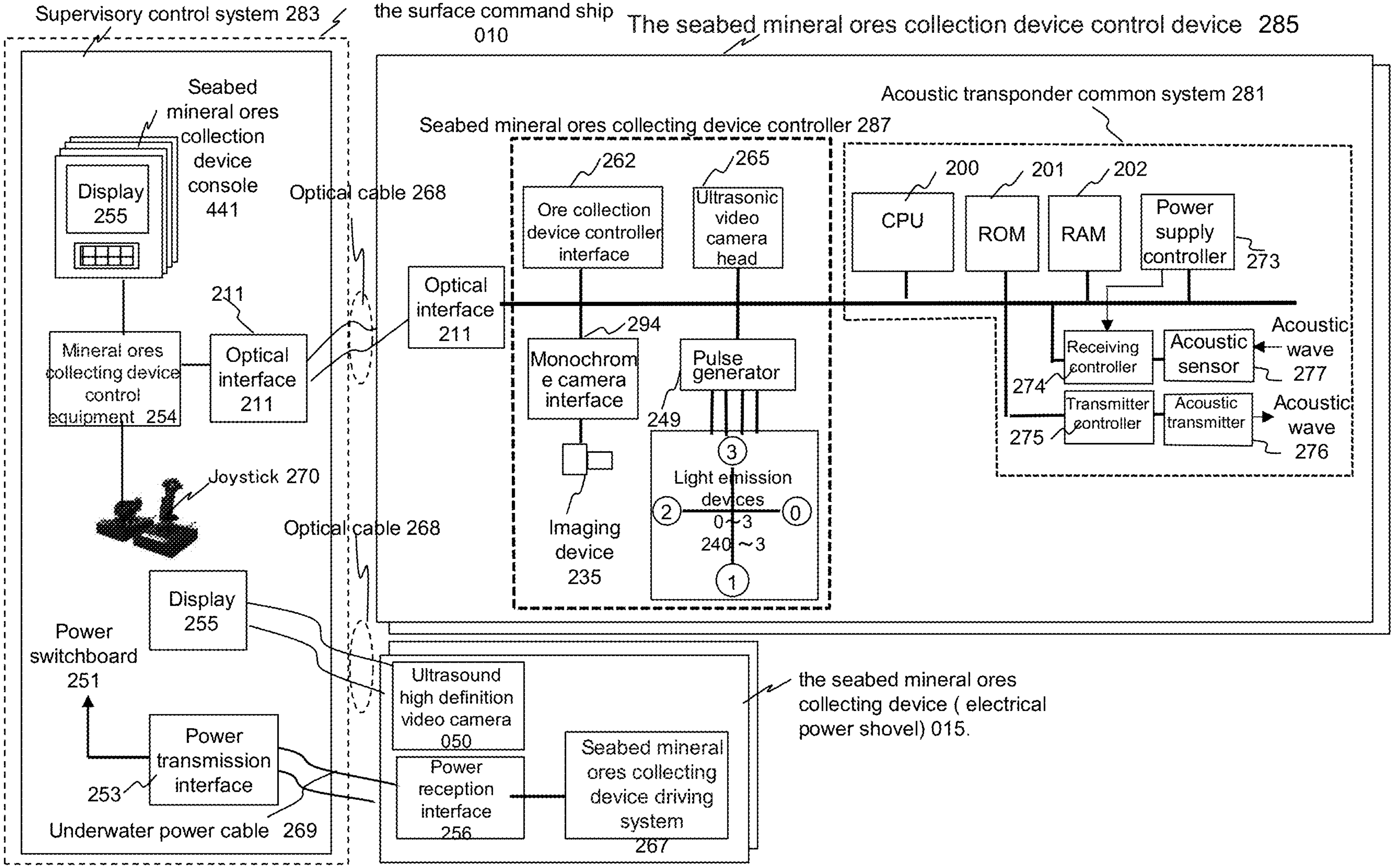

Supervisory control system 283
the surface command ship 010
The seabed mineral ores collection device control device 285
Acoustic transponder common system 281
Seabed mineral ores collecting device controller 287
Seabed mineral ores collection device console 441
Display 255
Optical cable 268
262
265
200
201
202
CPU
ROM
RAM
Power supply controller
273
Ore collection device controller interface
Ultrasonic video camera head
Optical interface 211
211
Optical interface 211
Mineral ores collecting device control equipment 254
294
Monochrome camera interface
Pulse generator
249
Receiving controller
Acoustic sensor
Acoustic wave 277
274
Transmitter controller
Acoustic transmitter
Acoustic wave 276
275
3
Light emission devices
2
0
0~3
240~3
1
Imaging device 235
Joystick 270
Optical cable 268
Display 255
Power switchboard 251
Ultrasound high definition video camera 050
the seabed mineral ores collecting device (electrical power shovel) 015.
Power transmission interface
253
Power reception interface 256
Seabed mineral ores collecting device driving system 267
Underwater power cable 269

Fig. 31A

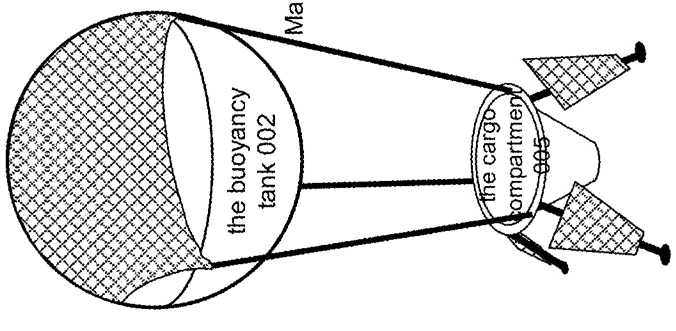


Fig. 31B

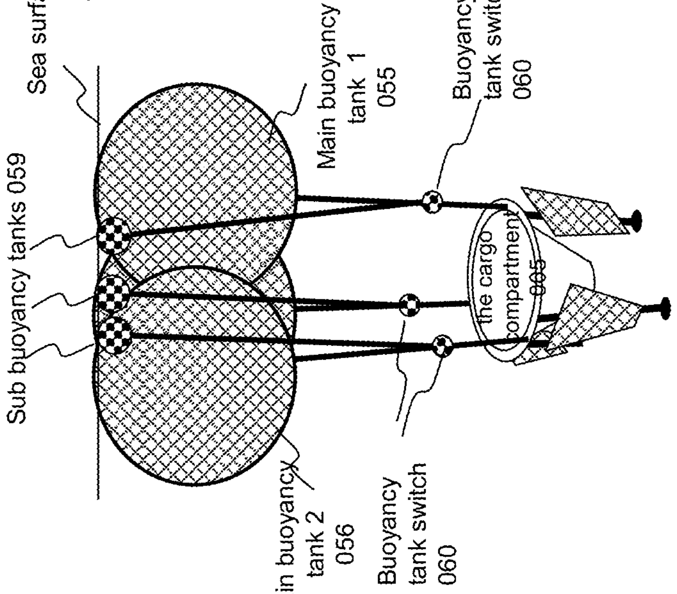


Fig. 31C

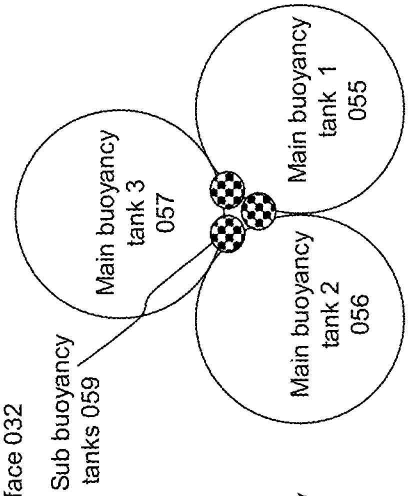


Fig. 31D

Fig. 31E

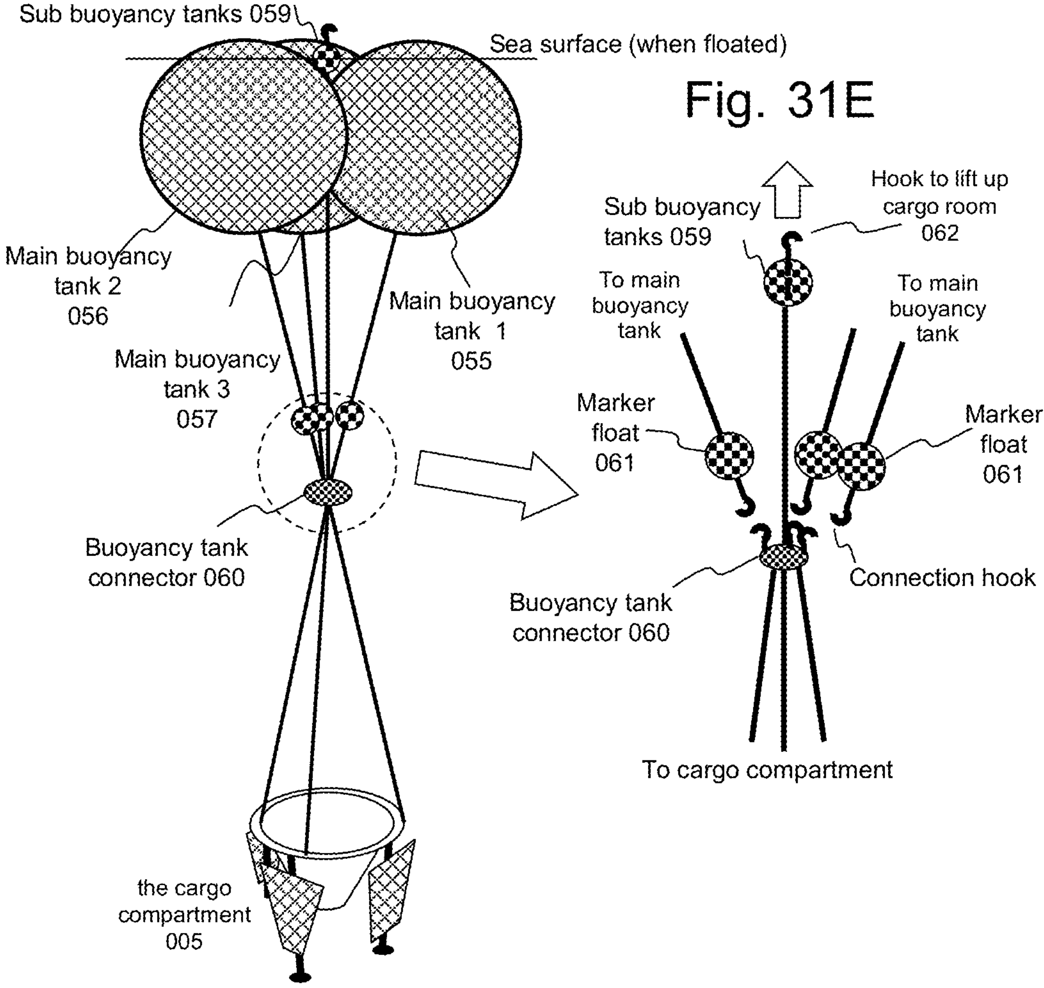


Fig. 31F

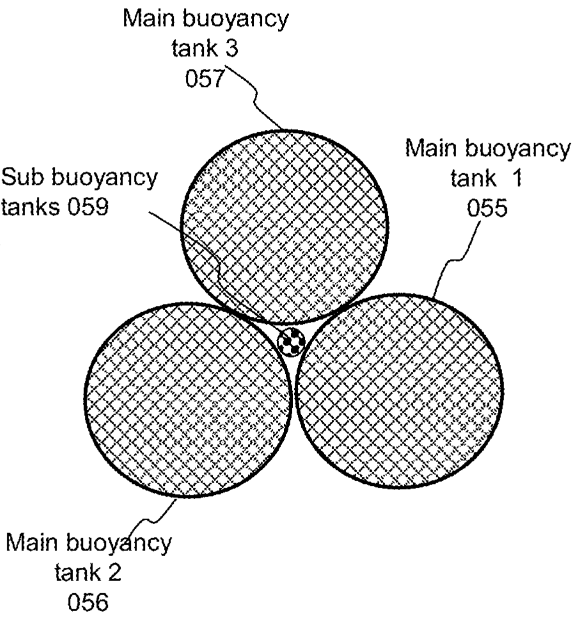


Fig. 32

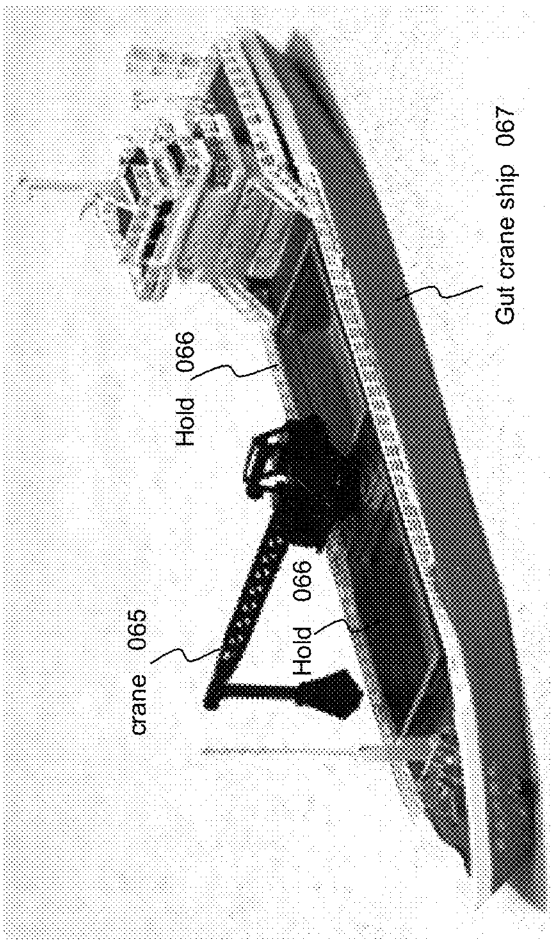


Fig. 33A

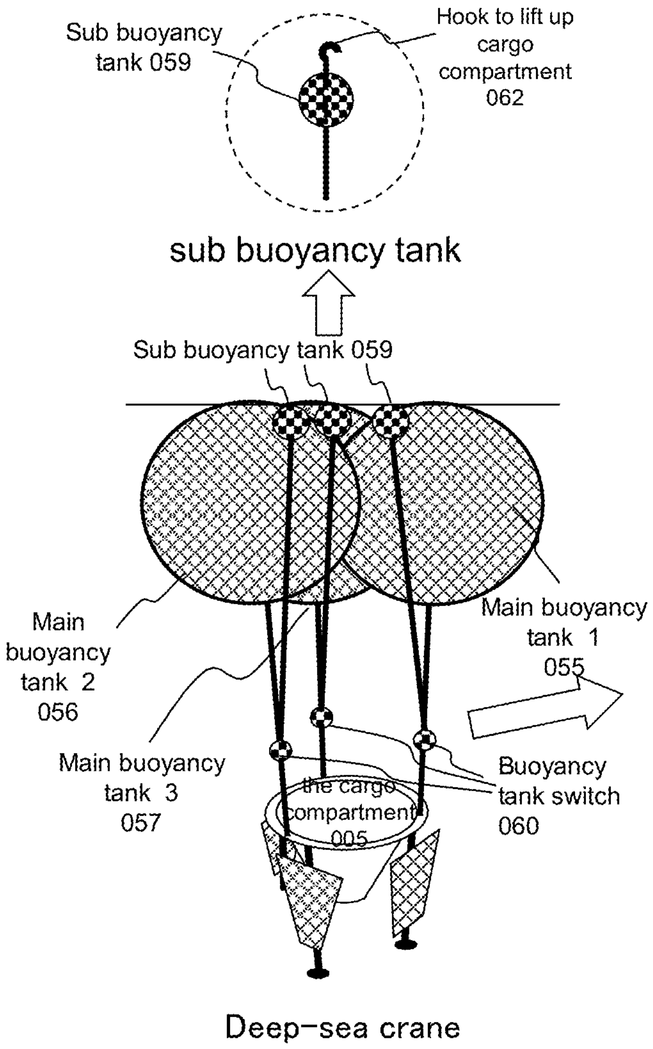


Fig. 33B

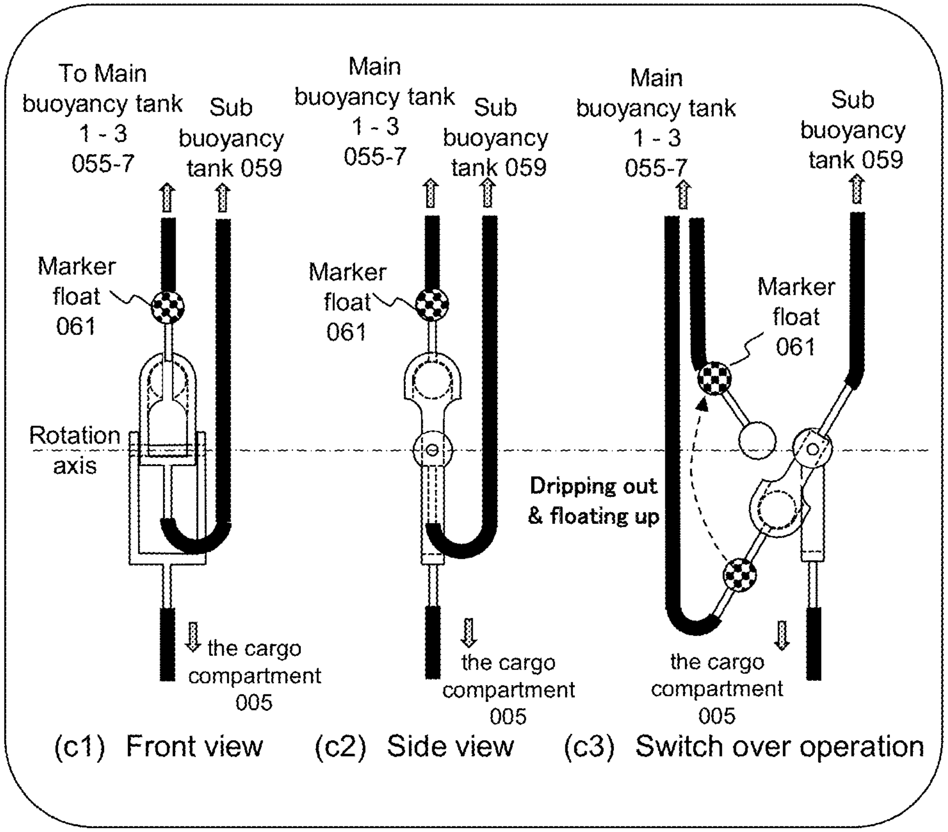


Fig. 34A

Descending crane

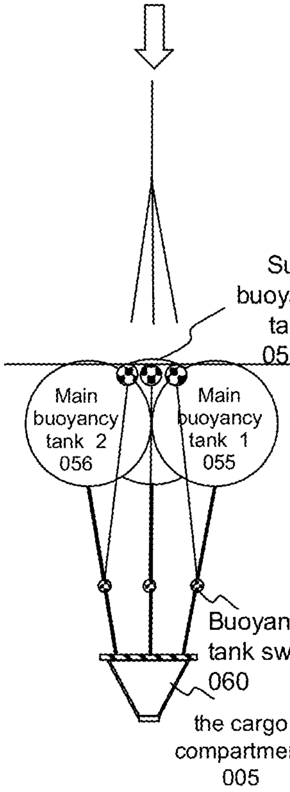


Fig. 34B

Connecting the crane
and the hooks
(by sea surface work)

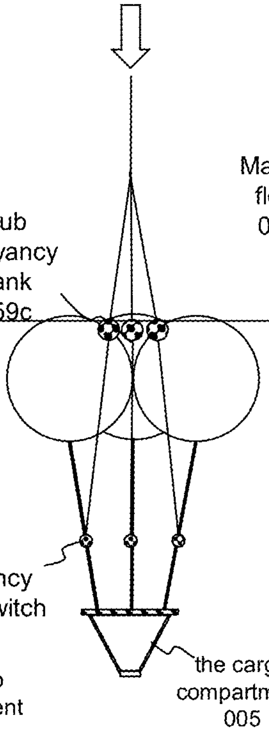


Fig. 34C

Pulling up the
cargo room

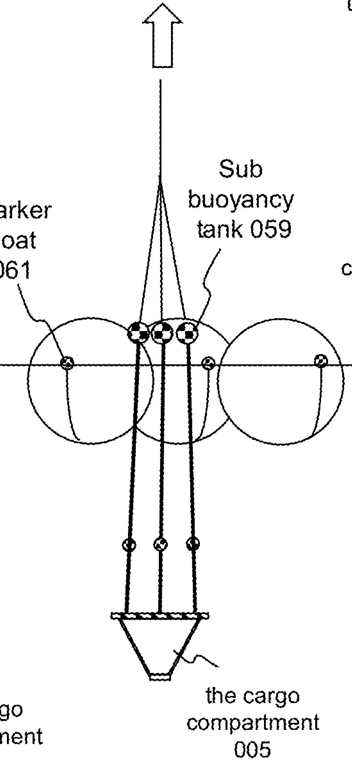
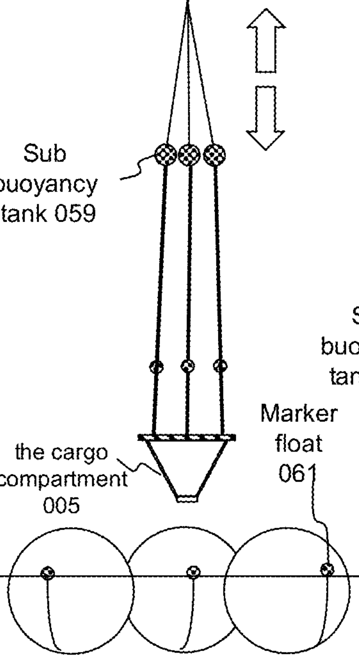
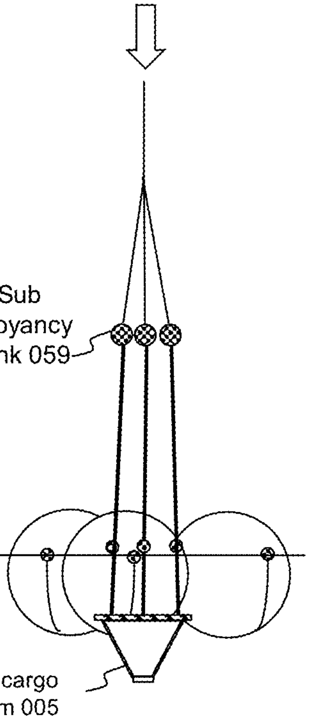


Fig. 34D



Pulling up the cargo
compartment w/ore and
descending down the
cargo room w/ballast
using crane

Fig. 34E



Connecting marker float
061 to buoyancy tank
switch 060
(by sea surface work)

Fig. 34F

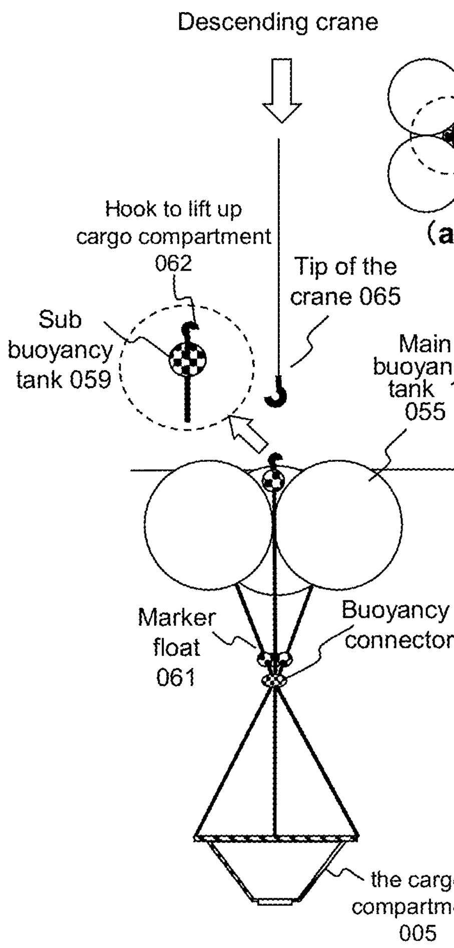
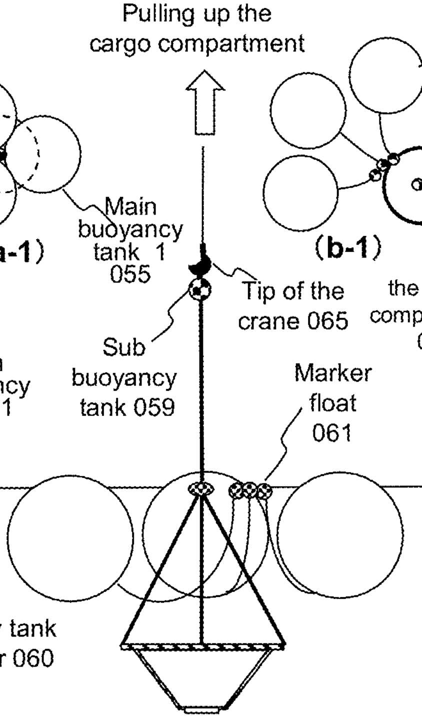
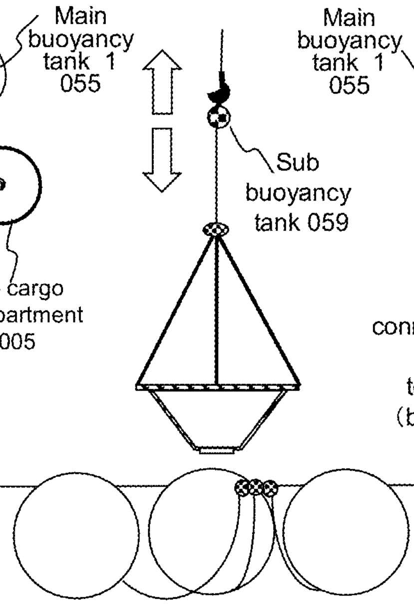


Fig. 34G



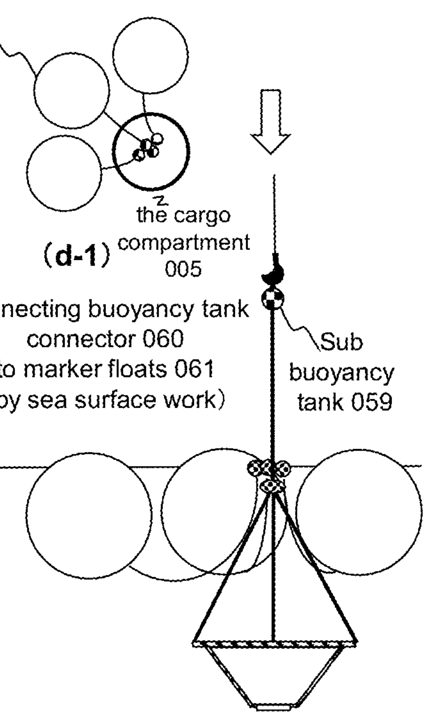
Separating buoyancy tank connector 060 from marker floats 061 (by sea surface work)

Fig. 34H



Pulling up the cargo room w/ore and descending down the cargo room w/ballast using crane

Fig. 34I



connecting buoyancy tank connector 060 to marker floats 061 (by sea surface work)

Fig. 35

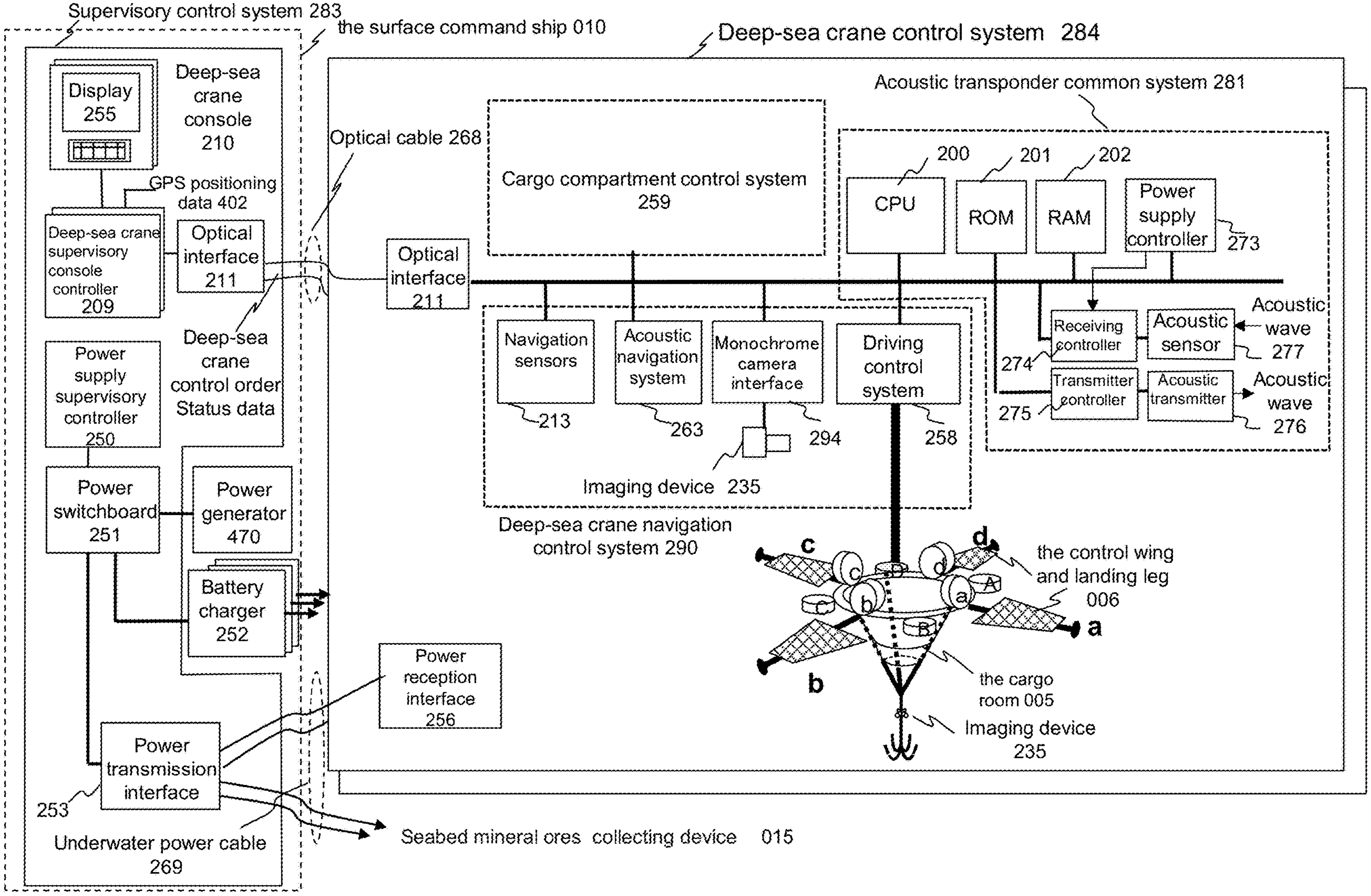

Supervisory control system 283
the surface command ship 010
Deep-sea crane control system 284
Acoustic transponder common system 281
Display 255
Deep-sea crane console 210
GPS positioning data 402
Deep-sea crane supervisory console controller 209
Optical interface 211
Optical cable 268
Optical interface 211
Deep-sea crane control order Status data
Cargo compartment control system 259
200
201
202
CPU
ROM
RAM
Power supply controller
273
Receiving controller
274
Acoustic sensor
Acoustic wave 277
Transmitter controller
275
Acoustic transmitter
Acoustic wave 276
Navigation sensors
213
Acoustic navigation system
263
Monochrome camera interface
294
Driving control system
258
Imaging device 235
Deep-sea crane navigation control system 290
Power supply supervisory controller 250
Power switchboard 251
Power generator 470
Battery charger 252
c
d
the control wing and landing leg 006
a
b
the cargo room 005
Imaging device 235
Power reception interface 256
Power transmission interface
253
Underwater power cable 269
Seabed mineral ores collecting device 015

Fig. 36A

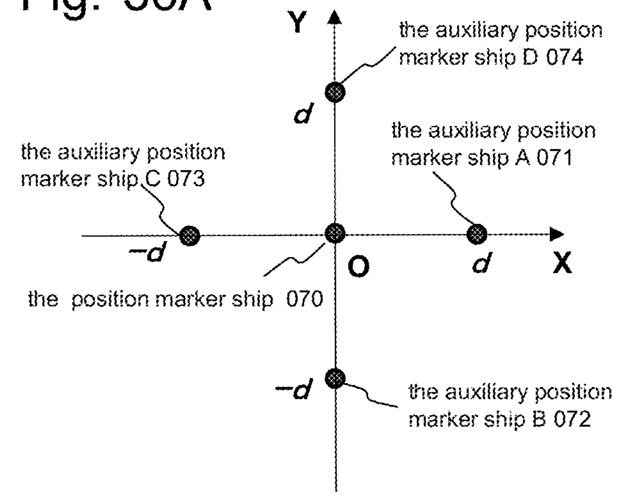


Fig. 36B

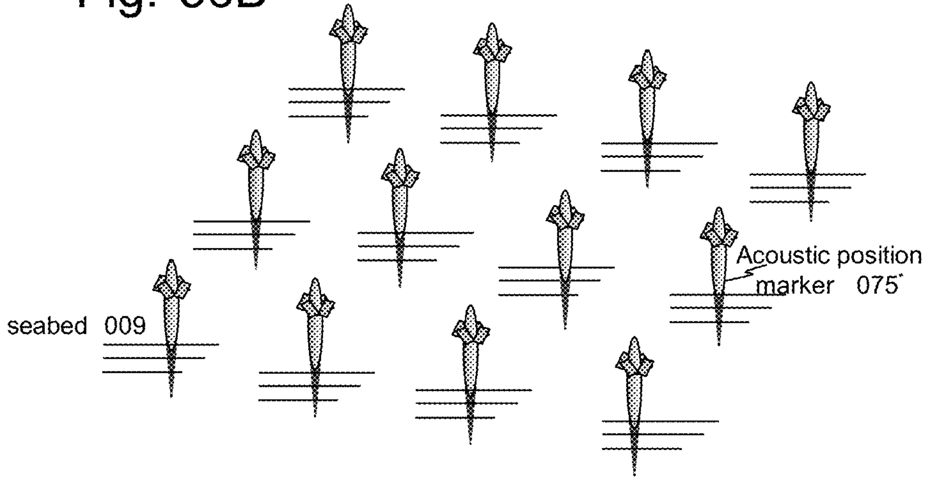


Fig. 36C

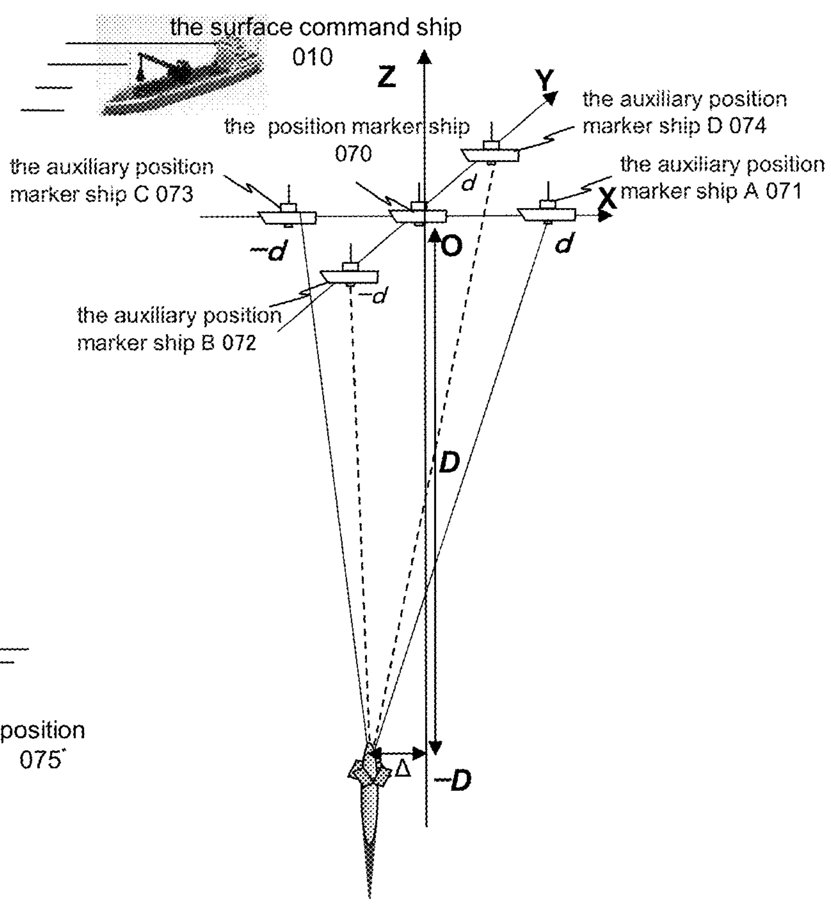


Fig. 37A

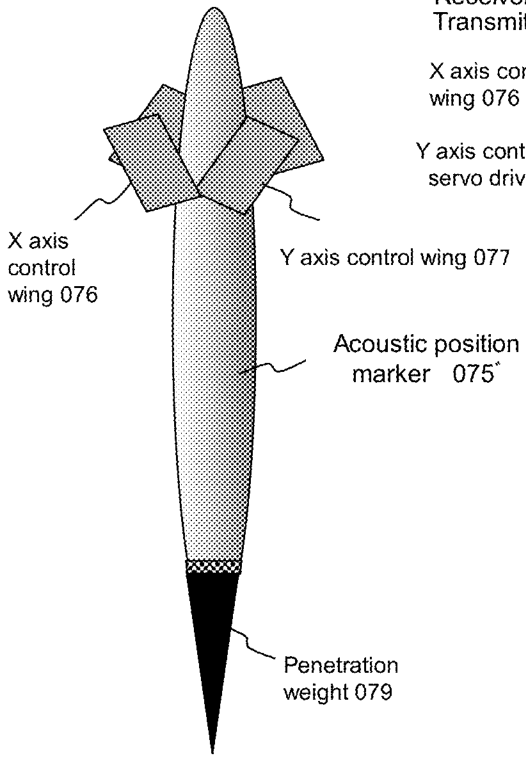


Fig. 37B

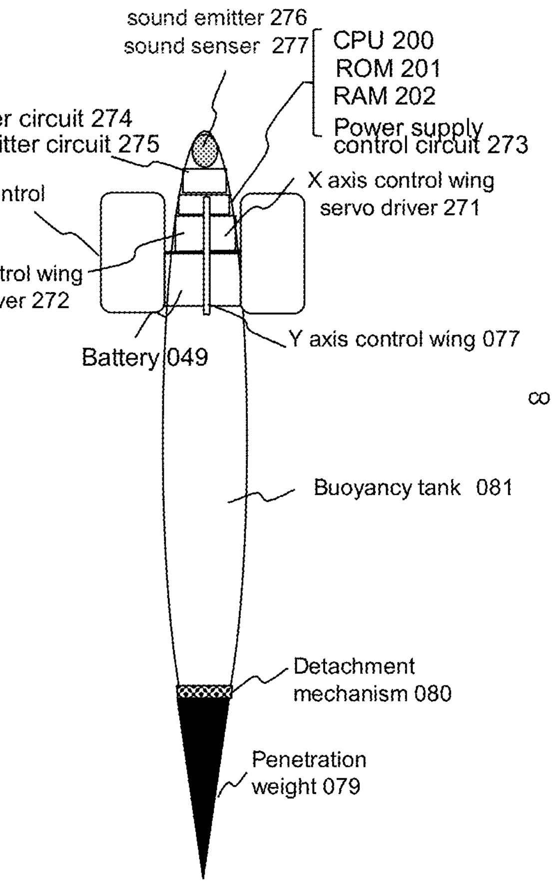


Fig. 37C

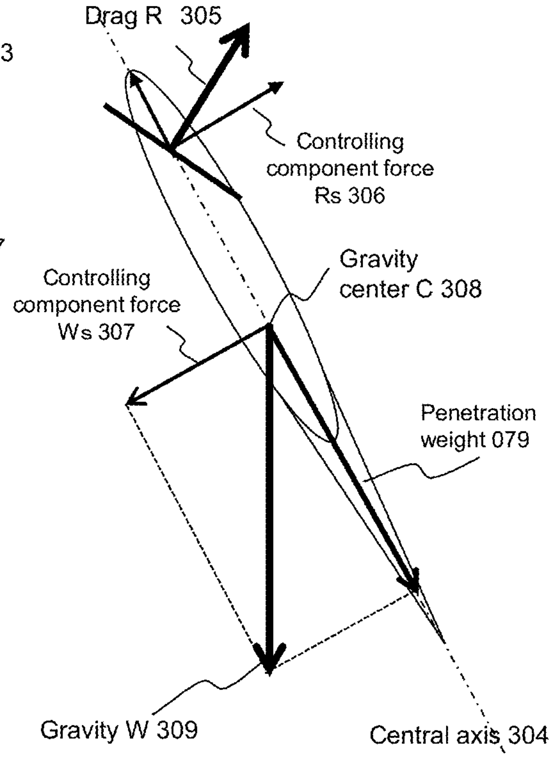


Fig. 38A

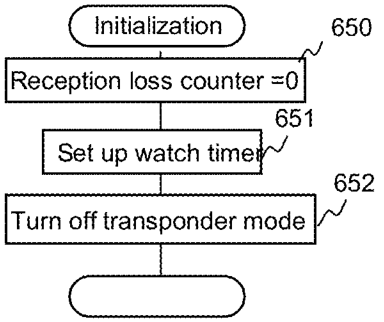


Fig. 38D

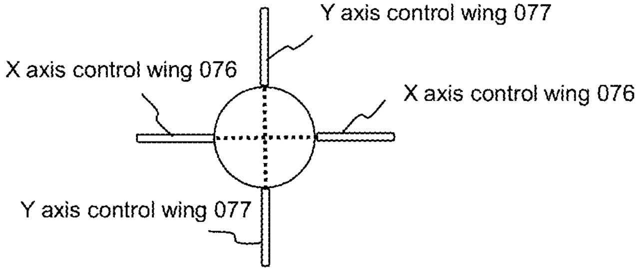


Fig. 38B

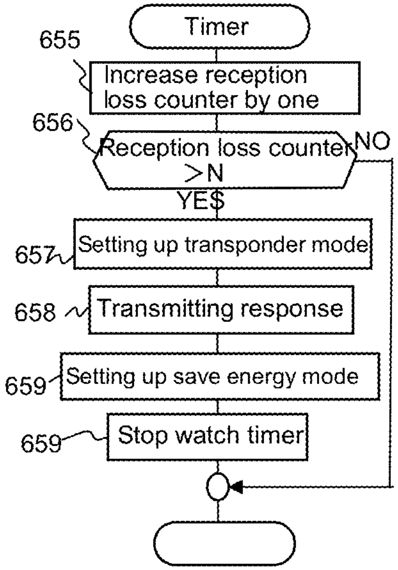


Fig. 38C

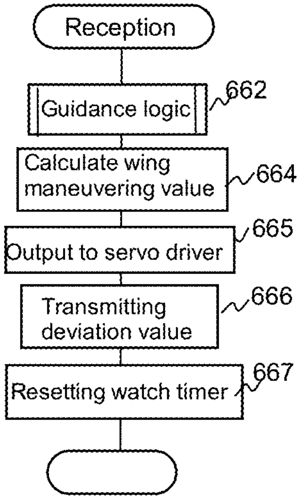


Fig. 38E

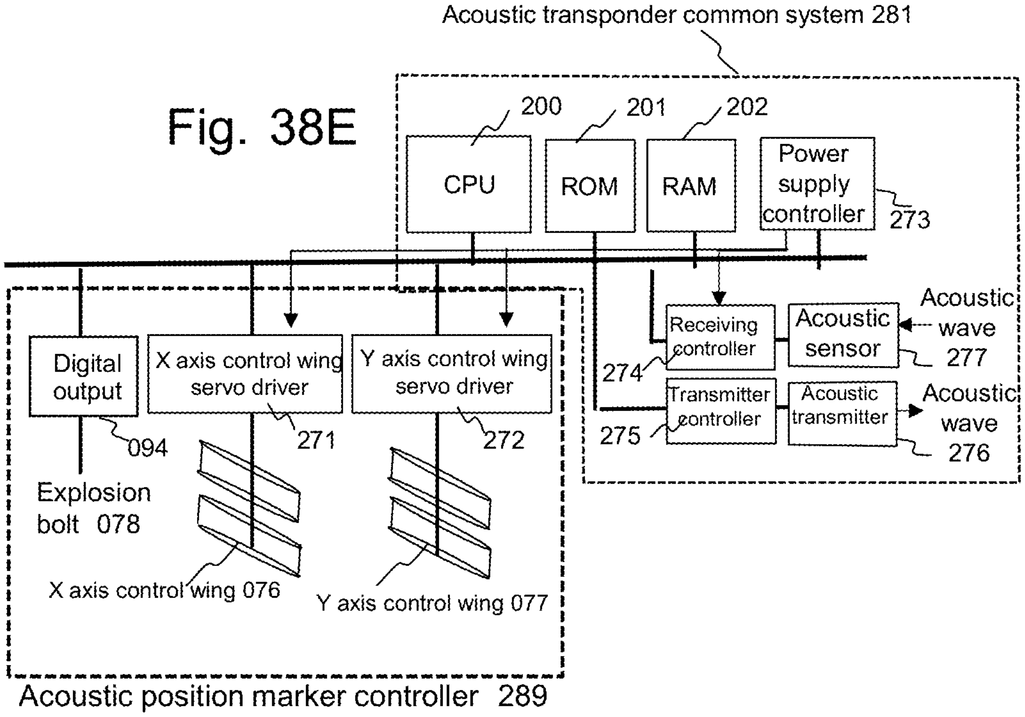


Fig. 39A

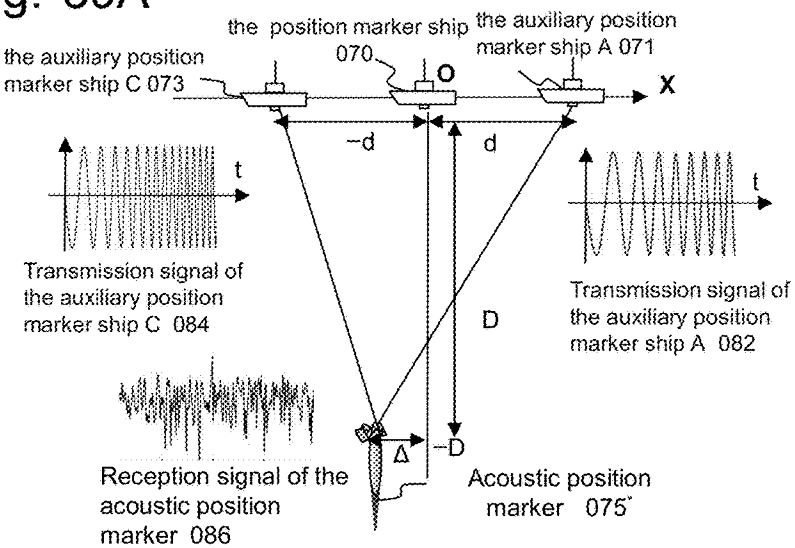
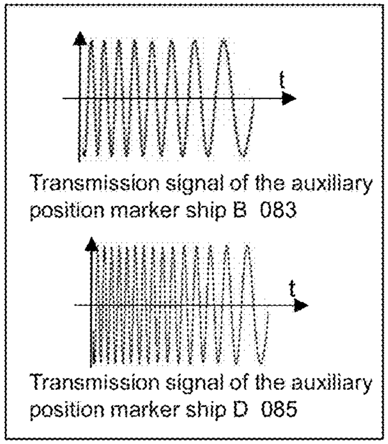


Fig. 39B



(b) Sound wave form

Fig. 39C

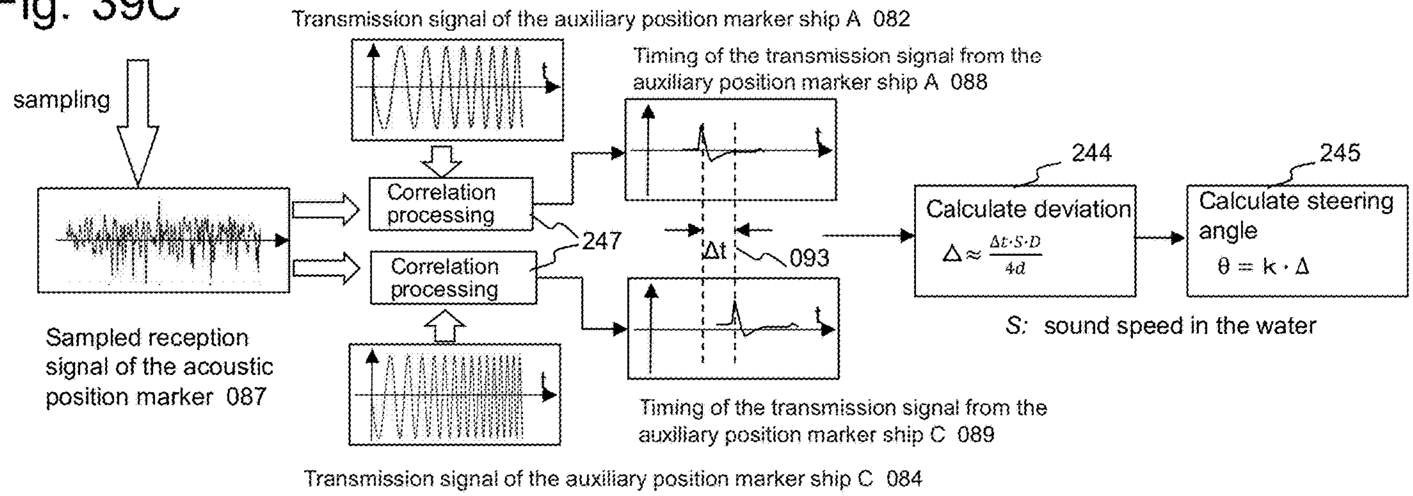


Fig. 40B

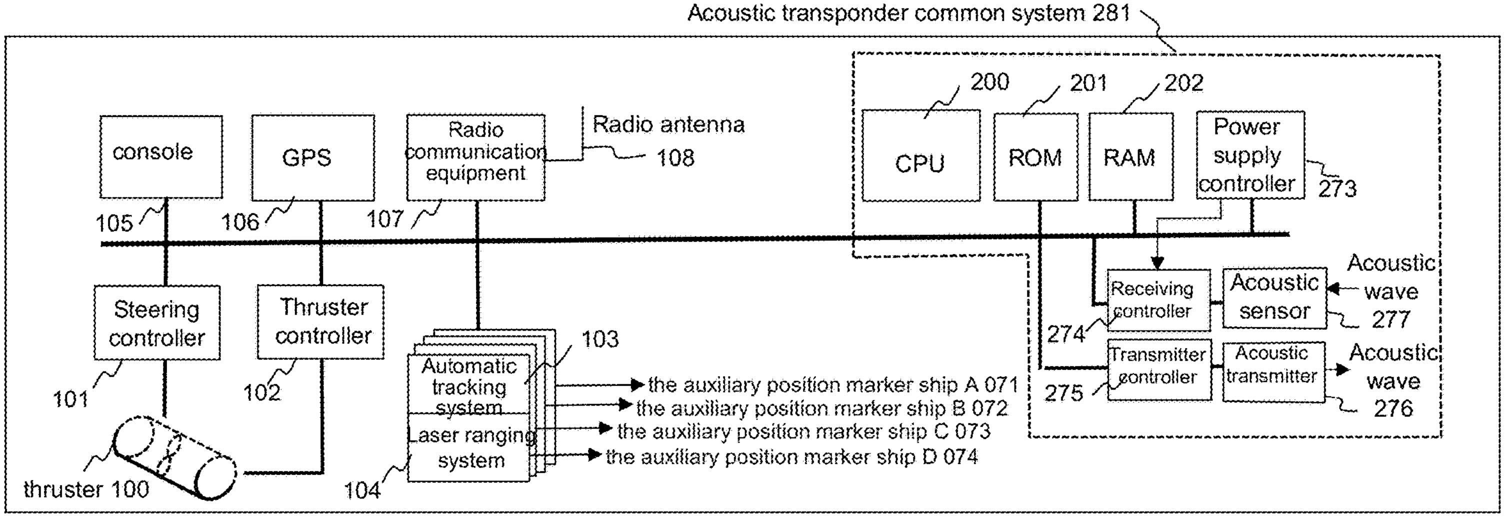


Fig. 40A

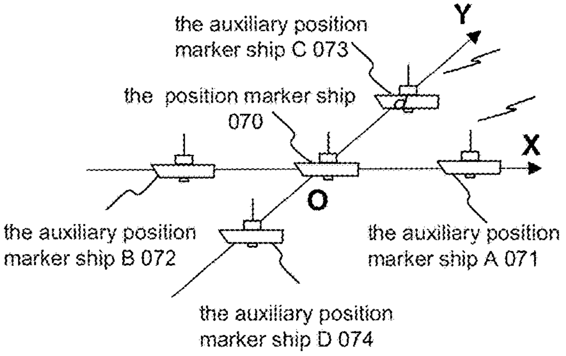


Fig. 40C

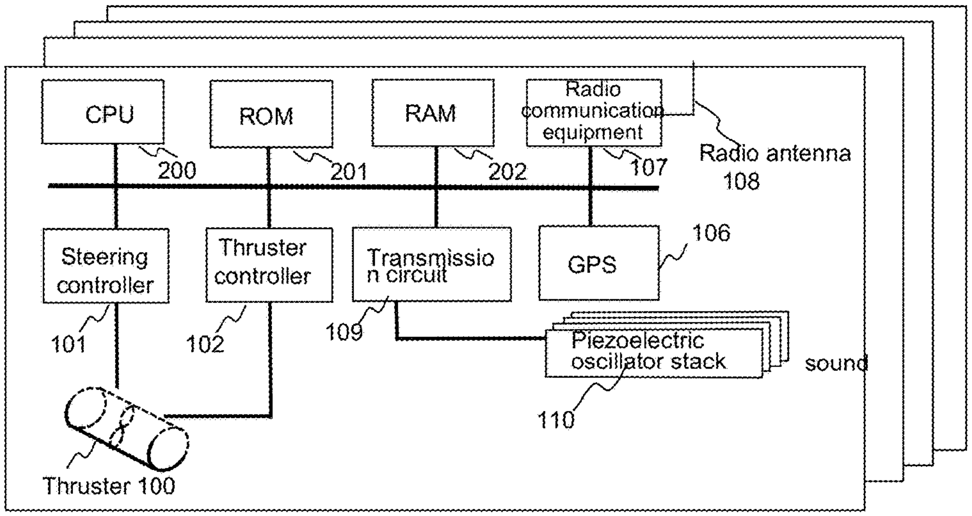


Fig. 41A

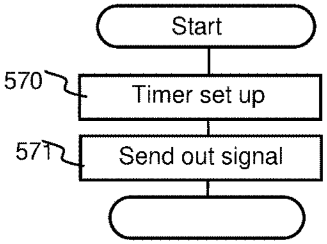


Fig. 41B

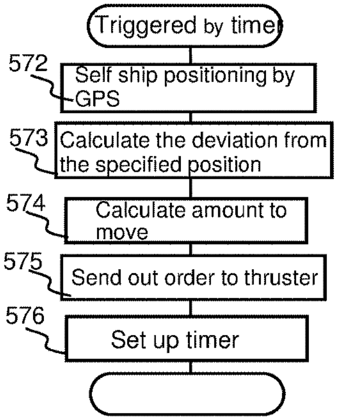


Fig. 41E

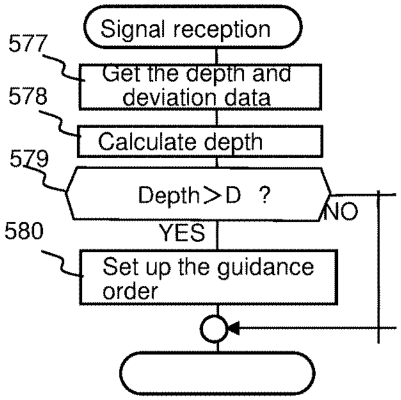


Fig. 41G

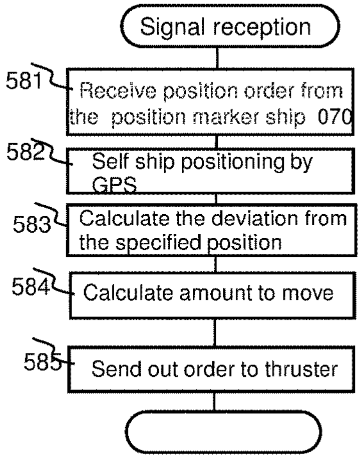


Fig. 41C

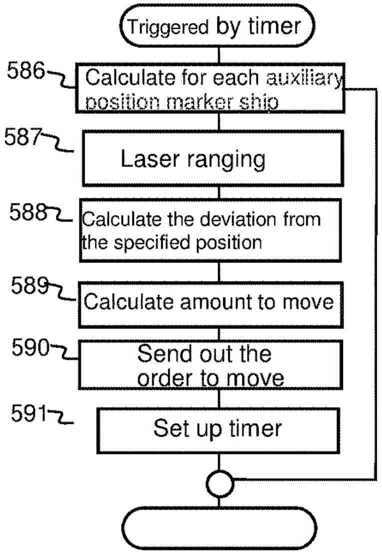


Fig. 41D

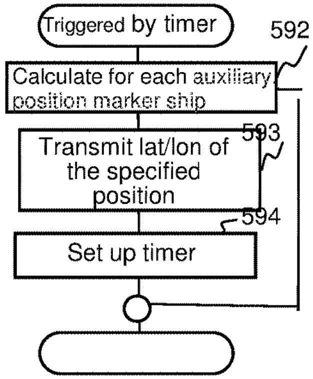


Fig. 41F

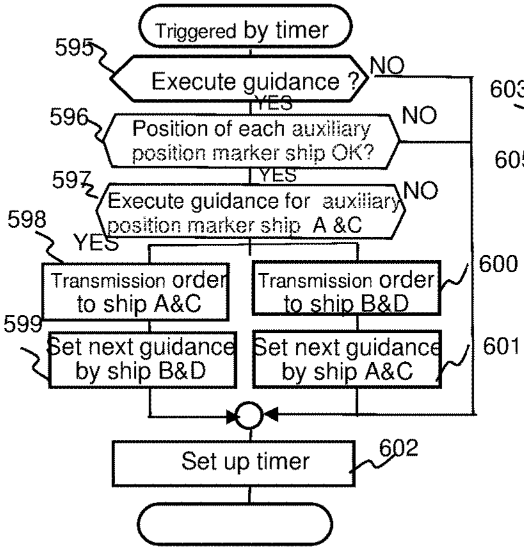


Fig. 41H

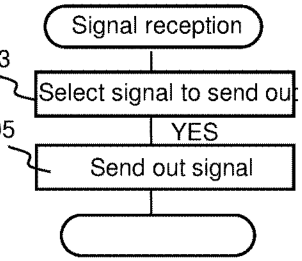


Fig. 42A

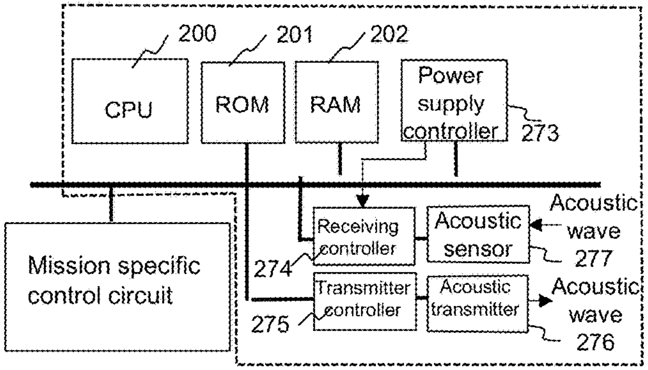


Fig. 42B

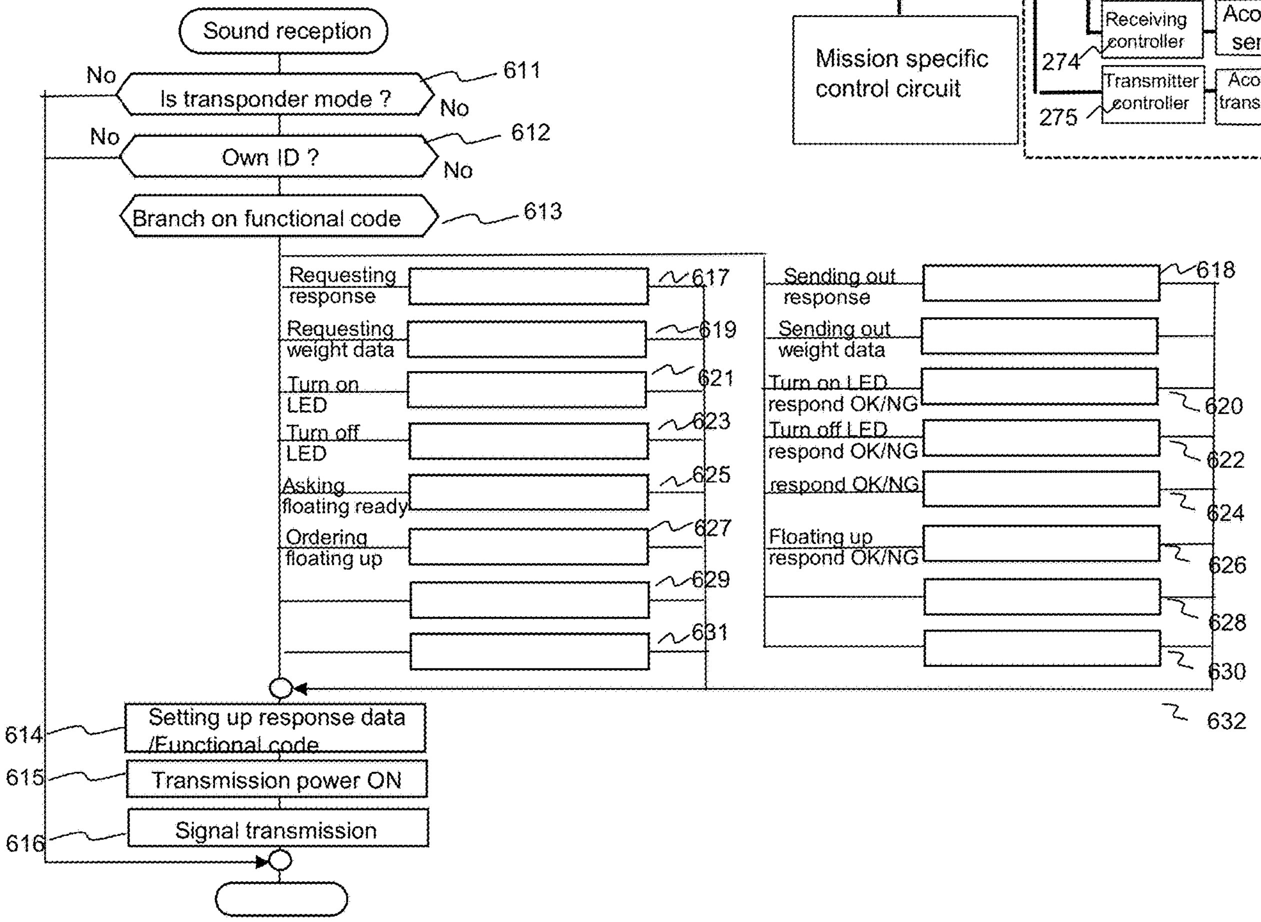


Fig. 43B

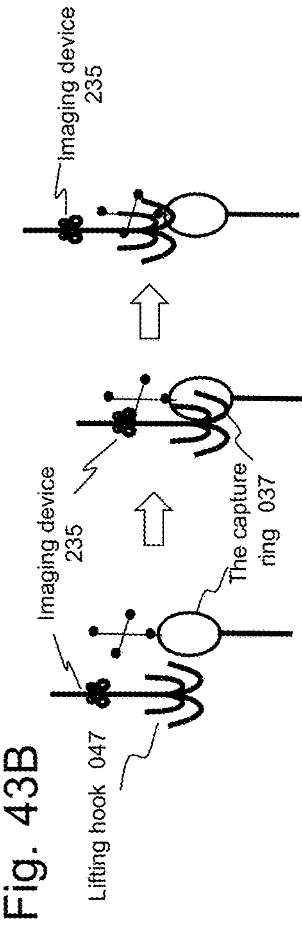


Fig. 43A

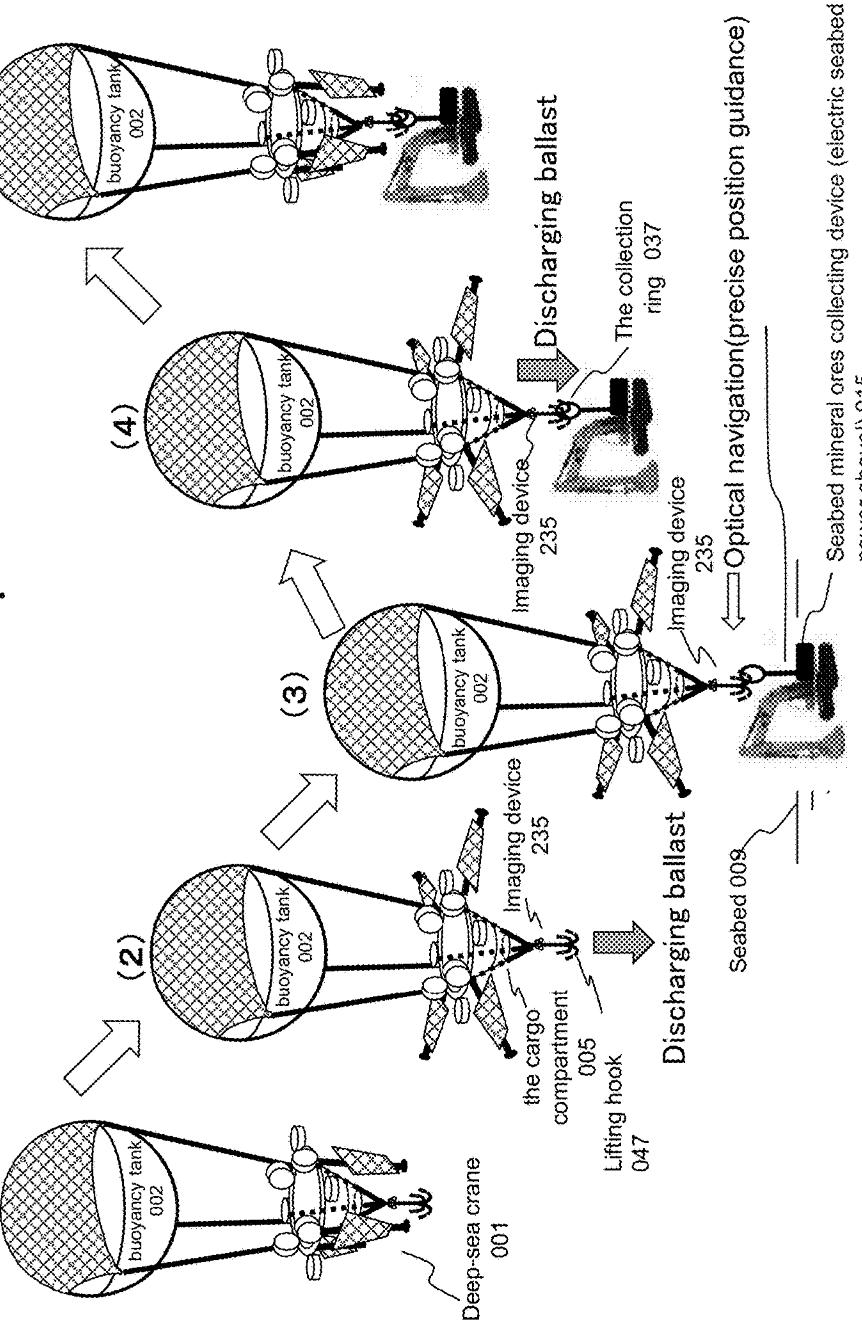


Fig. 44A

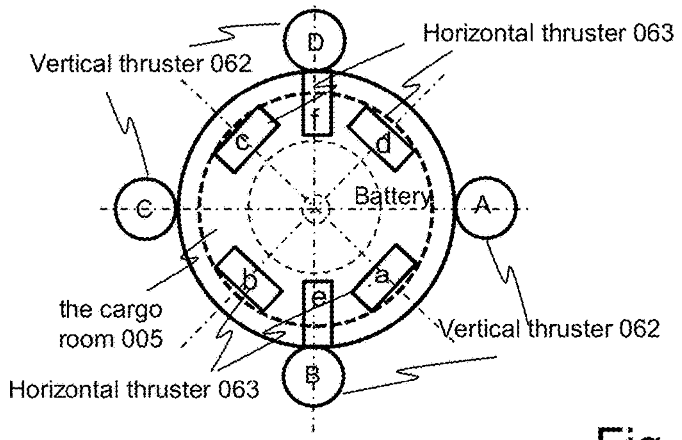


Fig. 44C

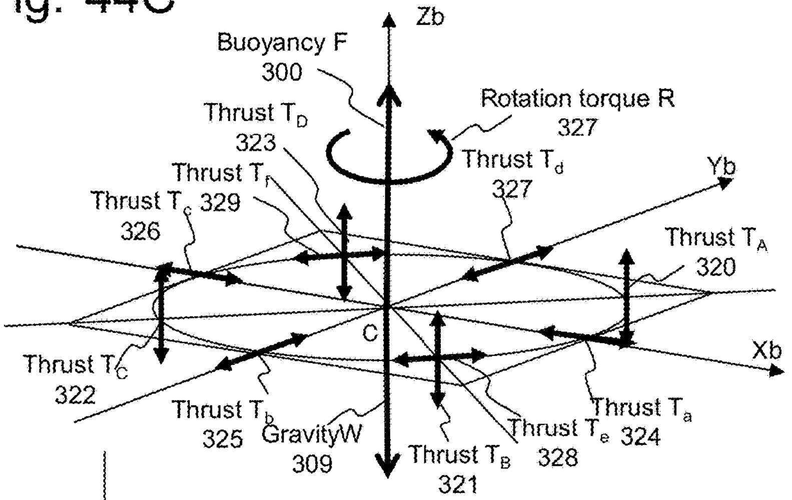


Fig. 44B

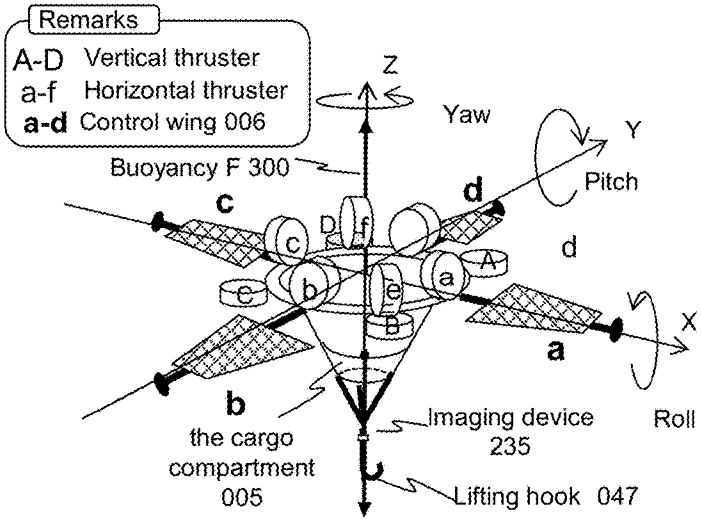


Fig. 44D

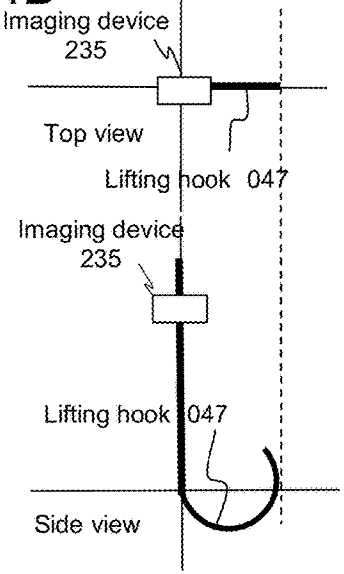


Fig. 44E

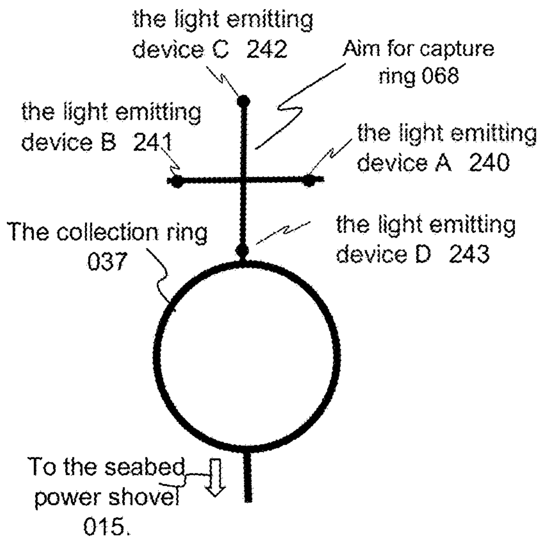


Fig. 45A

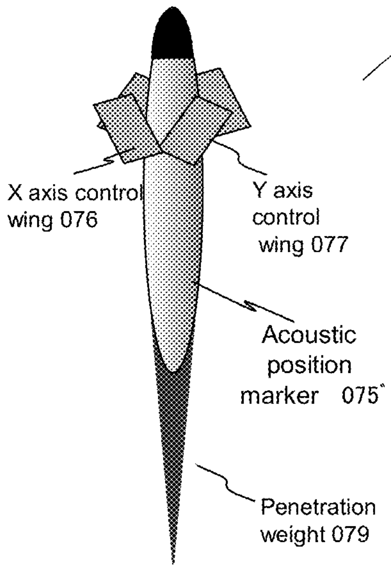


Fig. 45B

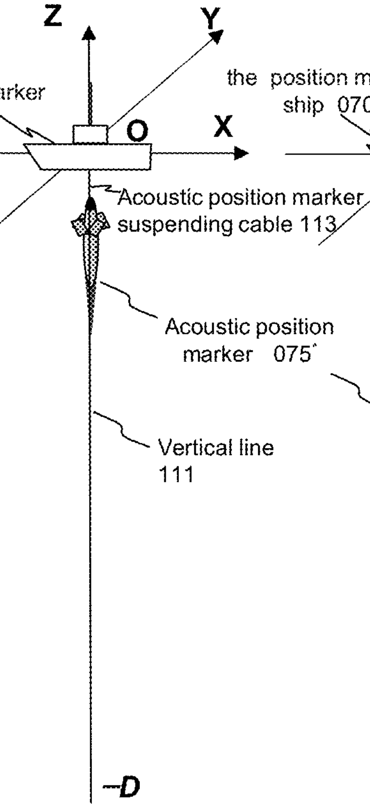


Fig. 45C

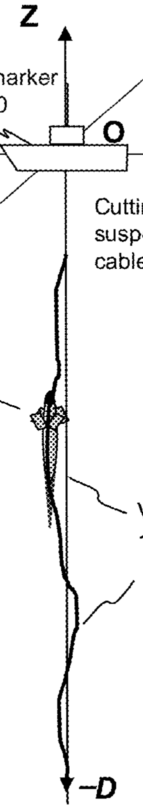
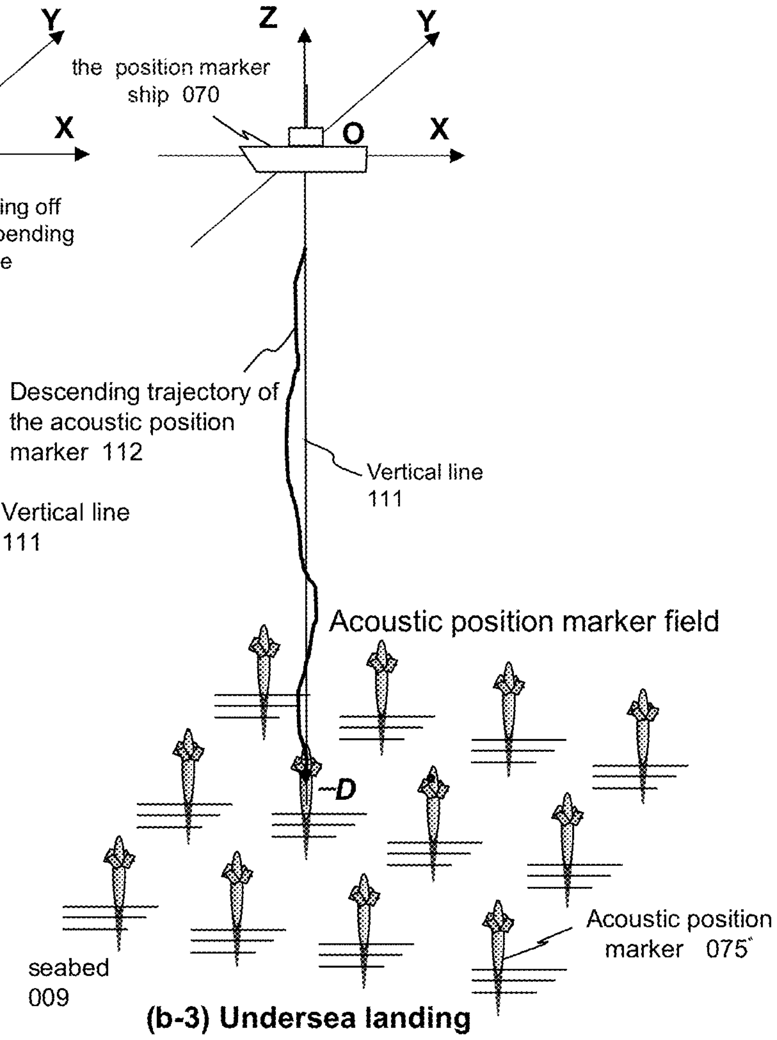


Fig. 45D



(b-3) Undersea landing

Fig. 46A

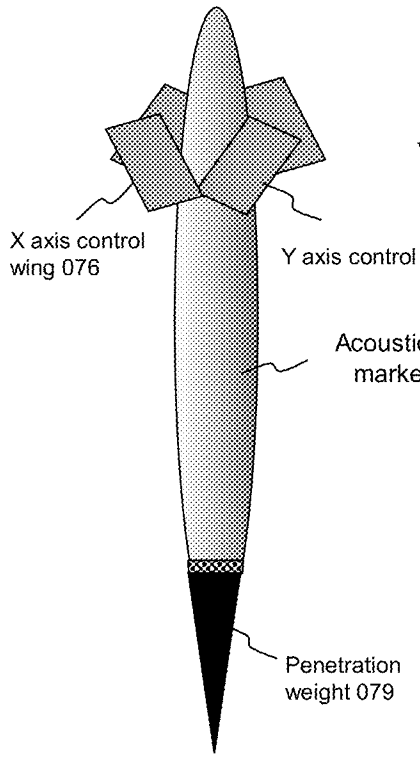


Fig. 46B

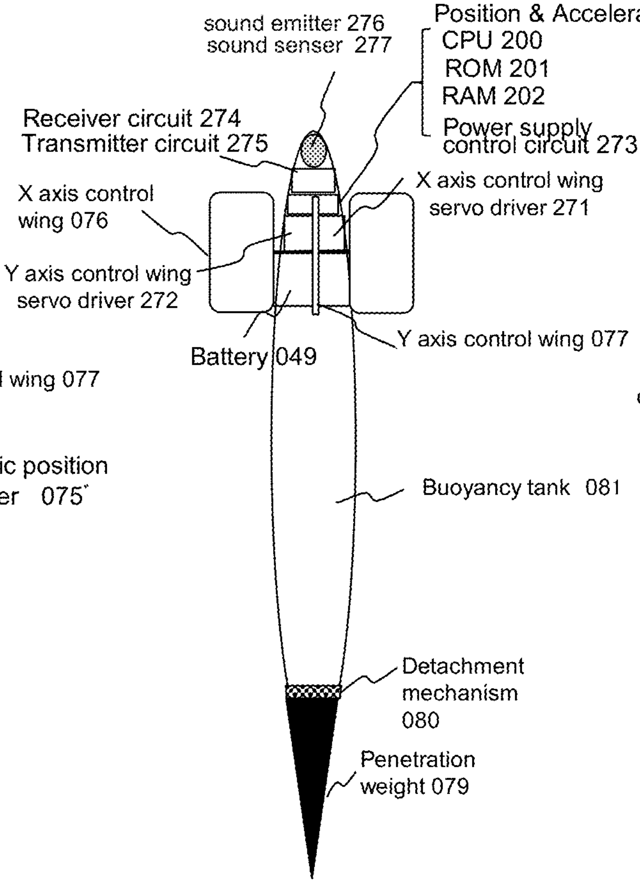


Fig. 46C

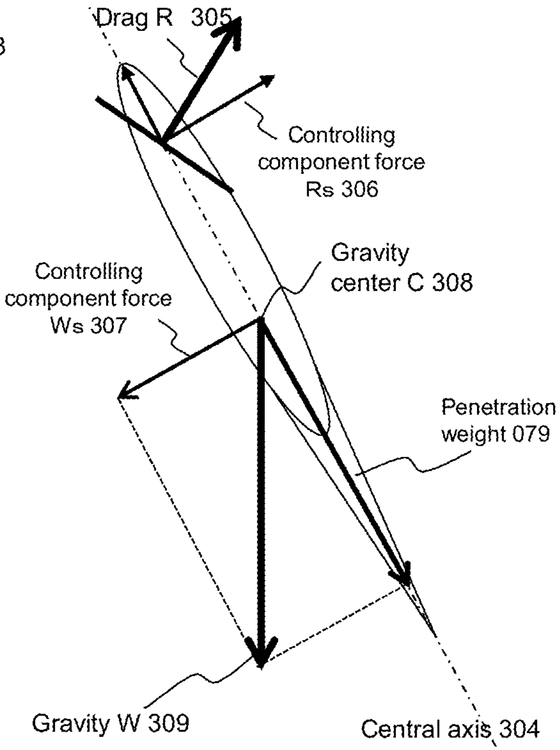


Fig. 47A

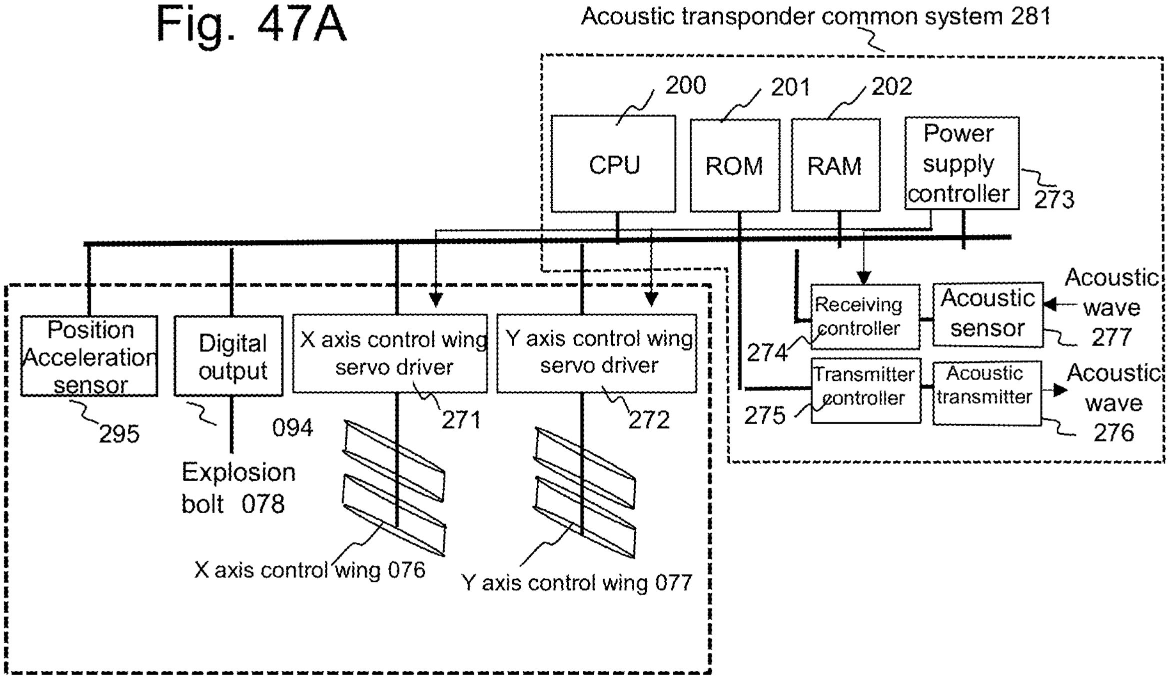


Fig. 47C

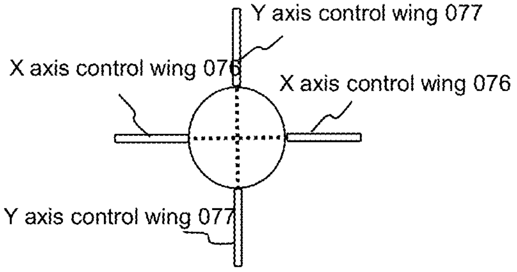


Fig. 47B

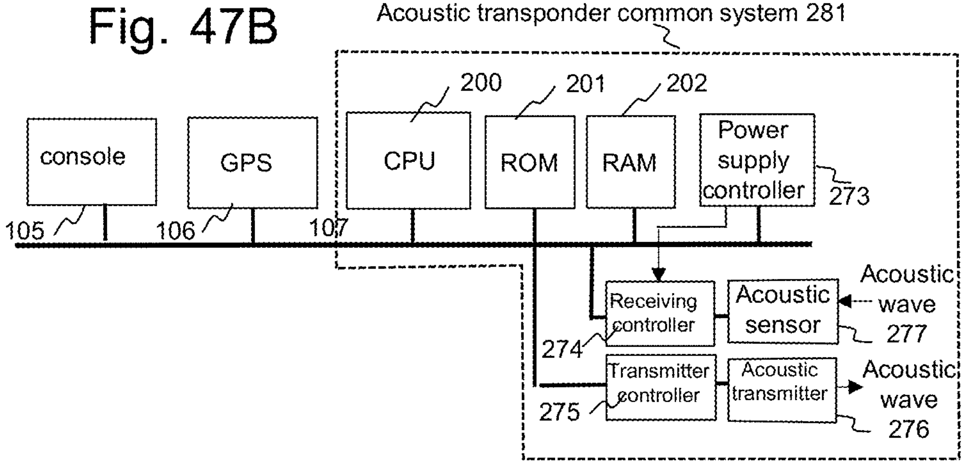


Fig. 48A

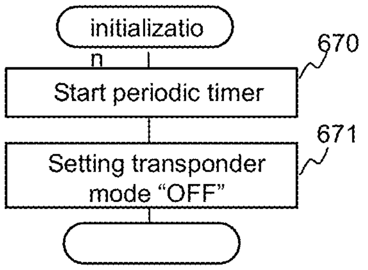


Fig. 48B

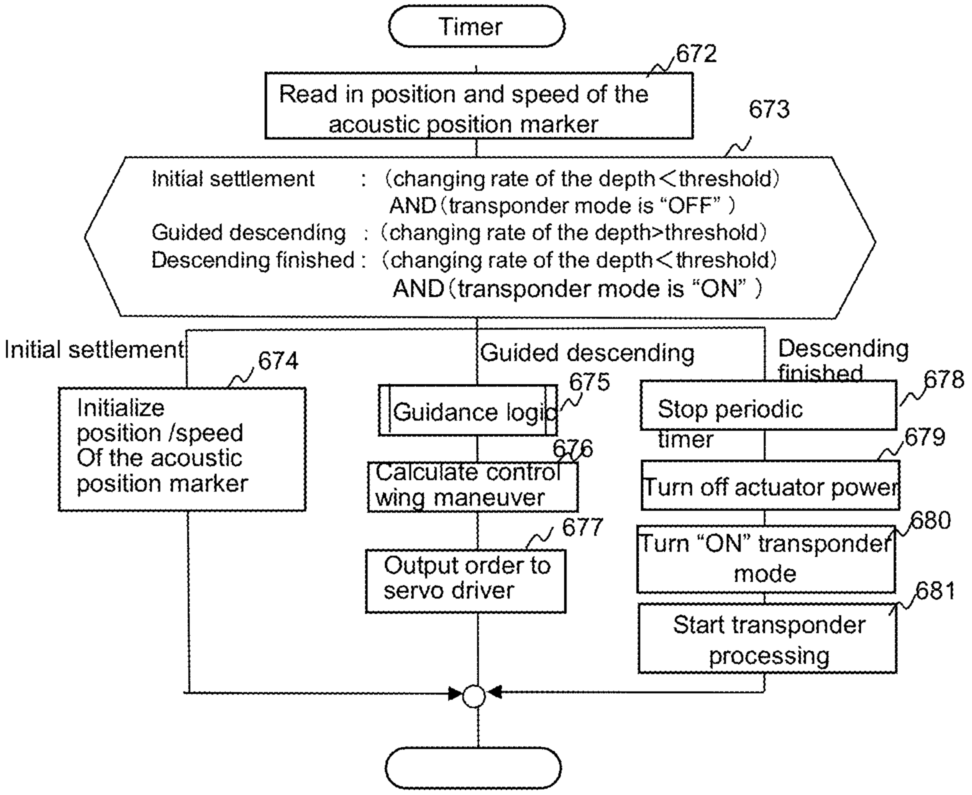


Fig. 49A

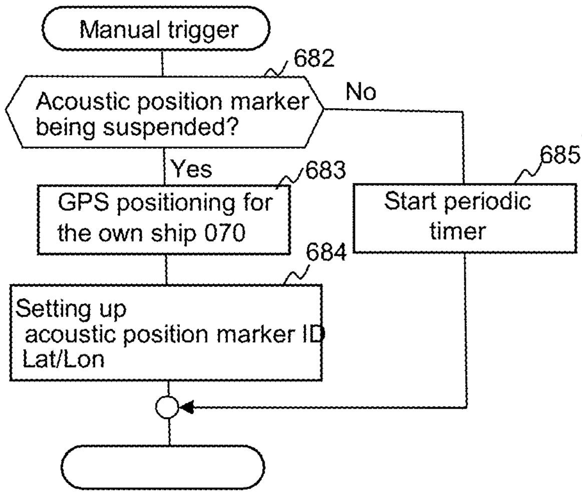


Fig. 49B

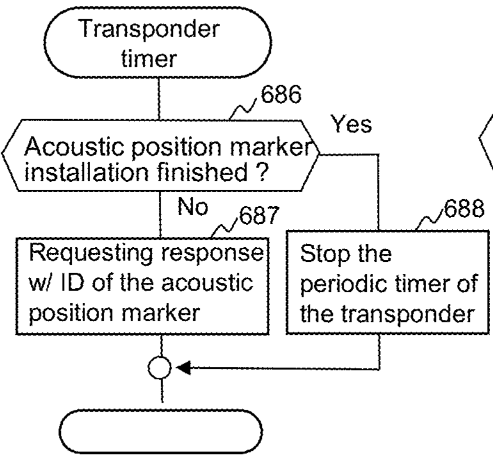
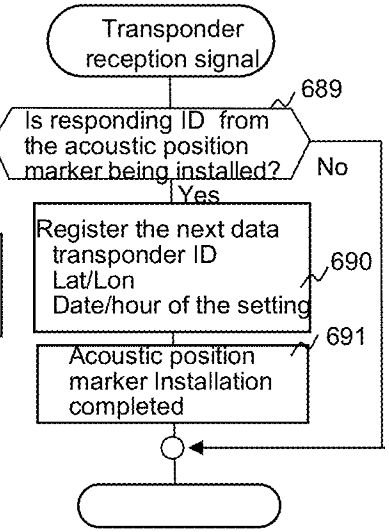


Fig. 49C



SEABED RESOURCE LIFTING APPARATUS

FOREIGN PATENT DOCUMENTS

[0001] WO2013118876A1 "Collection method and collection system of seabed hydrothermal mineral resources"

[0002] Japanese Unexamined Patent Application Publication No. 2011-196047 "Delivery system and method"

[0003] Japanese Patent Application Laid-Open No. 2017-066850 International Application PCT/JP2016/0836 "Pile resource harvesting device"

OTHER PUBLICATIONS

[0004] SALVAGE, Nobuo Shimizu, Journal of the Shipbuilding Society of Japan, May 2002

[0005] "Evaluation of slurry transfer of large-sized particles in lift pipes related to the development of seabed mineral resources" Takano et al. 14th Maritime Research Institute of Technology Research Presentation, June 2014

[0006] "Ocean energy and mineral resource development plan" Ministry of Economy, Trade and Industry December 2013

[0007] "Latest trends in the development of the latest seabed mineral resources" Yoichi Oda, Mitsui & Co., Ltd. Strategic Research Institute, April 2013

[0008] "Development of a seabed hydrothermal deposit drilling element technology testing machine" Mitsubishi Heavy Industries Technical Report 2013 No. 2 Satellite Attitude Tracking By Quaterion-Based Backstepping, Raymond Kristiansen, Norweigian University of Science and Technology, Norway, 2005

[0009] "Submarine hydrothermal deposit mining/lifting pilot test" JOGMEC NEWS 2018, March Sound Metrics http://www.soundmetrics.com/

CROSS REFERENCE TO RELATED APPLICATION

[0010] This application is a U.S. continuation application filed under 35 USC111(a) claiming benefit under 35 USC120 and 365(c) of PCT application JP2019/029712, filed on 29 Jul. 2019, which claims priority to Japanese Patent Application No. 2018-143015, filed on Jun. 30, 2018, the entire contents of which are incorporated herein reference.

BACKGROUND OF THE INVENTION

1. Field of Invention

[0011] The present invention relates to a device for picking up objects from the seabed. In particular, the present invention relates to a system for collecting and collecting mineral ores on the sea floor, and relates to a device for collecting to the sea surface by using the buoyancy of a liquid having a lower specific gravity than water without inputting energy for collection. Exhausting gas from the components of the device balances the pressure inside and outside to avoid the need for pressure resistance in the underwater environment. Furthermore, this device is characterized by the fact that it does not require a structure between the sea surface and the sea floor by autonomously sailing underwater.

2. Description of the Related Art

[0012] Attempts to recover objects from the seabed have been made in the field of salvage, dredging, and drilling offshore oilfields. With regard to the collection of seafloor minerals, trials have been started for collecting 1000 m-level seafloor minerals, and recovery of seafloor resources at the 2000 m-5000 m level has not been established because there is no established methodological method or economic prospects. The present invention relates to an apparatus for economically recovering seabed resources up to a level of 6500 m, and provides state-of-the-art technologies for control engineering, space engineering, information engineering, and acousto-optics, which are other fields not conventionally used in ocean development. By combining them, it was newly devised to realize with existing hardware technology without mechanical challenge under high pressure environment.

[0013] The conventional technique will be described below. The collection of seabed minerals has been conventionally discussed as an extension of salvage technology, dredging technology and offshore oil drilling technology. As for the salvage technique, as outlined in "SALVAGE, Nobuo Shimizu", there are a "major rotation system" in which a wire is pulled up, a "balloon system" utilizing buoyancy, and a "grab system" in which the wire is directly grasped.

[0014] "Large turning method" is not performed in the deep sea because it involves diving work with wires. In the "balloon system", metal or rubber balloons containing compressed air are used to pull up in the sea, but horizontal movement is the main cause because of gas expansion accompanying changes in depth, and the depth is 100 m or less. The "grab method" is a method of directly grasping the arm by extending it to the seabed. In the 1970s, the US CIA raised the Soviet sunken submarine from the bottom of the sea for the purpose of gathering nuclear strategic information. It is the only record that has been pulled up from the deep sea, and there are no examples. According to publicly available information, raising the sinking submarine in the Soviet Union is likely to be an extension of offshore oil drilling technology. The both methods are not suitable for collecting seafloor mineral resources from the deep sea because the quietness of the sea surface is indispensable because the work ships on the water are directly involved dynamically.

[0015] At present, mineral ores extraction from the seabed is not economically feasible, and it is best to take samples by deep sea exploration boats, unmanned robot arms, or boring. Exceptionally, in oil fields and gas fields, if you make a hole, it will be ejected by being pushed out by the internal pressure, so by installing a recovery facility such as a pipe at the opening, you can mine at a relatively low cost. A method of pumping up hot water in which mineral resources are melted from a seabed hot water pool has been proposed (Patent Document 1). This method can also be carried out by pouring a special solvent into the ore deposit as in the case of shale gas mining, vacuuming the dissolved minerals onto the water, and then separating and collecting the minerals.

[0016] As a method of recovering mineral resources from the seabed surface strata, as an extension of dredging technology, a test development of elemental technology for excavating a 1000 m deep seabed hydrothermal deposit (such as chimney), making it into slurry and sending it to the sea by an underwater pump, which is disclosed by JP 2011-196047 "Delivery system and method", and "Development of a seabed hydrothermal deposit drilling element technology testing machine" Mitsubishi Heavy Industries. A pilot project for mining and recovering hydrothermal deposits with a seabed of 1600 m was implemented in 2017, and 16 tons were recovered in 1.5 months, but no commercial prospects have been established. ("Submarine hydrothermal deposit mining/lifting pilot test")

[0017] Mining and collecting of seabed mineral ores is the stage when the trial development of elemental technology for the submarine hydrothermal deposit at a depth of 1600 m has finally begun. Cobalt-rich crusts, manganese nodules, and rare earth deposits are distributed on the surface of the deep sea deeper than 1000 m, but they are still in the stage of resource survey, and resource recovery, including methodologies, has not been started. ("Ocean energy and mineral resource development plan") Similar to the present invention, there is PCT/JP2016/0836 of the same applicant as the present invention as a technique for collecting an object from the seabed without challenging the mechanical limit in a high-pressure environment. In PCT/JP2016/0836, by using the buoyancy of hydrogen gas generated on the seabed, the internal pressure of the lifting equipment and the surrounding seawater pressure are made the same to solve mechanical and structural problems such as pressure resistance technology under high pressure environment, and buoyancy is used. Furthermore, since hydrogen gas generated on the seabed becomes an excess during the collection process, it was absorbed by toluene and recovered as MCH (methylcyclohexane), and it was used as a hydrogen energy source to solve the problem of recovery energy efficiency.

[0018] Cobalt-rich crust, manganese nodules, and rare earth deposits are deposited on the sea floor, and if they are above ground, they can be collected by power shovels or bulldozers. Mining trials of hydrothermal deposits are preceded mainly by the fact that hydrothermal deposits are relatively shallow inside and outside the depth of 1000 m, and the depth is an obstacle to the development of seabed mineral resources deeper than 1000 m, and the conventional salvage technology and dredging technology, Extension of offshore oil drilling technology has not solved it.

[0019] In the world of living things, sperm whales do not use any special pressure resistance technology in living organisms, use almost no energy, dive up to 3000 m and prey on squid and return to the sea surface. The reason why sperm whales can easily go back and forth between the deep sea floor and the sea surface without obstructing the depth is that the internal and external pressures of liquid and solid are equalized in vivo to avoid structural problems in high pressure environment. Second, since it can move independently of objects on the sea floor or on the sea and is autonomous both structurally and as a moving body, there are few restrictions as a structure. Thirdly, whales move up and down using buoyancy to move up and down in a liquid such as underwater by adjusting the buoyancy using the change in the specific gravity of "brain oil" depending on the temperature and using almost no energy. It shows that it is the most energy efficient means.

[0020] However, in view of the above problems, there is no other way than the following two ways to collect mineral ores by obtaining buoyancy that counteracts the underwater weight of the mineral ores on the seabed.

The first is a method of generating buoyancy from nothing in water, and the method of PCT/JP2016/0836 by the same inventor as this patent has been addressed from this viewpoint. The most efficient method in the seabed under the high pressure environment is the generation of hydrogen with the minimum molecular weight by electrolysis of water. This method can efficiently bring in pure water from the source to the seabed, transmit power to the seabed, and recover surplus hydrogen in the floating process. Hydrogen gas is generated on the seabed and used as a buoyancy source for the collection of seabed resources. Toluene absorbs surplus hydrogen gas as it floats, becomes MCH, and is recovered and reused as a hydrogen energy source.

[0021] However, in this method, the following (a) to (d) are indispensable. (a) Electric power for generating hydrogen gas by electrolysis on the seabed, (b) Electrolysis device on the seabed, (c) Organic hydride reactor for hydrogen absorption during the floating process, (d) Recovery process Hydrogen reaction controller.

[0022] The second is the method of the present invention. That is, buoyancy is canceled from the surface of the sea in the form of "buoyancy"+"ballast" to bring a buoyancy source to the seabed, and "ballast" is separated to generate buoyancy that does not exist until then.

Since ballast is a solid or liquid with a high specific gravity, it is not affected by water pressure during the process of bringing it from the sea surface to the sea floor, and its specific gravity is also constant. If the buoyancy source is liquid, it will not be affected by water pressure on the seabed. The most suitable substances as buoyancy sources are n-pentane (boiling point 36.1° C., specific gravity 0.626), which is liquid at room temperature and has the lowest specific gravity, or gasoline (specific gravity 0.70), which is inexpensive in cost.

In the method of the present invention, the hydrogen-related equipment of items (a) to (d) required in the first method can be omitted. This has the advantage of reducing costs and is easy to handle as the buoyancy source of the liquid may be kept sealed from beginning to end. On the other hand, it is necessary to solve the following two points, which is the subject of the present invention.

[0023] (1) At the seabed, it is necessary to separate the ballast from the buoyancy source brought in with the ballast, and to switch the ballast and the mineral ores to be collected by remote control to the buoyancy source generating large buoyancy.

[0024] (2) In order to commercially collect offshore resources, the process must be continuously repeated. If gas is brought from the sea surface to the bottom of the sea as a buoyancy source, it is necessary to use a pressure-resistant shell, and it is clear that efficiency and cost do not match this method, if it is calculated. Blowing high-pressure air from the sea surface with a pipe can be said to be this modification.

BRIEF SUMMARY OF THE INVENTION

[0025] First, in order to fundamentally avoid the obstacles of the high pressure environment, the gas is excluded from the components, the inner and outer pressures are made equal, and the pressure resistant equipment is eliminated, thereby avoiding the pressure resistance requirement. For this reason, a liquid having a lighter specific gravity than water at room temperature (for example, n-pentane or gasoline) is used as a buoyancy source for collection. To reach the source of buoyancy to the bottom of the sea, sink it with ballast to counteract the buoyancy and replace the ballast with the recovered mineral ores at the seabed. The method of the present invention facilitates scale-up of the apparatus because there is no mechanically high stress point.

[0026] Second, the buoyancy-based collection method does not require a high-lift pump, as compared with a method in which seabed mineral ores are slurried in the sea and pumped to the surface of the sea. The movable mechanism, the high-pressure pipe, the friction mechanism, and the pressure-resistant mechanism with a large pressure difference are eliminated, and the problems of abrasion and sealing of the transportation pipe due to slurry transportation do not occur. Further, according to the method of the present invention, since the object to be recovered is lifted from the seabed as it is, there is no restriction on the size and shape and physical properties of the recovered object. Since there is little information on seabed resources, visibility is poor on the seabed, and the means for collecting information is limited. It is possible to avoid energy input and seawater pollution due to ore crushing and slurry formation. There is a great advantage to remove the ore processing on the sea floor, such as making it into a slurry, and to collect the raw ore as it is. In addition, high pressure pumping of minerals from the seabed was avoided to avoid energy waste.

[0027] Thirdly, the underwater weight of the component equipment is reduced so that all equipment could float on the sea surface by buoyancy as part of regular operation. As the result, maintenance and inspection of all equipment becomes easy. Furthermore, since it is possible to ascend and descend by autonomous navigation, there is no mechanical connection between undersea and seabed structures such as lifting pipes and surface vessels, and it is possible to ease the marine conditions and the position control conditions of surface command ships The cost of surface command ships will be reduced. At the same time, this facilitates the movement of equipment installed on the seabed, which makes it possible to realize maneuverability suitable for collecting thin and wide-spread ore/minerals on the seabed. Fourth, while increasing the moving speed by means of changing the difference in buoyancy to improve the facility utilization rate, the resistance blades are deployed to reduce the terminal speed by using the resistance of water, thereby it is possible to land on the seabed and return to a surface command ship safely.

[0028] However, the first to fourth means described above can be means for solving the problem only when they can be concretely realized in the real world. The method of ensuring realization is described below. The deep-sea crane **001** is with one or more ball-shaped buoyancy tanks **002** with a liquid whose specific gravity is lighter than water, loads ballast in the cargo compartment, and descends from the surface command ship **010** to the sea floor. On the seabed, the ballast and the collected seabed mineral ores are exchanged, and the deep sea crane **001** floats above to the sea surface.

[0029] (1) Guaranteeing Feasibility by Weight Reduction

[0030] In order to utilize the buoyancy, it is necessary to make the specific gravity of the total device around 1.0, and it is essential to reduce the weight of the entire device. Therefore, a lightweight and tough material including a tough carbon fiber resin having a specific gravity of about 1.8 is used as the structural material. In particular, when realizing a deep-sea crane that collects seabed mineral ores, it is important in terms of economy to increase the ratio of ballast, which is equivalent to the collected seabed mineral ore, to the total weight of the deep sea crane while maintaining the total weight of the deep sea crane when traveling back and forth between the sea floor and the sea surface at around 1.0. Here, the specific gravity of around 1.0 means that it is possible to softly land on the sea floor by free fall by means of its own weight.

[0031] The weight reduction of the deep-sea crane **001** is an important requirement that determines the success or failure of the realization, so it will be examined below.

(A) When Ascending

[0032] As a trial calculation example, the specifications of a typical deep-sea crane (unit: mm) that recovers about 10 tons of seabed mineral ores in one time from 1,000 to 6,500 m in depth, is shown in FIG. **1**A.
The liquid to be filled is gasoline (specific gravity 0.70) as a buoyancy source, the capacity of the buoyancy tank **002** of radius 2 m is 33.51 m3, and when carbon fiber resin of 5 mm thick is is used, the volume of the float tank shell is 0.251 m3, and when the typical specific gravity of 1.8 used, then its underwater weight becomes 0.20 tons.

Volume V=2.0×2.0×2.0×π×4/3=33.51 m3

[0033] Buoyancy=33.51×0.30=10.05 tons
Surface area S=4×2.0×2.0×π=50.26 m2
Underwater weight W=50.26×0.005×0.8=0.20 tons
The maximum shear stress applied to the outer shell is 10.05/2 tons of buoyancy, which is applied to the outer shell of the center of the sphere in the vertical direction while climbing and descending. The cross-sectional area of the outer wall columnar portion is 314.2 cm2 when the wall thickness is 5 mm, and the typical shear stress of carbon fiber resin is 150 kgf/mm2 and the compressive fracture stress is 100 kgf/mm2. It is 30 times stronger than the load. As described above, it can be said that the present invention is sufficiently feasible with the current technology.

(B) When Descending

[0034] Since the buoyancy tank is filled with 33.51 m3 of gasoline when descending, if the equipment weight of the deep sea crane is 33.51 tons together with the ballast in the cargo compartment **005**, its overall specific gravity will be 1.0. By adding a small amount of weight and setting the specific gravity to 1.0+α, it is possible to gently descend toward the sea floor, and it is possible to softly land on the sea floor. (FIG. **2**) Since the buoyancy tank is estimated to be 0.2 tons, if the cargo compartment and additional equipment are up to 0.5 tons, the ballast is 9.35 tons and 9.3 tons of ore can be loaded on the seabed. Since the deep sea crane **002** has no physical restrictions, it can take seabed mineral ores freely. As shown in FIG. **3**B, if a buoyancy tank with a diameter of 9.0 m is used, 100 tons of seabed mineral ores can be collected.

(2) Realization of Commercial Operation

[0035] The system according to the present invention is a system that continuously collects seabed mineral ores, therefore such an operation must be specifically realized.
An operation form in accordance with this purpose is shown in FIG. **4**.
The deep-sea crane **001** plays the role of a crane that uses the buoyancy of gasoline to collect seabed mineral ores from the seabed **009**. In addition to the deep-sea crane **001**, a function to collect seabed mineral ores and load them into the

deep-sea crane **001** is necessary. For this purpose, the seabed mineral ores collecting device (electric seabed power shovel) **015** is installed on the seabed. Submarine resources are widely present on the seabed at a depth of 1000 m to 6500 m. The seafloor hydrothermal deposits are rock masses, and the manganese nodules are scattered like gravel on the seabed. Cobalt-rich crust is deposited as thin pillow lava on the sea floor, and rare earth mud is deposited for several to 10 m at a depth of several meters on the sea floor.

[0036] On the ground, these seabed mineral ores can be collected with a power shovel. On the seabed, since there is no means for loading seabed mineral ores into the deep sea crane **001**, a seabed mineral ores collecting device (electric seabed power shovel) **015** is used for loading them.

As visibility is generally not guaranteed on the seabed, an ultrasonic high-definition video camera is used as a countermeasure, which is mounted on the seabed power shovel **015** and operated by remote control from the surface command ship **010**. At the time of filing of the present invention, what has been put to practical use commercially is a visibility of 35 to 80 m, a field of view of 29°, a beam number of 96 (resolution), and 20 frames/sec. (Sound Metrics http://www.soundmetrics.com/)

[0037] FIG. **29**A is an example of an electric seabed power shovel. The power shovel is driven by a hydraulic mechanism, but since the drive mechanism operates by a differential pressure, which does not depend on the surrounding pressure environment in principle. It can be operated even in a high-pressure environment on the seabed if the electro-hydraulic mechanism and the moving mechanism are motor-driven. Power supply and remote control are performed from the surface command **010**.

The ultrasonic high-definition video camera **050** is installed on the remote control platform **265** which is operated by remote control from the surface command ship **010**, and a view in any direction can be obtained from the surface command ship **010**. A capture ring **037** is provided above the center of gravity of the electric seabed power shovel **015** and is used for its recovery operation from the seabed.

[0038] In FIG. **2**, the deep-sea crane **001** that has left the seabed rises toward the surface command ship **010** on the levitation path **046** and arrives at the sea surface **032**. The surface command ship **010** recovers the collected seabed mineral ores **018** from the deep sea crane **001**. After the collection, the ballast is loaded in the cargo compartment **005** and the ballast is dropped to the seabed through the sinking route **044**.

The surface command ship **010** carries the ballast from the departure port, collects the seabed mineral ores **018** at the mine point sea, returns to the port of departure, and repeats this round trip.

[0039] The surface command ship **010** is a base ship that serves as a core for collecting mineral ores on the sea floor. It occupies the upper part of the seabed where seabed mineral ores are collected, and directs their collection, maintenance of equipment, and supply of power. The surface command ship **010** carries a plurality of deep-sea cranes **001** and a seabed power shovel **015**, advances to a mineral ore collection point, and expands in the sea and on the surface of the sea. The surface command ship **010** controls the operation of all relevant equipment and is equipped with a system for that purpose.

The surface command ship **010** can change its position depending on the resource status of the seabed. Since the deep sea crane **001** can have a specific gravity of around 1.0, it can be deployed at a new location after being first levitated to the sea surface and collected.

[0040] According to the present invention, since the mineral ores are collected from the seabed by buoyancy, the energy consumption is small, and the equipment that reciprocates on the seabed does not contain gas, so that the mechanical effect due to the seabed depth is small, and the range from less than 1000 m to more than 5000 m is wide. Applicable to further, since there is no structurally restricted portion for strength, scale-up is easy. Furthermore, since the collected seabed mineral ores are not pulverized, it does not cause pollution in the sea.

BRIEF EXPLANATION OF DRAWINGS

[0041] FIG. **1**A is a side view of a deep-sea crane.

[0042] FIG. **1**B is a top view of a deep-sea crane.

[0043] FIG. **1**C is a top view of a deep-sea crane.

[0044] FIG. **2** is an overview of a seabed mineral ores collection system.

[0045] FIG. **3**A is an overview of a deep-sea crane.

[0046] FIG. **3**B is a table showing buoyancy tank volume and buoyancy specifications.

[0047] FIG. **4** is a diagram showing ore loading to a deep-sea crane.

[0048] FIG. **5**A is a cross section diagram of a cargo compartment before loading collected mineral ores.

[0049] FIG. **5**B is a cross section diagram of a cargo compartment while loading collected mineral ores.

[0050] FIG. **5**C is a cross section diagram of a cargo compartment after mineral ores loading completed.

[0051] FIG. **5**D is a cross section diagram of a partition mechanism.

[0052] FIG. **5**E is a top view diagram of a partition mechanism.

[0053] FIG. **6**A is an overview of a water injection mechanism **2** of a cargo compartment.

[0054] FIG. **6**B is an overview of the water injection mechanism **1&2** and a cargo compartment.

[0055] FIG. **6**C is an overview of a water injection mechanism **3** of a cargo compartment.

[0056] FIG. **6**D is an overview of a water injection pipe.

[0057] FIG. **7**A is a diagram of an aperture mechanism (being open) of a ballast discharge mechanism.

[0058] FIG. **7**B is a diagram of an aperture mechanism (being closed) of a ballast discharge mechanism.

[0059] FIG. **8** is a diagram showing a cargo compartment control system.

[0060] FIG. **9** is a diagram showing a time transition of the cargo compartment components.

[0061] FIG. **10**A is a processing flow (A) of a cargo compartment control process.

[0062] FIG. **10**B is a processing flow (B) of a cargo compartment control process.

[0063] FIG. **11**A is an overview of ore loading to a seabed mineral ores collection container.

[0064] FIG. **11**B is a drawing of a seabed mineral ores collection container.

[0065] FIG. **12** is a diagram showing a configuration of a seabed mineral ores collection container control device.

[0066] FIG. **13** is a diagram showing a processing flow of the seabed mineral ores collection container control device.

[0067] FIG. **14** is a diagram showing a block diagram of a supervisory control system.

[0068] FIG. **15** is a diagram showing a processing flow of an navigation control system of the deep-sea crane.

[0069] FIG. **16**A is a diagram showing an navigation strategy of a deep-sea crane.

[0070] FIG. **16**B is a diagram showing a processing flow of an inertial navigation system.

[0071] FIG. **17**A is an overview of allocating sensors on a deep-sea crane.

[0072] FIG. **17**B is a diagram showing an acoustic propagation from a seabed transponder to a deep-sea crane.

[0073] FIG. **17**C is a diagram showing an acoustic propagation from a surface transponder to a deep-sea crane.

[0074] FIG. **18**A is an 3D view of a principle of acoustic navigation.

[0075] FIG. **18**B is an horizontal view of a principle of acoustic navigation.

[0076] FIG. **18**C is a vertical view of a principle of acoustic navigation.

[0077] FIG. **19** is a diagram showing processing flow an acoustic navigation.

[0078] FIG. **20**A is a diagram of an acoustic transmission signal pattern.

[0079] FIG. **20**B is a diagram showing a block diagram of a acoustic navigation system **141**.

[0080] FIG. **20**C is a time chart of an acoustic transmission/reception sequence.

[0081] FIG. **20**D is a diagram showing processing flow **1** of an acoustic distance measurement.

[0082] FIG. **20**E is a diagram showing processing flow **2** of an acoustic distance measurement.

[0083] FIG. **20**F is a diagram showing processing flow **3** of an acoustic distance measurement.

[0084] FIG. **21**A is a detailed diagram of an imaged aim in a diagram showing a principle (**1**) of optical distance measurement,

[0085] FIG. **21**B is a diagram showing a principle (**1**) of optical distance measurement,

[0086] FIG. **21**C is images of a capture ring aim.

[0087] FIG. **21**D is a diagram showing processing flow of an optical distance measurement

[0088] FIG. **22**A is a diagram showing a principle (**2**) of optical distance measurement using line segment AC.

[0089] FIG. **22**B is a diagram showing control force vectors.

[0090] FIG. **22**C is a diagram showing imaged aim for an optical distance measurement

[0091] FIG. **23**A Is an overview of position/speed control system of a deep-sea crane.

[0092] FIG. **23**B is a diagram showing control force vectors.

[0093] FIG. **23**C is a diagram showing generated forces by a wing.

[0094] FIG. **23**D is a diagram showing generated lift by a wing.

[0095] FIG. **24**A is a drawing showing a top view of attachment for precision control attachment

[0096] FIG. **24**B is an overview of the of attachment for precision control attachment

[0097] FIG. **24**C is a diagram showing generated forces by a precision control attachment

[0098] FIG. **24**D is a drawing showing a rendezvous mechanism.

[0099] FIG. **24**E is a drawing showing a rendezvous target.

[0100] FIG. **25**A is a diagram showing no braking operation of a deep-sea crane

[0101] FIG. **25**B is a diagram showing full braking operation of a deep-sea crane.

[0102] FIG. **26**A is a diagram showing rotation operation of a deep-sea crane.

[0103] FIG. **26**B is a diagram showing horizontal move operation of a deep-sea crane.

[0104] FIG. **26**C is a diagram showing rotation operation of a deep-sea crane using lift of wing.

[0105] FIG. **26**D is a diagram showing horizontal move operation of a deep-sea crane using lift of wing.

[0106] FIG. **27**A is an overview showing installation of a seabed mineral ores collecting device.

[0107] FIG. **27**B is an overview showing floating up after installation of a seabed mineral ores collecting device.

[0108] FIG. **28**A is a diagram showing a descending deep-sea crane w/o load.

[0109] FIG. **28**B is a diagram showing a descending deep-sea crane with vacant seabed mineral ores collection containers

[0110] FIG. **28**C is a diagram showing float up of the seabed mineral ores collecting device.

[0111] FIG. **28**D is a diagram showing float up of the loaded seabed mineral ores collecting container.

[0112] FIG. **29**A is an overview a seabed mineral ores collecting device (electric seabed power shovel).

[0113] FIG. **29**B is an overview of various attachments for a a seabed mineral ores collecting device.

[0114] FIG. **30** is a diagram showing a supervisory control device of a seabed mineral ores collecting device.

[0115] FIG. **31**A is an overview of a deep sea crane w/ one buoyancy tank.

[0116] FIG. **31**B is an overview of a deep sea crane w/ three buoyancy tanks.

[0117] FIG. **31**C is a top view of a deep-sea crane w/ three divided tanks.

[0118] FIG. **31**D Is an overview of a deep sea crane w/ three buoyancy tanks bundled together.

[0119] FIG. **31**E is an overview of a deep sea crane bundling mechanism w/ three buoyancy tanks bundled together.

[0120] FIG. **31**F is a top view of a deep-sea crane w/ three divided tanks bundled together.

[0121] FIG. **32** is an overview of a surface command ship, a gut crane ship.

[0122] FIG. **33**A is an overview of a sub buoyancy tank of a deep-sea crane w/ three buoyancy tanks.

[0123] FIG. **33**B is an diagram showing operation of buoyancy tank switch a deep-sea crane w/ three buoyancy tanks.

[0124] FIG. **34**A is a diagram showing a cargo handling procedure (a) of a deep-sea crane w/ three tanks.

[0125] FIG. **34**B is a diagram showing a cargo handling procedure (b) of a deep-sea crane w/ three tanks.

[0126] FIG. **34**C is a diagram showing a cargo handling procedure (c) of a deep-sea crane w/ three tanks.

[0127] FIG. **34**D is a diagram showing a cargo handling procedure (d) of a deep-sea crane w/ three tanks.

[0128] FIG. **34**E is a diagram showing a cargo handling procedure (e) of a deep-sea crane w/ three tanks.

[0129] FIG. **34**F is a diagram showing a cargo handling procedure (f) of a deep-sea crane w/ bundled three tanks.

[0130] FIG. **34**G is a diagram showing a cargo handling procedure (g) of a deep-sea crane w/ bundled three tanks.

[0131] FIG. **34**H is a diagram showing a cargo handling procedure (h) of a deep-sea crane w/ bundled three tanks.

[0132] FIG. **34**I is a diagram showing a cargo handling procedure (i) of a deep-sea crane w/ bundled three tanks.

[0133] FIG. **35** is a diagram showing a supervisory control device of a deep-sea crane.

[0134] FIG. **36**A is a top view diagram showing installation of the acoustically guided acoustic position markers.

[0135] FIG. **36**B is an overview acoustic position marker field.

[0136] FIG. **36**C is a diagram showing an instillation method of acoustic position markers.

[0137] FIG. **37**A is an overview of an acoustic position marker.

[0138] FIG. **37**B is a diagram showing structure of an acoustic position marker.

[0139] FIG. **37**C is a diagram showing structure of an acoustic position marker.

[0140] FIG. **38**A is A processing flow diagram of an acoustically guided acoustic position marker/initialization.

[0141] FIG. **38**B is A processing flow diagram of an acoustically guided acoustic position marker/guidance supervision.

[0142] FIG. **38**C is A processing flow diagram of an acoustically guided acoustic position marker/guidance processing.

[0143] FIG. **38**D is a drawing showing an axial view of acoustic position marker.

[0144] FIG. **38**E is a diagram showing an acoustic position marker control system.

[0145] FIG. **39**A is a diagram showing the guidance logic of the acoustically guided acoustic position marker/sound propagation diagram.

[0146] FIG. **39**B is a diagram showing the guidance logic of the acoustically guided acoustic position marker/sound wave form.

[0147] FIG. **39**C is a diagram showing the guidance logic of the acoustically guided acoustic position marker/Signal processing logic.

[0148] FIG. **40**A is an overview of an operation of insatiling acoustic position markers.

[0149] FIG. **40**B is a diagram showing a position marker ship **071**.

[0150] FIG. **40**C is a diagram showing auxiliary position marker ships.

[0151] FIG. **41**A is a diagram showing a processing flow of an acoustically guided acoustic position marker installation system.

[0152] FIG. **41**B is a diagram showing a processing flow of an acoustically guided acoustic position marker installation system.

[0153] FIG. **41**C is a diagram showing a processing flow of an acoustically guided acoustic position marker installation system.

[0154] FIG. **41**D is a diagram showing a processing flow of an acoustically guided acoustic position marker installation system.

[0155] FIG. **41**E is a diagram showing a processing flow of an acoustically guided acoustic position marker installation system.

[0156] FIG. **41**F is a diagram showing a processing flow of an acoustically guided acoustic position marker installation system.

[0157] FIG. **41**G is a diagram showing a processing flow of an acoustically guided acoustic position marker installation system.

[0158] FIG. **41**H is a diagram showing a processing flow of an acoustically guided acoustic position marker installation system.

[0159] FIG. **42**A is a processing flow diagram of an acoustic transponder common system.

[0160] FIG. **42**B is a diagram showing flow of transponder common system.

[0161] FIG. **43**A is a diagram showing a capture operation diagram of a seabed mineral ores collecting device (electric power shovel).

[0162] FIG. **43**B is an overview showing an optical precise control operation to capture seabed mineral ores collecting device.

[0163] FIG. **44**A is a top view drawing of attachment for precision control.

[0164] FIG. **44**B is an overview of of an attachment for precision control.

[0165] FIG. **44**C is a diagram showing force vectors for precision control.

[0166] FIG. **44**D is a diagram showing a rendezvous mechanism.

[0167] FIG. **44**E is a diagram showing an rendezvous target FIG. **45**A is an overview of an inertially guided acoustic position marker.

[0168] FIG. **45**B is a diagram showing installation of inertially guided acoustic position markers/settled suspension.

[0169] FIG. **45**C is a diagram showing installation of inertially guided acoustic position markers/inertial guidance.

[0170] FIG. **45**D is a diagram showing installation of inertially guided acoustic position markers/undersea landing.

[0171] FIG. **46**A is an overview of an inertially guided acoustic position marker.

[0172] FIG. **46**B is a diagram showing structure of an inertially guided acoustic position marker.

[0173] FIG. **46**C is a diagram showing operating forces of an inertially guided acoustic position marker.

[0174] FIG. **47**A is a diagram showing the configuration of an inertially guided acoustic position marker control device.

[0175] FIG. **47**B is a diagram showing the configuration of a position marker ship control system.

[0176] FIG. **47**C is a diagram showing control wings of inertially guided acoustic position marker control device FIG. **48**A is a processing flow diagram of the inertially guided acoustic position marker control device/Initialization.

[0177] FIG. **48**B is a processing flow diagram of the inertially guided acoustic position marker control device/guidance.

[0178] FIG. **49**A is a processing flow diagram (a**1**) of a position marker ship control device for inertially guided acoustic position markers.

[0179] FIG. **49**B is a processing flow diagram (a**2**) of a position marker ship control device for inertially guided acoustic position markers.

[0180] FIG. **49**C is a processing flow diagram (a**3**) of a position marker ship control device for inertially guided acoustic position markers.

DETAILED DESCRIPTION OF THE INVENTION

[0181] Hereinafter, modes for carrying out the present invention will be described in detail with reference to the drawings. The present invention is not limited to the following description, and various modifications can be made without departing from the scope of the invention. In this document, a device that repeatedly collects seabed mineral ores by going back and forth between the deep sea floor and the surface of the sea is referred to as a "deep sea crane", and the entire system including peripheral support devices is called a "seabed resource collection system" ((FIG. **2** Overall view of the seabed mineral ores collection system). The deep-sea crane adopts all of the following three points that should be learned from sperm whales.

(1) Balancing internal and external pressure
(2) Utilising buoyancy
(3) Moving autonomously (autonomous navigation)

[0182] The collection of the present invention is carried out by operating the buoyancy of a liquid having a low specific gravity which is liquid at room temperature in combination with the gravity of a ballast. It is a system that exchanges ballast transported from land over the sea surface with almost equal weight of seabed mineral ores on the seabed, and is characterized by not inputting energy itself. Also, since the buoyancy source is sealed, it is not possible to newly generate a buoyancy source due to the method.

(1) Specific Gravity Control

[0183] a. It is possible to reduce the specific gravity by discarding the mounted ballast and reducing the underwater weight.

b. Specific gravity cannot be increased while ascending or descending.

(2) Terminal Speed Control

[0184] When moving in a viscous fluid such as water under the influence of gravity or buoyancy, there is a terminal velocity that becomes constant in balance with the drag force. The specific gravity is set near the seawater specific gravity, but if a is set to be smaller than the seawater specific gravity, it floats at a constant final velocity specified by a and the shape of the deep-sea crane. When the specific gravity of the deep sea crane **001** is larger than the specific gravity of seawater, and the larger part is a, the crane descends at a constant final speed defined by a and the shape of the deep sea crane. If α is adjusted and there is a speed reducer, the terminal speed is adjusted by increasing or decreasing the resistance by deploying the speed reducer.

(3) Descent from the Sea Surface and Landing

a. When descending, set the specific gravity to seawater specific gravity$+\alpha$. The larger α is, the shorter the descent time is, but the amount of consumed ballast increases, and there is a drawback that the control described in the following item b. becomes difficult, and the optimum value is obtained by adjustment

b. When the landing approaches, the ballast is discarded and the terminal speed is approached to 0 to softly land.

(4) Ascending from the Sea Floor to the Sea Surface

At the time of ascending, the specific gravity is set to seawater specific gravity minus α to ascend, and the speed is adjusted by the control wing and landing leg **006** to reach the vicinity of the surface command ship **010**. In the case of excessive buoyancy such as floating from the sea bottom with an empty load, the deceleration parachute **064** (FIG. **27**B) is used.

I Seabed Mineral Ores Collection Equipment Components

1. Deep Sea Crane

[0185] The deep-sea crane **001** has a structure similar to that of a balloon as shown in FIG. **1**A, and an unmanned submersible in which a cargo compartment **005** is suspended by a suspending net **003** and a suspending rope **004** from a spherical buoyancy tank **002** that reciprocates between the sea surface and the seabed to collect the seabed mineral ores. Adopting a spherical buoyancy tank **002** is easy to manufacture, has a large volume with respect to the surface area, is easy to obtain strength compared to other shapes, has simple characteristics as an underwater vehicle, and has simple structural calculations needed.

The deep-sea crane **001** does not need to have pressure resistance because the internal and external pressures are almost the same regardless of the depth in the sea. The buoyancy tank **002** can be made of a lightweight metal such as duralumin or a carbon fiber resin that is lightweight and has high strength. It is sealed filling with a liquid such as n cyclopentane (specific gravity 0.63 at room temperature) or gasoline (specific gravity 0.70 at room temperature). Gasoline has less buoyancy, but has the advantage of lower price.

[0186] The deep-sea crane **001** travels back and forth between the sea floor and the sea surface by autonomous navigation. When descending from the sea level, ballast is loaded and sinks, and when rising, the seabed mineral ores are loaded instead of ballast. Buoyancy corresponding to the loaded ore at the time of ascent is obtained by dumping ballast on the seabed. Further, controllable wings and landing legs **006** are installed in the cargo compartment **005** to control and decelerate the deep sea crane. In FIG. **1**A and FIG. **23**A, control wings and landing legs **006***a, b, c, d* are provided, and two each in the positive and negative directions of the X axis and Y symmetrical to the Z axis of the cargo compartment **005** of the deep-sea crane **001**. Since the control wing and landing leg **006** is used in an operation in which the weight of the load in the buoyancy tank **002** and the cargo compartment **005** is balanced, the load burdened at the time of landing is small.

[0187] The main feature of Deep Sea Crane **001** is to replace the ballast and the collected seabed mineral ores with a lightweight and simple mechanism using gravity. On the seabed, the cargo compartment **005** is landed using the control wing and landing leg **006**, and the buoyancy tank floats upward. There is a ore loading gap **092** between the buoyancy tank **002** and the cargo compartment **006**. The collected seabed mineral ores are fed from above the cargo compartment to push out the ballast from below and replace the ballast with the collected ore. The amount of ballast dumped is adjusted to keep landing on the seabed and to float up.

[0188] Since the deep-sea crane **001** is an autonomous underwater vehicle, guidance control is essential for this purpose, therefore underwater acoustics, image processing, inertial navigation, and control theory are applied. An optical fiber cable is used for control and image signal communication with the surface command ship **010**.

FIG. **17**A is a top view of the deep-sea crane **001**, in which the sound generator **230** and the acoustic sensors A to D **231-234** are installed for guiding the deep-sea crane **001** to the surface command ship **010** at the time of ascent FIG. **17**A is a bottom view of the cargo compartment **005** of the deep-sea crane **001**. A sound generator **230**, acoustic sensors A to D **231-234**, and an image sensor **235** are installed for the purpose of guiding the deep-sea crane **001** to the landing point **011** when descending. These operation methods and examples will be described in detail in the section "I Navigation system". In FIG. **2**, a power supply and signal cable **012** is connected to the deep sea crane **001**, and control signals and power are supplied from the surface command ship **010**. The signal cable can be made lighter by using optical fiber. It is necessary that the electric device is completely oil-immersed or water-immersed, and the electronic circuit also has pressure resistance by a method including resin encapsulation. The power source may be a rechargeable battery equipped with a deep sea crane **001**.

1.1 Collecting the Seabed Mineral Ores in the Cargo Compartment

[0189] The deep sea crane **001** approaches the sea floor with the buoyancy of the buoyancy tank **002** and the weight of the ballast mounted in the cargo compartment **005** slightly larger than the specific gravity of water. The landing speed can be controlled by finely adjusting the amount of ballast dropped from the lower part of the cargo compartment Setting a fixed value determined by the mechanical strength of the deep-sea crane, about 0.7 m/s. The opening of the control wing and landing leg **006** can be automatically adjusted according to the ups and downs of the seabed.

[0190] The descending path and the floating path of the deep-sea crane **001** are controlled by controlling the degree of opening and the rotation angle of the control wing and landing leg **006** of FIG. **23**A. The control wing and landing leg **006** has a wing installed to control and brake the water flow. The control to input energy is not performed, and the potential energy at the time of descent or ascent is converted by the control blade to be a control force.

[0191] FIG. **23**C is a diagram showing a mechanism of generation of a control force by the control wing and landing leg **006**, and FIG. **23**A shows a sinking process in which the gravity vector **309** is larger than the buoyancy vector **300** by the sinking force **303**. At this time, if the inclined control wing **006** as shown in FIG. **23**B exists, the control blade drag force **302** is generated at a right angle to the control wing **006**, and as a result, the wing thrust force **314** is generated. In FIG. **23**C, the wing thrust **314** moves diagonally downward, but since the deep-sea crane drag **315** cancels the wing thrust **314** in the opposite direction, it descends at a constant speed in the wing thrust **314** direction. FIG. **23**B shows the wing thrust on each control wing and landing leg. For the thrust in the horizontal direction, a lift force vertical to the wing surface may be used. In FIG. **26**A, each control blade tilts in the same direction around the axis to rotate the deep-sea crane. The direction of rotation is opposite when descending and when ascending. In FIG. **26**B, two opposing control wings are tilted in the same direction on the horizontal coordinate plane. The other two should be vertically oriented so that no control force is generated in the horizontal direction. FIG. **25**A shows the case where the degree of open leg is minimized to minimize the braking force, and FIG. **25**B is the case where the degree of open leg is maximized to maximize the braking force. In FIG. **1**, an opening/dosing mechanism of the landing leg and a weight sensor **007** are provided at each root of the control wing/landing leg **006** to set the opening angle of the control wing and landing leg **006** within the opening adjustment range **048**. It is controlled by the deep sea crane controller **284**. The adjustment of the braking force is performed by the control wing control system **222** based on the decelerator individual control amount calculation **220** of FIG. **14** for the deep sea crane **001**.

[0192] FIG. **4** shows the loading operation of the collected seabed mineral ores on the deep sea crane **001**. The collected ores are input from above the cargo compartment **005** by an electric power shovel (a seabed mineral ores collecting device), but the input amount is monitored by a weight scale (opening/closing mechanism and weight sensor **007**) at the base of the landing leg, and the amount corresponding to the input amount is checked. Discard the ballast from the ballast discharging mechanism. Even if all ballast are dumped, if the specific gravity of the deep-sea crane becomes larger than seawater, it will not be able to ascend. Therefore, the residual ballast amount is constantly monitored by an algorithm from the change in the weighing value at the base of the control and landing wings. The collection of ore is stopped and the surface is raised.

(1) Structure and Operation of Cargo Compartment

[0193] The cargo compartment **005** has the following policies.

First, in order to exchange the ores to be collected with the ballast on the sea floor by utilizing the gravity, the structure of the cargo compartment **005** carrying the ballast and the collected ores is determined. The cargo compartment **005** uses gravity to abandon the ballast, has an open shape for loading the collected ore, and has a discharge port that can be opened and closed at the lower end. A suitable shape for this purpose is a truncated cone that opens upwards. The collected ore is loaded from above and the ballast can be discharged from the discharge port at the bottom. For the ballast, fine sand is used to ensure fluidity. Secondly, in order to avoid mixing with the ballast and the collected ore, a partition wall that covers the upper part of the cargo compartment **005** is provided. The structure will move to the discharge port at the lower end while occupying the boundary with the ballast as it is charged. The partition wall may be a bellows type and extends downward, or may be a membrane type.

[0194] Third, when exchanging the ballast with the collected ore, the amount of dumped ballast is controlled so that the generated buoyancy is less than the total weight of the deep sea crane (the total weight of the ballast, the collected ore, and the collected equipment). For this purpose, a sensor that measures the total water weight of the deep-sea crane is installed, and the amount of ballast dumped is predicted and controlled by a computer. When loading of recovered ore is completed and levitation is started, the total weight of the deep sea crane should be smaller than that of water. Fourth, it is necessary to secure the liquidity of the ballast. This is because it is necessary to accurately control the total weight of the deep sea crane according to the loaded ore to be loaded, and the fluidity of the ballast is essential to control the ballast discharge port and the ballast discharge amount accurately. For this purpose, the structure is such that the particle size of the ballast is made fine and at the same time the water stream is jetted in order to increase the fluidity.

[0195] FIG. **5**A-**5**C show a mechanism which exchanges the ballast with the thrown-in collected ores. The cargo compartment having a shape of a truncated cone having a structure of squeezing to the lower side. FIG. **5**A shows that the cargo compartment **005** at the time of landing is filled with ballast. The ballast is fine-grained earth and sand, and the discharge amount can be finely adjusted by the discharging mechanism **008** provided at the lower end of the cargo compartment **005**. The dumping of ballast is performed by gravity, and the transportation cost and environmental load can be reduced by using the concentration slag and the smelter slag of collected ores. By covering the upper part with the partitioning mechanism **016**, even if the collected ore is charged from the upper part and the ballast dump is carried out from the ballast discharging mechanism **008** at the lower end.

It is possible to prevent dumping of collected ore and mixing of collected ores with ballast. FIG. **5**D and FIG. **5**E show an example of a partition mechanism having a bellows structure that can be extended downward, and a membrane structure may be used. FIG. **5**B shows an intermediate process of charging the collected ores, and FIG. **5**C shows the end of charging the collected ores. In actual operation, it is necessary to make the specific gravity of the deep-sea crane lighter than seawater when ascending, so it is necessary to leave ballast for dumping.

[0196] FIG. **7**A is a sectional view taken along line AB. An aperture mechanism/weight sensor **007** is provided at each root of the control wing/landing leg **006** to control the opening angle of the control wing/landing leg **006** within the opening adjustment range **048**. FIG. **2** shows an operation example of the deep sea crane **001** of FIG. **1**A. With the control wings and landing legs **006** of the cargo compartment **005** folded (FIG. **2** (*a*)), a ballast is installed in the cargo compartment **005** to bring the overall specific gravity to 1.0+α, and the deep sea crane **001** is dropped to the seabed. After the navigation control of the inertial navigation section **090** and the acoustic navigation section **091**, the deep-sea crane **001** opens the control wing and landing leg **006** at a position close to the seabed (FIG. **2** (*c*), decelerates, and dumps the ballast if necessary). It makes a soft landing (FIG. **2** (*c*)).

[0197] FIG. **4** shows an example of ore loading on the seabed. The collected ore **018** is loaded from the ore loading gap **092** between the buoyancy tank **002** and the cargo compartment **009** by the electric power shovel **015**, which drives a hydraulic system with an electric motor. The electric power shovel **015** has a weight of about 6 to 8 tons, and the buoyancy due to the gasoline filled in the buoyancy tank **002** is about 10 tons in the case of the system of FIG. **1**A. You can bring it to the sea floor. The cargo compartment **005** is equipped with a ballast that balances the buoyancy of the buoyancy tank **002** and is softly landed on the sea floor. seabed electric power shovel **015** puts the collected ore **018** into the cargo compartment **005**. The deep-sea crane **001** discards ballast corresponding to the input collected ore **018** from the ballast discharging mechanism **008**, and adjusts the discard amount so that the deep-sea crane **001** does not float. There is an aperture mechanism and weight sensor **007** at each root of the control wing and landing leg **006** in FIG. **1**A. If the sum of the measured values is positive, it indicates a landing state. When the collected ore **023** is loaded into the deep-sea crane **001** in a landing state, the weight measurement value increases, so the weight corresponding to the increased amount is discarded from the ballast discharging mechanism **008**.

[0198] It is possible to attach various attachments (FIG. **27**B) to the seabed electric power shovel **015** in advance so as to be convenient for the operation of introducing the collected ores. It is desirable that the ballast **017** is replaced with the collected seabed mineral ores **018** at the as much as possible in the collected mineral input of FIG. **4**. The following measures are effective in achieving this.

[0199] (1) A discharge throttling mechanism capable of adjusting the degree of opening is installed at the exit of the ballast discharging mechanism **008**, and the ballast is prepared with fine particles so that only the ballast is dumped and the final ore loading space is secured.

[0200] (2) In order to deal with the case where the collected seabed mineral ores **018** is fine particles such as rare earth mud, the ballast upper surface is covered with a membrane or an expandable partition mechanism, and the portion below the partition mechanism **016** is discarded.

[0201] When loading of the collected ore **018** to the deep-sea crane **001** is completed in FIG. **2** (*d*), the remaining ballast is dropped to obtain buoyancy and levitate (FIG. **2** (*e*)). Further, the control wing and landing implantation leg **006** is folded (FIG. **2** (*f*)) to reduce resistance and rise, and as the sea surface approaches, the control wing and landing leg **006** is opened to decelerate, It is guided near the surface command ship **010** in FIG. **16**A.

[0202] An operation example of ore loading on the seabed will be described with reference to FIG. **4**. Since the cargo compartment **005** is suspended from the buoyancy tank **002** by three suspension ropes **004**, there is a ore loading gap **092** between the buoyancy tank **002** and the cargo compartment **005**. The seabed electric power shovel **015** can put the collected ore **018** there. FIG. **5**A shows a state in which the ballast **017** is loaded in the cargo compartment **005** and brought to the seabed. There is a partition mechanism **016** that covers the ballast **017**. FIG. **5**E is a top view seen from above, and FIG. **5**D the partition mechanism **016** is a cutaway view. The partitioning mechanism **016** is a bellows mechanism that can expand and contract as shown in FIG. **5**D, and is in the state of FIG. **5**A when compressed. When the collected ore **018** is loaded into the cargo compartment **005** from above, the ballast **017** is discarded downward by gravity by the ballast discharging mechanism **008** and the collected ore **018** is mounted above the partition mechanism **016** as shown in FIG. **5**B. FIG. **5**C shows a state when the collected ores have been loaded, the ballast **017** is completely disposed of below the ballast discharging mechanism **008**, and the collected ore **018** is mounted above the partitioning mechanism **016**. The partitioning mechanism **016** extends and is in close contact with the inside of the cargo compartment **005**. The collected ore **018** pushes out the ballast **017** by gravity.

[0203] FIG. **6** shows an example of a water flow mechanism installed below the partition mechanism **016** on the inner wall of the cargo compartment **005**. Water is injected from the water injection mechanism **1 023** and water injection mechanism **2 025** through the water injection hole **027** of the water injection pipe **026** to increase the fluidity of the ballast **017**. The gravity of the collected ore **018** makes it easier for the ballast **017** to be pushed out of the ballast discharging mechanism **008**. In the example of FIG. **6**, the water injection mechanism is divided into two systems so as to improve reliability, and even if one system does not operate, there is no hindrance to the total weight control of the deep sea crane. The water flow generators **1 023** and **2 025** that drive the water flow are also installed in each system and are duplicated. FIG. **7** shows an example of the structure of the discharge aperture mechanism. FIG. **7**A shows the state when the aperture port is opened. In the case of the configuration example, the aperture mechanism has fan-shaped openings formed in the disk at intervals of 22.5 degrees and is arranged so as to be vertically stacked as shown in the FIG. **7**A CD sectional view.

As shown in the cross-sectional view FIG. **7**A AB, the diaphragm plate **1 028** and the diaphragm plate **2 029** are placed in an open state. When it is arranged as shown in the sectional view FIG. **7**B AB, it is in a closed state. Opening and closing operations are shown in FIG. **7**A top view and FIG. **7**B top view. The rotary drive mechanism **1 030** moves the aperture plate **1 028** through the motor **1 021-1** and the worm gear **033-1** to move the gear cut around the aperture plate **1 028** to rotate. The rotary drive mechanism **2 031** causes the aperture plate **2 029** to rotate by moving the gear cut around the aperture plate **2 029** through the motor **2 021-2** and the worm gear **2033-2**. This controls the aperture state of the ballast discharge mechanism **008**. Opening and closing the ballast discharging mechanism **008** of the cargo compartment **005** is extremely important for controlling the total weight of the deep-sea crane **001**, because if the specific gravity cannot be made smaller than that of seawater by failing to release the ballast, it will be impossible to float to the sea surface. If the specific gravity becomes less than seawater before the end of ore loading, unintentional levitation will occur. In order to prevent such a situation, the ballast discharge controlling mechanism of the cargo compartment divides the aperture plate into two parts so that even if one system of the rotary drive mechanism malfunctions, the remaining system can be used to float up the deep sea crane. The double system is also introduced in the water flow mechanism of the cargo compartment shown in FIG. **6**C, and is configured so that the function does not stop even if one of the water injection mechanism **1 023** and the water injection mechanism **2 025** fails.

[0204] The cargo compartment control system described in FIG. **8** controls the entire collected ore loading mechanism. The system itself is a microcomputer control system, and the strain gauge of the opening/dosing mechanism and weight sensor **007** measures the load applied to each leg of the control wing and landing leg **006**. Landing continues if the underwater weight is positive. The weight of the water at the time of the first landing increases by the amount added every time the collected ore **018** is added. Since the ballast weight released from the ballast discharging mechanism **008** can be measured, the remaining ballast amount can be calculated from the known ballast weight brought to the seabed when landing. The collected ore **018** may be added to the extent that it can float if the remaining ballast is completely discarded. The amount of ballast discharged is controlled by adjusting the opening of ballast discharge controlling mechanism shown in FIG. **7**. The rotary drive mechanism **1 030** and the rotary drive mechanism **2 031** are controlled by the 2-channel motor controller **204**, and the rotational position is captured by the rotation position sensor **205**. In order to control the 2-channel water injection mechanism of FIG. **6**C, the water flow generator **1 019** and the water flow generator **2 020** are controlled by the 2-channel motor control device **2041**, and are taken in by the rotation speed intake device **2051**. The status values including the total weight of the deep sea crane **001** are reported to the supervisory control system **283** via theooptical interface **211**. Further, based on the float up command of the deep sea crane, the ballast discharge controlling mechanism of the cargo compartment in FIG. **7** is controlled to make the specific gravity of the total weight of the deep sea crane **001** smaller than that of seawater for levitation by abandoning the ballast.

[0205] FIG. **9** is a graph showing an example of the time transition of the cargo compartment load composition. The actual weight that can be measured is the ballast weight brought into the seabed and the underwater weight of the entire deep-sea crane (hereinafter, "total underwater weight") measured by the weight sensors (strain gauge) **007** (installed in the control wings and landing legs **006**). The solid line in FIG. **9** shows the change over time in the total underwater weight, which is a measurable value.

(e) shows the total underwater weight=0, and when the total underwater weight falls below this value, it floats.

(d) The total underwater weight threshold is controlled so that it does not fall below the total underwater weight threshold in order to avoid unplanned ascent during the seabed stay.

(h) is the state when the deep-sea crane landed on the seabed, and the total underwater weight was >0.

The total underwater weight >(d), which means that "If the total underwater weight is more than the threshold of the total underwater weight, the ballast is discharged."

(b) The total underwater weight change due to ballast dump control shows the weight change at this time. The estimated value of the remaining amount of ballast is reduced by the reduced value at this time (curve with thick dotted line in the figure). When the collected ore is loaded into the cargo compartment **005**, the weight of the entire water weight increases by the amount of one batch of ore input. In response to this increase, the ballast is discarded until the total underwater weight reaches (d) the total underwater weight threshold. If collected ore is allowed to be loaded into the cargo compartment **005** after dumping ballast, the total weight of water will increase by (b) one batch of ore input. By repeating this process, when the estimated value of remaining ballast amount reaches the threshold value of estimated remaining amount of ballast (c) at time (g), further ore input is stopped and the remaining ballast is discarded to float up. If you do not, you will not be able to ascend, so throw the ballast so that the total underwater weight is (f) the ascent threshold.

[0206] A diagram of the cargo compartment control system in FIG. **8** is a system configuration for realizing the time transition of the composition of the cargo in the cargo compartment shown in FIG. **9**. The software of the cargo compartment control system is shown in the process flow of FIG. **10**. The operation of the processing system is the periodic processing by the timer, and the periodic processing is activated at the initial activation in FIG. **10**A. FIG. **10**B defines the entire cycle process. In FIG. **10**, a processing block **502** takes in weight measurement data which is plant measurement data, rotational positions of the rotary drive mechanisms **1** and **2**, and rotational speeds of the jet pumps

1 and **2**. In a processing block **503**, it is calculated a change amount/change rate of the plant measurement data including rationality check and noise removal. The processing block **504** permits the input of ore when the ballast discardable amount is larger than the upper limit of one batch of the input amount of collected ore, when the dumping of the ballast is stopped, and when the total weight of water is settled. The amount of ballast that can be disposed of is the weight of the ballast brought to the seabed minus the integrated value of the ballast discarded, and then subtracting the safety value. The processing block **505** displays an alarm of prohibition of the input of collected ore on the console **441** of the surface command ship **010** in order to prevent the input of the ore into the cargo compartment **005**. It is transmitted to the surface command ship **010** via the optical cable **268**.

[0207] Process block **504** determines if the collected ore input is permitted. Input of collected ore is allowed only while ballast dumping is stopped. If the value of the weight sensors **007** that are periodically taken in are settled, and the display **255** of the surface command ship **010** does not permit the input of the collected ore, then it is determined that the ore input is not permitted, then proceeds to processing block **505**. When it is determined that the ore charging is permitted, it is determined that it is dangerous to perform the plant (deep sea crane) control because the state is changing, and the process proceeds to the processing block **507**.

[0208] In processing block **507**, checking if there is no request for dumping ballast and that dumping of ballast is not in progress. Since the ore loading is allowed only when there is no ballast dumping, the display of the ore loading disapproval display on the display **255** of the surface command ship **010** is erased in processing block **508**. If there is ballast dumping, the aperture mechanism of the cargo compartment is closed in processing block **513**, and an ore charging disapproval display is requested in the display **255** of surface command ship **010** in processing block **514**.

[0209] If the processing block **504** prohibits the ore loading, the ballast dump control is permitted, and the processing block **505** requests the display **255** of the surface command ship **010** to request an alarm display indicating that the ore loading is prohibited. The processing block **506** determines whether it is not a floating command, ore is not being put in, and the weight measurement data is normal. If the determination result is YES, it means that the ballast dumping control is performed, and if the determination result is NO, it means an emergency command from the surface command ship **010** or a floating control by completion of loading of the ores. In processing block **509**, the total underwater weight threshold of FIG. **9** (*d*) is set to the target value of the ballast dump control. In processing block **510**, the floating up threshold value shown in FIG. **9**(*f*) is set to the target value for ballast dump control.

[0210] The processing block **511** shifts to processing block **513** to stop the ballast dumping when the total underwater weight of the deep-sea crane is equal to or less than the threshold value. That is, the rotary drive mechanisms **1**, **031** and **2**.**032** of the aperture mechanism of the cargo compartment **005** of FIG. **7** are driven to close, and the water injection mechanism of the cargo compartment **005** of FIG. **6** for fluidizing the ballast is also stopped. If the total underwater weight of the deep-sea crane is equal to or greater than the threshold value, a control calculation toward the threshold value is performed in processing block **512**. PID control of a digital system that is periodically activated by a timer is a known technique, and controls the opening of the aperture mechanism of the cargo compartment **005** of FIG. **7** and, at the same time, water is injected into the water injection mechanism to increase the fluidity of the ballast. In processing block **515**, the present plant value is stored as the previous plant value in preparation for the processing of the next sampling cycle, and in processing block **516**, a timer is set to start the processing of the next sampling cycle.

1.2 Ore Collection Operation Using Seabed Mineral Ores Collection Containers

[0211] The ore loading can be performed using the seabed mineral ores collection container **034** shown in FIG. **11** instead of using the cargo compartment **005**. It is also possible to throw in the collected mineral ores **018** with the seabed mineral ores collecting device **015** in the seabed mineral ores collection container **034**, which has been previously carried into the sea bottom by the deep sea crane **001**. As an advantage of this container **034**, firstly, it can separate the mining operation by the ore collecting device **015** from the surfacing operation by the deep-sea crane **001**. The deep-sea crane **001** can concentrate in the surfacing when the sea surface condition is quiet. We should notice that the sea floor is not easily affected by the sea surface condition, therefore it is possible to continue mining with the ore collecting device **015**. Secondly, when the collected ore **018** is overloaded, the risk that the deep sea crane **001** cannot float up and bring lost can be eliminated. In particular, it is possible to discharge excess ore from the overloaded ore collection container **034** by the ore collection device **015**, and this kind of erroneous operation can be avoided. On the other hand, it is necessary for the lifting hook **047** of the cargo compartment **005** of FIG. **28**B to capture the capture ring **037** of the ore collection container **034** in FIG. **11**A.

[0212] This operation needs precise position control of the deep sea crane **001** (this precise position control can also be used for collecting the ore collecting device **015** from the sea bottom). The ballast discharging mechanism of the cargo compartment **005** and the ore loading mechanism are not required, but the precision position control mechanism of the deep sea crane **001** (FIG. **24**A to E) precision control attachment) is required. Further, a ore collection container **034** is additionally required, and a weight sensor **035** for weighing the collected ore **018**, functions to be captured using the capture ring **037**, and a docking communication function with the deep sea crane **001** are required.

[0213] The position/speed control of the deep-sea crane **001** according to FIG. **23** cannot move upward from a stationary state because there is no active propulsive force. In order to perform precise alignment, the precision control attachment shown in FIG. **24** is added to the cargo compartment **005** to provide the following functions.

(1) Horizontal thrust FIG. **24**A Horizontal thrusters a to d
(2) Vertical thrust FIG. **24**A Vertical thrusters A to D
(3) Imaging device for optical navigation

[0214] FIG. **24**D Imaging device **235**

(4) Lifting hook FIG. **24**D

In above (1) and (2), a thrust force for precise positioning is applied, and in (3), the target position is precisely measured from the captured image by optical navigation. (4) The lifting hook **047** is attached directly below the imaging device **235**, and the capture ring is lifted as shown in FIG.

28C. When the precision control attachment is added on the cargo compartment **005** its thrust effects are shown in the action vector diagram of FIG. **24**C. FIG. **28**B shows a operation which shows the ore collection container **034** is brought to the seabed. Since the ore collection container **034** is empty, it is lightweight and can be brought in large quantities to the seabed instead of the ballast.

[0215] FIG. **11** shows an ore collection method using the ore collection container **034** installed on the seabed. When the ore collecting container **034** is installed on the seabed and the capture ring **037** at the tip is lightly pressed down by the ore collecting device **015** with the shroud **036** being closed, then the locking mechanism **040** is released, so the shroud **036** is opened.

[0216] The lock mechanism **040** is a push latch mechanism, for example, when a lock of a push latch mechanism is pushed for the first time the lock is released, when it is pushed for the second time, the lock is locked. The opening/closing mechanism **038** is opened by a spring when the lock mechanism **040** is disengaged. The shroud **036** needs to dump the ballast loaded in the cargo compartment **005** when the ore collecting container **034** is suspended and the deep-sea crane **001** floats up.

The seabed mineral ores collection container **034** is equipped with a microcomputer system and exchanges the following information with the deep-sea crane **001** to manage the ore get loaded into it and to float up from the seabed. The seabed mineral ores collection container control device **286** shown in FIG. **12** is installed in the ore collection container **034**, and its processing flow is as shown in FIG. **13**. The identification number (ID) of the ore collection container **034** installed on the seabed is defined in advance.

[0217] A series of operations from placing the seabed mineral ores collection container **034** to the seabed to its surfacing is as follows.

(1) As shown in FIG. **28**B, plural ores collection containers are carried into the seabed. The posture when placed on the seabed is not guaranteed.

(2) The moving image captured by the imaging device **235** of the ore collecting device **015** or the ultrasonic high-definition video camera **050** is monitored by the display **255** of the surface command ship **010** in FIG. **30** and the arm of the ore collecting device **015** is operated by the control stick **270** to erect and align each ore collector.

(3) Since it is necessary to know the identification number (ID) of the ore collection container **034** into which the ore is put, the acoustic transponders sequentially make inquiries. The ore collection container **034** blinks the capture ring **037**.

(4) Since the ore collection container **034** into which the ore is put is determined together with the ID, it is necessary to open the shroud **036**. Therefore, since the lock mechanism **040** is a lock of the push latch mechanism, the shroud **036** is locked from above and the ore collection device is pressed. When pushed down by the **015** arm, the shroud **036** opens.

(5) When the collected ore are put into the ore collection container **034**, the weight increases. Since the weight sensor **035** measures the weight, the seabed mineral ores collection container control device **282** calculates the weight based on the processing flow (FIG. **13**), and responds to the weight inquiry.

When the control device **285** of the ore collecting device determines that the specified weight has been reached, the arm of the ore collecting device **015** is operated to close the shroud **036** of each ore collecting device **034** and push down from above to lock the lock mechanism **040**. Since the ore collection container control device **282** is ready for collection, it is displayed on the seabed mineral ores collection device console **441** through the control device **285** that the collection is OK. The capture ring **037** for lifting the ore collection container **034** is illuminated turning on the LED adjacent to the upper side

(6) The deep sea crane **001** is precisely position-controlled to be docked on the hoisting hook and the LED-lighted capture ring **037**, and the lifting hook **047** is used for fishing as shown in FIG. **28**D. FIG. **43** shows the operation of lifting up the ore collecting device **015** from the seabed, and also the container **034** filled with the collected ores can be lifted up instead of the ore collecting device **015**.

(7) When the ballast in the cargo compartment **005** is dumped in the state of FIG. **28**D, the specific gravity of the deep-sea crane becomes lighter than that of seawater, and it floats above the sea surface.

2. Ore Collector

[0218] Since deep sea crane **001** does not use a lifting pipe to lift up the ores, it does not need to make the ores into a slurry or to granulate them, and the collected ores can be floated up in a state close to the original shape.

[0219] Therefore, the ore collecting apparatus **015** can can best utilize the know-hows of the ground mining machines.

[0220] Mining itself is done on the ground with mining equipment, and supports various vein conditions. There are the following types of seabed resources, and each has different characteristics when mining is done.

(1) Seawater hydrothermal deposits exist as rock masses in the form of mounds

(2) Cobalt-rich crust exists on the seabed in the shape of pillows

(3) Manganese nodules scatter as nodules of 10 centimeters or more

(4) Rare earth mud exists several meters to 10 meters below the seabed mud in layers of several meters to 10 meters.

[0221] All mining equipment is a large-scale construction machine, and if you add various attachments (bucket, breaker, rotary crusher, rocking swing gripper, etc.) to the construction machine, for example, the power shovel shown in FIG. **29**, It can handle different forms of resource existence on the seabed. Since the drive mechanism of the construction machine is operated by a hydraulic mechanism and the drive force is a differential pressure, the high pressure on the seabed is not related to the differential pressure, so there is no obstacle in principle. Since a construction machine on the ground operates a hydraulic pump by an internal combustion engine, it can be operated in water by replacing it to an electric motor. Construction equipment that operates underwater with a remote control has already been put to practical use. FIG. **29** shows an example of a remote controlled underwater construction machine. In order to be operated from the surface command ship **010**, a power signal cable **012** is connected to transmit power from a generator on the surface command ship, and a signal is sent by an optical cable.

[0222] Since the Sun light does not reach the seabed, the visibility may not be guaranteed, As a countermeasure an ultrasonic video camera (for example, http://www.soundmetrics.com) is installed in addition to the floodlight and optical imaging device. The capture ring **037** in FIG. **11**C is used when the ore collection container **034** is picked up from the sea bottom by the deep sea crane **001**. LED light emitters and an acoustic transponder are provided around the capture ring, and the deep sea crane **001** is precisely guided. It is used for the purpose of guiding the lifting hook of **047** in FIG. **24**C so that it can be easily captured.

2.1 Installation and Collection Operation

[0223] In addition to collecting mineral ores collected from the seabed, the deep-sea crane **001** needs to perform operations such as bringing a seabed mineral ores collecting device **015** (eclectic power shovel) from the surface to the seabed instead of ballasts in the cargo compartment **005** and lifting up the mineral ores collecting device **015** from the seabed to the sea.

[0224] In order to perform this operation, the following points are different from the case where the collected ores are loaded from the seabed into the cargo compartment **005**.

(1) Bringing the Seabed Mineral Ores Collecting Device **015** to the Seabed

[0225] When descending to the seabed, as shown in FIG. **27**A, a seabed mineral ores collecting device **015** can be suspended under the cargo compartment **005** and be softly landed on the seabed. When descending, a ballast for adjustment is installed so as to satisfy the conditions for the buoyancy of the buoyancy tank **002**, and when approaching the seabed, the control wing and landing leg **006** is opened and the ballast is dumped and landed adjusting the speed.

After the ore collecting device **015** is installed on the seabed, there is insufficient ballast in the cargo compartment **005**, and there is no ore collecting device **015**, the total buoyancy of the deep sea crane **001** becomes excessive and it rapidly rises, causing damage to the deep sea crane **001** by the stress at sea surface. To prevent this situation, the braking parachute is opened when climbing (FIG. **27**B). The ore collecting device **015** can also be lowered to the seabed by the crane **065** of the gut crane ship **067**.

(2) Recovery of the Seabed Mineral Ores Collection Device from the Seabed

[0226] In order to collect the seabed mineral ores collecting device **015** existing on the seabed, it is necessary to capture it using the lifting hook **047** installed at the lower part of the cargo compartment **005**. It is also required the precision control of millimeter order in position accuracy and several centimeters per second in relative speed. After capturing the ore collecting device **015** on the lifting hook **047**, the ballast in the cargo compartment **005** is discarded, and the specific gravity of the deep-sea crane **001** is made lighter than that of seawater and floated to the surface of the sea.

Since the operations of (1) and (2) of the ore collection device **015** require precise control unlike the collection of the collected seabed mineral ores, the partition mechanism **016** in FIG. **5**A-E for separating the ballast and the collected ore at the upper part of the cargo compartment **005** is replaced. The precision control attachments are shown in FIG. **24**AB. In FIG. **24**, there are four electric vertical thrusters and four horizontal thrusters are provided, and a secondary battery is attached as a power source. The thrusters are controlled by images from the image device **235** provided on the lifting hook **047**.

[0227] FIG. **27**A is a diagram showing the operation when the ore collecting device **015** is installed on the seabed. FIG. **28**C and FIG. **43** are diagrams showing the operation when the ore collecting device **015** is recovered from the seabed. Since recovery from the seabed is not a frequent operation, the precision control attachment is installed at the top of the cargo compartment temporally. The weight of the precision control attachment and the ore collecting device **015** needs to be less than the ore collecting capacity of the deep sea crane **001**. FIG. **43** shows an operation example when the ore collecting device **015** is collected from the seabed for the purpose of maintenance, etc. A ballast is mounted on the deep-sea crane **001** and lowered to the seabed (FIG. **43**A (**1**)). When approaching the seabed, the control wings and landing legs **006** are opened for precise position guidance and to decelerate to the maximum extent, and the ballast is also adjusted and discarded to stop at the seabed (FIG. **43**A (**2**)). The lifting hook **047** is precisely and optically guided to the capture ring **037** attached to the upper part of the ore collecting device (electric power shovel) **015** by the imaging device **235** at the tip, and the lifting hook **047** is moved to the capture ring **037** to suspend it (FIG. **43**A (**3**)). The ballast in the ore collecting device **015** is dropped to float up (FIG. **43**A (**4**)).

3. Surface Command Ship

3.1 Selection of Ship Type

[0228] In the operation of the deep-sea crane **001** of the present invention, since no underwater structure such as an offshore drilling rig is used, a fixed position control mechanism, a moon pool and a bow thruster are not required. in addition, by devising a cargo handling method so that it can be handled by a small crane on board and can be operated by a 699-ton class gut ore carrier, it can be used as a surface command ship **010**.

[0229] The gut ore carrier can also be used as a collection ore carrier. The carrier carries the ballast from the departure port, functions as a surface command ship **010**, loads the collected minerals instead of the ballast, returns to the port of departure, and repeats this round trip. Since the ballast is freely dropped to the seabed from the ballast discharge mechanism **009** at the lower end of the cargo compartment **005**, fine particles are indispensable, and it is convenient in terms of quantity and transportation to use metal-extracted slag.

[0230] The surface command ship **010** occupies the sea-surface of the collection seabed, directs the mining of resources, maintains equipment, carries one or more deep sea cranes **001** and a seabed power shovel **015**, and advances to the ore collection point and deploys them in the sea. The surface command ship **010** controls the operation of all related equipment.

The functions that the surface command ship **010** should have are as follows.

(1) From the mother port, equipped with a plurality of deep-sea cranes **001**, seabed mineral ores collection devices (electric power shovels) **015**, and power generation equipment to advance to a mineral collection point, occupy the sea of the collection seabed, deploy these equipment in the sea and on the sea surface, In addition, it will be guided from the sea to its own ship and collected.

(2) An acoustic position marker **075** for guiding the deep-sea crane **001** is dropped and installed at a suitable place for collecting minerals.

(3) Accurately maintain its own position with respect to the ocean currents in the Pacific Ocean where there are seabed resources.

(4) The location will be changed depending on the resource status of the seabed and the new location will be deployed.

(5) Collect and maintain equipment that is deployed in the sea or on the surface of the sea.

(6) Supply power to equipment deployed underwater and on the surface of the sea.

(7) The deep-sea cranes **001** and ballast are mounted to settle toward the sea floor and the mineral resources collected from the sea floor are recovered.

3.2 Cargo Handling Method

[0231] The gut crane ship is a small standard cargo ship in which one or two compartments for loading gravel as shown in FIG. **32** are provided and a crane used to lift gravel from the seabed is mounted on the ship. Assuming the operation of the seabed resources, the assumed operating area is legally classified as "near sea" and must be at least 699 tons. Loading capacity is possible up to about 1300 tons. Consider an operation in which the ballast is loaded to the mining point on the ocean, and the ballast is exchanged for the collected ore and returned. Gut crane vessels have the advantage of low charter costs, but as shown below, they must be operated according to their capabilities, including cargo handling methods.

(1) Fixed Point Maintenance Function

[0232] The bow thruster, which is not equipped, corrects the ship position by measuring the position by GPS against the direction in which the sea current and the wind flow. By using the Japanese GPS positioning satellite "MICHIBIKI", the position itself can be grasped with high accuracy. The direction of the ship depends on the sea condition, but there is no undersea structure. It is necessary to equip the automatic position holding function by GPS in order to reduce the load on the personnel.

(2) Cargo Handling

[0233] Since the crane **065** shown in FIG. **32** is used for cargo handling in the open sea, it is necessary to take measures against wind storms. Since the buoyancy tank **002** of the deep-sea crane **001** weighs 30 tons or more, it is avoided to unload the entire deep-sea crane **001**, and only the cargo compartment **005** is unloaded, leaving it on the sea surface. FIG. **33** shows cargo handling equipment.

In order to separate the cargo compartment **005** from the buoyancy tank **001** and collect it, it is desirable that the connection point between the buoyancy tank **001** and the cargo compartment **005** comes to the sea surface in the center of the buoyancy tank, so the buoyancy tank as shown in **31** (*b*), is divided into three parts so that a gap is formed in the center (FIGS. **31**B,C,D,E,F).

Each of the three divided main buoyancy tanks **055** to **057** shown in FIG. **33**A is provided with a sub-buoyancy tank **059** with a cargo compartment lifting hook **062** so that the sub-buoyancy tank **059** can be lifted up above the sea surface. The tip of the crane **065** hooks the hook to lift up cargo compartment at sea surface work (FIG. **34**B, or FIG. **34**G).

When the load applied to the sub buoyancy tank **059** becomes large, the connection with the main buoyancy tank is automatically disconnected (FIG. **33**B,FIG. **31**E), and as shown in FIG. **34**C or FIG. **34**G,H, the main buoyancy tank is separated and floats on the sea surface. Further, as shown in FIG. **34**D and FIG. **34**H, being lifted up from the sea surface the ores are collected. The cargo compartment **005** loaded with ballast is also hung on the sea surface, and as shown in FIG. **34**D or FIG. **34**I As shown in FIG. **34**E or FIG. **34**I, the marker float of the main buoyancy tank on the sea surface and the buoyancy tank changeover switch are adjacent to each other on the sea surface, so that the two are connected by sea level work.

Further, when the cargo compartment is lowered to the sea surface, the buoyancy source is switched to the main buoyancy tank and the descent is started (FIGS. **34**B,A and **34**F). The cargo compartment **005** caught by the crane has a size and weight that can be handled on board. In the case of descent, the tip of the crane wire is released in FIGS. **34**B and **34**F.

The following work must be done manually at sea.

That is, the work of hooking the tip of the crane to the cargo compartment of the deep-sea crane that has surfaced to the sea surface (FIG. **34**A,B, FIG. **34**F), and the work of connecting the cargo hold to the main buoyancy tank before descending to the seabed (FIG. **34**E, FIG. **34**I, FIG. **34**B, FIG. **34**F), and the operation of releasing the tip of the crane wire.

By the ingenuity shown in FIGS. **34**A-**1**,**34**A-E, cargo handling by the gut crane is made possible and diving work could be avoided, but the work was carried out by lowering the small boat from the gut crane ship. It must be calm to some extent. On the seabed, the electric power shovel **015**, which is an electric construction machine, is operated by remote control to perform mining, but prior to loading into the cargo compartment, preparatory work such as mining, crushing, and accumulation is required. Since the work on the seabed is not affected by the wind waves on the sea surface, these preparatory work should be performed when the cargo handling work on the sea surface is not possible due to the wind waves, and the collection of seabed mineral resources collected when the cargo handling work on the sea surface is possible.

4. Acoustic Position Marker

[0234] As positioning by radio waves such as GPS is not possible on the sea bottom, including the deep sea, a precise position reference on the sea surface is obtained by GPS. An acoustic position marker will be installed directly below the precise position reference on the sea surface to serve as a precise position reference on the seabed, so as to work using position information on the seabed will be possible. Position markers are placed on the seabed in a form that allows the latitude and longitude to be referenced, and open pit digging on the seabed can be efficiently advanced. Since the GPS latitude/longitude information can be obtained with high accuracy on the sea surface, there is a technical feature in using this information as a fixed point position reference for the sea floor immediately below. As a method of guiding the acoustic position marker from the sea surface to the sea floor immediately below the high-accuracy latitude and longitude on the sea surface, there are a method of using sound and a method of inertial navigation as described below.

4.1 Installation by Acoustic Guidance

[0235] As a technical feature,
Firstly, the only sound wave that can be used as an information transmission means is used as a means for setting a position marker between the sea surface and the sea bottom, but the sound wave is characterized by refraction and not going straight because the temperature distribution in the sea is not uniform . . . For this reason, we pay the utmost attention to the sound propagation characteristics in the sea for position location. That is, the temperature distribution changes in layers with respect to the depth in the sea, and there is the characteristic that straightness is guaranteed without refraction in the direction perpendicular to the layer, and acoustic signals can be used in the range near the direct point.
Secondly, the acoustic marker is guided and installed under the fixed point position reference on the sea surface by the signal processing and control technology using the acoustic signal.

[0236] An example of the configuration and installation procedure of the acoustic position marker is described with reference to FIG. **36**A-C. FIG. **37**A is an outline view of the acoustic position marker **075**, which sinks in the sea by gravity. At the time of sinking, the X-axis steering blade **076** and the Y-axis steering blade **077** are controlled to change the sinking path. Acoustic position marker setting method is as shown in FIG. **36**C, the position marker ship **070** is occupied on the surface of the sea, then the acoustic position marker **075** is lowered immediately below, and the position of the acoustic position marker **075** is located on the seabed **009** by its own weight by the penetrating weight **079**. As the flow velocity on the seabed is 1 to 2 cm/sec in the deep sea, the location can be kept by setting the X-axis steering wing **076** and the Y-axis steering **077** horizontally on the seabed.

[0237] FIG. **37**B shows the structure of the acoustic position marker **079**. FIG. **37**A is a front view showing that an X-axis steering blade **076** for guidance and a Y-axis steering blade **077** for guidance are installed orthogonal to the long axis of the cylindrical acoustic position marker **075**. FIG. **37**B is a side sectional view of the acoustic position marker **079**. There are one set of X-axis steering wings **075** and one set of Y-axis steering wings **075** outside the acoustic position marker **075**, and an X-axis steering wing servo drive device **271** and a Y-axis steering wing servo drive device **272** are incorporated to control the angle for guidance. Since the acoustic position indicator **079** needs to withstand the high-pressure environment in the deep sea, the inside must be oil-immersed and the equipment inside must function completely in the oil-immersed state. The X and Y axis steering wing servo drive device may be of a level realized by a radio control machine.
The sound emitter **276** and the sound sensor **277** are installed at the tail of the acoustic position marker **079**. The dynamic characteristic for the guidance control is defined by the motion characteristic acting force vector in FIG. **37**C. By placing the center of the reaction force including the X-axis steering wing **076**, the Y-axis steering wing **077**, and the acoustic position marker **075** in the tail, the X-axis steering wing **076** and the Y-axis steering wing **077** are operated to be able to control the dropping direction of the acoustic position marker **075**. The steering component force Ws and the steering component force Rs act on the acoustic position marker **075** as a rotational moment.

[0238] After the acoustic position marker **075** is installed on the seabed, it is used as a transponder for a long time as an acoustic position marker. For this reason, a battery **031** that can be used for a long time is built in, a power supply control circuit **039** is also provided, and circuits other than those essential to the transponder are shut off to prepare for long-term operation. Since the acoustic position marker **075** is operated by a battery, a means for recovering to the sea surface is prepared as a countermeasure when the battery is consumed. As shown in FIG. **37**B, a buoyancy tank **081** in which an acoustic position marker **075** is filled with gasoline and a penetrating weight **079**, which is, for example, an iron weight, are connected and integrated by a detachment mechanism **080**. The specific gravity of **075** is larger than that of seawater, and when the penetrating weight **079** is separated, it becomes lighter than seawater so that it can be floated and collected on the surface of the sea. In the detachment mechanism **080**, when the digital output is turned on by the acoustic position marker control unit **289** of FIG. **38**C, the explosion bolt **078** is detached. The acoustic position marking portions other than the penetrating weight **079** can be reused by recharging after ascending. In the acoustic transponder common infrastructure shown in FIG. **42**A, the penetrating weight **079** is detached by a blast bolt or the like by a “floating command”. The levitation command is issued by monitoring the operation time after the acoustic position indicator **075** is input by the deep sea crane monitoring control system **209** of the surface command ship **010**.

[0239] FIG. **38**C shows the system configuration in the acoustic position marker **075**. The CPU **200**, the ROM **201**, and the RAM **202** are similar to the acoustic transponder common processing unit, and the X-axis steering wing servo drive device **271** and the Y-axis wing servo drive device **272** are publicly implemented in a radio-controlled system. The receiving controller **274** and the transmitter controller **275** are circuits that drive acoustic transmitter and acoustic sensor, which are piezoelectric elements, and are publicly implemented to convert sound waves and electric signals. The power supply control circuit **273** controls ON/OFF of power supply to system components in the acoustic position marker **075** shown in FIG. **38**B to reduce power consumption of the battery when operating as a transponder after installation on the seabed. It is implemented by the software described in FIG. **38**B.

[0240] The acoustic position marker **075** has the following operation modes.
(1) Guidance control mode
(2) Transponder mode
Before putting the acoustic position marker **075** into the sea, initialization is performed to set the guidance control mode in FIG. **38**A, and the transponder mode is turned off to set the guidance control mode.
When the guided acoustic signals are received from the position marker ship **070** on the sea surface and the unmanned auxiliary position marker ships A to D, the guidance process of FIG. **38**C calculates the steering wing operation amount **664** by the guidance logic **662** (FIG. **38**C). The signal reception monitoring timer is reset in **667**. In the guidance monitoring process of FIG. **38**B, when the guidance signal is not continuously received N times of the timer setting value, it is determined that the guidance control is not

performed, and the mode is changed to the transponder mode (processing block **657**).), And shifts to the energy saving mode (processing block **659**). If the acoustic vibration is received within the predetermined timer value, it is judged that the guidance control is continuously performed, and setting another monitoring timer to check whether there is no acoustic vibration in the next time frame (processing block **667**).

[0241] As shown in FIGS. **36**A and **39**A water surface view (XY), auxiliary position indicator vessels A, C, B and D **071** to **074** are arranged, centered on the position indicator vessel **070** at distances d in the X-axis and Y-axis directions respectively, and acoustic oscillation is command-controlled from the position indicator ship **070** wirelessly.

[0242] The distance of d can be made large, when the acoustic position marker **075** moves toward the seabed, the auxiliary position marker ships A and C B and D can not oscillate at the same time. Therefore, the propagation path difference for **075** cannot be obtained.

[0243] The two sets of vibration source are needed to oscillate at the same time. In order to distinguish the received vibration, the oscillation frequencies of one pair of the auxiliary position marking ships A and C are made different, 2.0 kHz to 2.4 kHz and 2.6 kHz to 3.0 kHz of the chirp signal, respectively.

[0244] FIG. **39**A is a vertical plane (XZ) diagram of the guidance. When the acoustic position marker **075** at the depth D is deviated by Δ from the vertical line, and the auxiliary position marker ship A**071** and C**073** are separated from the position marker **070** by d, the propagation path difference is calculated to be (Equation 001).

$$\text{Difference of propagation path length} \approx 4d\Delta/(D^2+d^2)^{\frac{1}{2}} \quad \text{[equation 01]}$$

[0245] Since the difference of propagation path is shown by (Equation 001), when the seabed depth is large, the installation error on the seabed can be reduced by increasing d. When d=100 m, a propagation path difference of 0.8 m can be ensured with an error of 10 m even for a depth of 5000 m, which is sufficiently practical.

[0246] The process block **662** guidance logic of FIG. **38**C is as shown in the guidance logic of the acoustic position marker in FIG. **39**A-C. The auxiliary position indicator ships A **071** and C **073** simultaneously oscillate acoustic signal **082** and **084** (FIG. **39**C). In order to be identifiable by the acoustic position marker **075**, the oscillating frequencies of the auxiliary position marker ships A and C and the auxiliary position marker ships B and D are made different, for example, 2.0 kHz to 2.4 kHz and 2.6 kHz to 3.0 kHz of chirp signal are respectively used. The transmission signal of the auxiliary position marker ship A **082** and the transmission signal of the auxiliary position marker ship C **084** are in linear increasing frequency, and in linear decreasing frequency. Thus, the deviation in the X-axis direction and the deviation in the Y-axis direction can be discriminated.

[0247] Although the sound propagation diagram in FIG. **39**A is for obtaining the deviation in the X-axis direction, the same discussion can be made in the Y-axis direction. The auxiliary position marking ship A oscillating sound **082** and the auxiliary position marking ship C oscillating sound **084** are received as the acoustic position target sounding sound **086** by overlapping with the acoustic position marker **075** with a time shift due to the difference in the propagation distance. The received signal is digitally sampled, and the correlation calculation processing **247** performs correlation with each of the auxiliary position marker ship A's oscillation sound **082** and the auxiliary position marker ship C's oscillation sound **084** stored in advance in the ROM.

As a result, the auxiliary position marker ship A's oscillation sound timing **088** and the auxiliary position marking ship C's oscillation sound timing **089** can be obtained, and the difference between them is Δt **093** and the response delay of the auxiliary position marking ship C **023** and the acoustic position marker **075**. Since the depth of the acoustic marker **075** is known, the X-axis component of the deviation Δ from the vertical line can be obtained from the processing block **244**. Based on this deviation, the X-axis control amount is obtained in the processing block **245**, and the X-axis control wing **076** and the Y-axis control wing **077** are operated to eliminate A. The same process is performed for the Y axis, and the X axis and the Y axis are alternatively processed to perform guidance control.

[0248] As shown in FIG. **40**A, the position marker ship **070** is placed on the sea surface at the latitude and longitude where the acoustic position marker **075** is installed, and the auxiliary position marker ship A **071** is located at both sides in d m apart in the orthogonal X axis and Y axis directions. The auxiliary position marker ships C**073**, D**074**, A**071**, and B**072** are deployed. The position-marking vessel **070** is assumed to be a small boat that is operated offshore when laying an acoustic position-marker, and the auxiliary position-marking vessels A, B, C, and D are assumed to be unmanned self-propelled boats.

[0249] FIG. **40**B shows a control system for the position marker ship **070**, which has the following four functions.

(1) Fixed point maintenance function for specified latitude and longitude

(2) Fixed point holding monitoring and control command function for the auxiliary position marking ship A**071**, the auxiliary position marking ship B**072**, the auxiliary position marking ship C**073**, and the auxiliary position marking ship D**074**

(3) Precise guidance mode oscillation command function for the auxiliary position marking ship A**071**, the auxiliary position marking ship B**072**, the auxiliary position marking ship C**073**, and the auxiliary position marking ship D**074**

(4) Tracking and monitoring function for the acoustic position marker **075**

(1) Fixed Point Maintenance Function for Specified Latitude and Longitude

[0250] The direction and propulsive force of the thruster **100** are controlled by the directional control device **101** and the propulsive force control device **102** to match the current position latitude/longitude measured by the GPS **107** with the target position latitude/longitude specified by the deep sea crane console **210**. Since the thrust of the thruster **100** is at a level capable of holding its own position against disturbances such as tidal currents, the position marker ship **070** is operated to move to the target position. The CPU **200** carries out the processing of FIG. **41**D.

(2) Monitoring Fixed Point Retention Holding and Command Control Functions for the Auxiliary Position Marker Ship A071, B072, C073, and D074.

[0251] The auxiliary position marker ship A**071**, B**072**, C**073**, and D**074** are lowered from the position marker ship

070 to the sea surface and deployed to fixed positions. Until the deployment, it can be realized by the technology of remote-controlled boat that is publicly implemented. After reaching the vicinity of the predetermined position, the positions of the auxiliary position marking ships A to D are periodically measured in the processing block **587** by the function of FIG. **41**C, and the deviation from the fixed position is calculated in the processing block **588**. The processing block **589** calculates the movement order, and the processing block **589** transmits the movement order to each of the auxiliary position marker ships A to D via the wireless communication device **107**. Processing block **591** is a timer setting for periodic execution. The laser distance measurement and laser azimuth measurement of the processing block **587** are assisted by locating the auxiliary position marker ships A to D by the laser position locating device **104**, then locking on and tracking by the automatic tracking device **103**. Even if the position marker ships A to D disturb their positions due to tidal currents and waves, the laser position locator **104** can continue tracking, and the distance and direction of the auxiliary position marker ships A to D can be continuously and automatically acquired. Such automatic tracking devices have been publicly implemented.

[0252] The movement order, which is transmitted to each of the auxiliary position marker ships A to D by the wireless communication device **107**, is received by the processing block **581** in FIG. **41**G, while the processing block **582** determines the own ship position from the measured value of the GSP **106**. The accuracy of GPS has improved to 6 cm, and if such GPS is available, instead of tracking by the laser position locator **104** and the automatic tracking device **103**, the latitude/longitude position is determined by the GPS **106** in FIG. **40**C. Measurement is performed, and the own ship position location value by GPS is used in processing block **584** of FIG. **41**G. A processing block **584** calculates a movement order, a processing block **585** obtains a thruster control command, and the directional control device **101** and the propulsion force control device **102** of FIG. **40**B,C controls to a fixed position.

[0253] When the position of the position marker ship shown in FIG. **40**A is held, the acoustic position marker **075** can be guided to the seabed in the guidance mode. The position marker ship **070** in FIG. **40**B is initialized in FIG. **41**A. In the processing block **579**, the guidance can be enabled when the certain depth D m is exceeded (FIG. **41**E). This is because until the depth exceeds a certain depth D m, the angle of the propagation path of the sound wave with the sea surface is small and accurate guidance cannot be performed. In FIG. **41**F, the acoustic position marker **075** is controlled so that the auxiliary position marker ships A, B, C and D oscillate acoustic signals. Since the oscillation is periodically performed, a timer is set in the processing block **602** to periodically activate the timer. At processing block **595**, it is determined whether the guidance is eligible. This is because the sounding body is installed at a horizontal distance d, and unless a certain depth is provided, the sound wave has no straightness and cannot be guided. The processing block **596** determines whether the positions of the auxiliary position marker ships A, B, C, D are settled, and if the positions are settled, acoustic oscillation is performed. The processing blocks **597** to **601** are for alternately oscillating the group of the auxiliary marker ships A and C and the group of the auxiliary marker ships A and D, and alternately measuring and guiding the deviation between the X axis and the Y axis.

4.2 Installation by Inertial Guidance

[0254] An inertial navigation sensor that uses a solid vibrating body as a position sensor and an acceleration sensor can be used as a small-sized, low-cost solid package for smartphones and robots. If the error accumulation due to the descent time is within a range that does not cause a problem, inertial navigation that can simplify the system can be used. FIG. **45** shows a method of installing an acoustic position marker by inertial guidance. First, in (b-**1**), an acoustic position marker is hung from a position marker ship **070** capable of accurately measuring latitude and longitude by a rope to settle it, and an inertial navigation sensor is initialized. When the hanging rope **113** is cut, it descends along the vertical line **111** toward the seabed as shown in (b-**2**). The X-axis steering wing **076** and the Y-axis steering wing **077** control not to deviate from the vertical line **111**, and trace the acoustic position marker descent path **112** to penetrate the seabed **009**. The external shape of the inertial guided acoustic position marker is the same as that of the acoustically guided acoustic position marker (FIG. **37**) although a position acceleration sensor **295** is added as shown in FIG. **46**.

FIG. **47** shows the configuration of the control device for the inertial guidance acoustic position marker. While the position & acceleration sensor **295** is added as compared with FIG. **38**C, the process of the guidance logic of the acoustic guidance shown in FIG. **39** can be omitted. When the guidance logic of FIG. **39** is processed by software, the software executed by CPU **200** should be changed (deleted).

[0255] FIG. **48**A and FIG. **48**B define the processing flow of the inertially guided acoustic position marker control device. Prior to FIG. **45**B, the initialization process of FIG. **48** A is executed once. After the periodic timer of the processing block **670** is started, FIG. **48**B the acoustic position marker guiding process is started. In the process block **672**, the state value of the position acceleration sensor **295** is read, and when there is no depth change in the process block **673**, the initialization of the position/velocity variable of the acoustic position marker is repeated corresponding to FIG. **45**B. Since the depth changes when the suspension cord is cut in FIG. **45**C, the process branches to descent guidance at a processing block **673**. The guidance logic of the processing block **675** obtains the deviations in the X-axis direction and the Y-axis direction from the vertical line **111**, and the control order is calculated in the processing block **676** by the control logic including the well-known PID control. Output to the servo system is performed in a processing block **677**, and the control wing is driven by the X-axis control wing servo driver **076** and the Y-axis control wing servo driver **077** in FIG. **47**A. When the acoustic position marker reaches the seabed **009** in FIG. **45**D, the depth does not change, and the cycle timer is stopped in processing block **678** in FIG. **48**B to stop the guidance processing. After the guidance control is stopped, since it functions as an acoustic transponder, the actuator power is turned off in processing block **679** to start the transponder processing (FIG. **42**). The processing of the position marker ship **070** that installs the inertially guided acoustic position marker is shown in FIG. **49**A. FIG. **47**B shows the hardware, in which the precise latitude/longitude is taken in by the GPS

106, and the latitude/longitude is continuously taken in from the GPS **106** in the processing block **683** while the hanging rope **113** is not cut, and the information is updated (processing. Block **684**). When the hanging rope **113** is cut, it is set that the hanging rope **113** is cut on the console **105** (PC keyboard) in FIG. **47**. Once the suspension cord **113** has been cut, the transponder is periodically activated for monitoring (processing block **685**). Response requests are sent periodically until there is a response from the acoustic position marker installed in FIG. **49**B. FIG. **49**C is activated when there is a response signal from the installed acoustic position marker, and if the ID matches the interrogating ID, it is determined that the installation is complete, and the acoustic position marker ID, latitude/longitude, and installation time are registered. (Input to the deep sea crane monitoring control system **209** of the surface command ship **010** using a USB memory or the like)

II. Navigation System

1. Composition Principles

[0256] In the lift-off using the buoyancy of the present invention, the deep-sea crane **001** which is a lift-up device autonomously travels between the starting point and the arrival point (the surface ship on the sea surface and the point on the seabed) by the control technology. It eliminates the need for mechanically connected structures such as pipes, and relaxes the mechanical constraints required for the system.

[0257] There are the following physical properties in the sea:

(1) In the sea, radio waves with straightness cannot be used and GPS cannot be used as a position sensor.

(2) The error of the inertial position sensor increases with time after initial setting

(3) The magnetic compass can be used if the pressure resistant shell is not the magnetic body.

(4) Sound waves with good propagation in the sea are not suitable for distance measurement and target azimuth detection when they deviate from the vertical direction.

(5) Optical distance measurement is indispensable for precise position measurement, but there is no guarantee of visibility in the sea except in the immediate vicinity. Furthermore, the movement of the seabed resources is mainly in the vertical direction, and the distance is as short as 6.5 km at most, but the landing point control is characterized by the requirement of meter order accuracy. In addition, although the navigation control requires a large amount of information to be transmitted, optical fiber communication is suitable because a radio wave does not pass through the sea and a sound wave with good propagation has a small amount of information capacity. Sensors that can be used underwater include (1) inertial position sensor, (2) depth gauge, (3) acoustic sensor, (4) optical sensor, and (5) geomagnetic sensor. For navigation control using these, There are inertial navigation, acoustic navigation, and optical navigation. these sensors are used in combination with the characteristics of navigation.

[0258] FIG. **16**A shows the entire navigation control for the deep sea crane **001** to reciprocate between the surface command ship **010** and the landing point **011**. During the inertial navigation section **090**, less time has passed since departure and the initial position can be accurately known. Therefore, the inertial sensor, depth gauge, and geomagnetic sensor (magnetic compass) are used together to determine the position/speed/attitude and the descent target. It is guided so as to minimize the deviation from the path **043**. In the descent target route **043**, the inertial navigation section **090** first approaches the range just above the landing point on the seabed, which is the target at the time of descent, and in the ascent target route **045**, it first approaches directly below the target maritime command ship **010**.

In the succeeding acoustic navigation section **091**, the influence of the bending of the sound ray due to the undersea temperature distribution is eliminated by reducing the deviation from just below and above the target when descending and when ascending. When the deep-sea crane **001** floats on the sea surface **032**, as the sea water is almost stopped at the sea bottom, the disturbance to the position and speed is small there, but on the sea surface, it is necessary to consider the relative motion of the waves near the surface command ship. In order to avoid the effects of sea waves, it is possible to concentrate in the lift up work when the sea climate is calm, and to concentrate on the sea bottom work when the sea weather is not suitable.

3. Navigation Control System

[0259] The navigation control system **212** in FIG. **14** operates according to the operation flow chart of the navigation control system in FIG. **15**.

In processing block **520**, it is determined whether the deep sea crane **001** leaves the surface command ship **010** before or after the surface command ship **010** is separated. In FIG. **14** the GPS positioning data **402** of the supervisory control system **287** is acquired as initialization data. If the deep sea crane **001** has not yet started floating from the seabed, the processing block **526** in FIG. **14** sets the position data held by the deep sea crane **001** as the initialization data. After the ascent or descent is started, the inertial navigation system will take measures to prevent the accuracy from deteriorating over time due to drift accumulation. At processing block **521**, navigation data including an inertial sensor, a digital compass, and a depth gauge is acquired. At process block **522**, a branch is made according to the navigation mode (inertial navigation, acoustic navigation, optical navigation). The navigation command **404** is given to the integrated control **215** of the operation control system **291** in the processing block **523**. The default setting at the start of ascent or descent is inertial navigation.

4 Inertial Navigation

[0260] The operation of the inertial navigation system is described in FIG. **16**. The pitch, yaw, and roll shown in FIG. **23**A are assigned to the deep-sea crane **001**. Since GPS cannot be used underwater, inertial navigation will accumulate position errors due to drift over time after initialization to the standard coordinates. For this reason, it is used at the initial stage where drift does not accumulate during both ascent and descent (inertial navigation section **090**), the deep-sea crane **001** is brought close to the target as much as possible in the horizontal plane, and the acoustic navigation of the next stage is performed to reach the target making sure the proximity is directly above or below. By making the sound wave propagation path closer to the vertical, the influence of refraction of sound wave propagation is eliminated. In the early stage of the path, while the inertial sensor drifts is small, the deep sea crane descends down or ascends up directly above or below the target, and then switches to acoustic guidance to minimize refraction of sound wave propagation due to seawater temperature distribution.

[0261] The process of inertial navigation **227** follows the process flow of the operation of the inertial navigation system shown in FIG. **16**B. Since GPS cannot be used, the current position is calculated by adding the moving distance obtained by the inertial navigation system to the initial position obtained at processing block **524** or **526** in FIG. **15** (processing block **530**). In processing block **531**, the drift of the inertial navigation sensor is estimated from the moving direction obtained from the depth system data and the electronic compass. In processing block **532**, the maximum likelihood latitude/longitude depth, velocity, and attitude corrected by the drift estimated value are obtained, and the deviation from the target route is further obtained.

[0262] In consideration of the refraction of the sound wave propagation path, the acoustic distance measuring range **091** has a cone that is directly above or directly below the final target point (sea bottom landing point **011** when descending. surface command ship **010** position when ascending) with high level of propagation straightness. In FIG. **16**B when it is confirmed in processing block **533** that deep sea crane **001** has entered the acoustic ranging range **042** in the inertial navigation system, processing block **534** issues a sounding command to acoustic navigation system **228**. A processing block **535** receives and confirms an echo from an acoustic position indicator (transponder) installed at the target point, and a processing block **536** confirms that the signal level exceeds the threshold value and the distance is equal to or less than the threshold value. At block **537**, switching to the acoustic navigation mode is performed.

5 Acoustic Navigation

[0263] The principle and method of realizing acoustic distance measurement are described in FIGS. **17-19**.

The acoustic sensors A to D **231** to **234** and the sound generator **230** are arranged on the top of the deep sea crane **001** (FIG. **17**A) and the bottom of the deep sea crane **001** (FIGS. **17**A. **17**B and **17**C). The acoustic navigation is used in the acoustic navigation section **042** of FIG. **16** succeeding to the inertial navigation. This is because there is an error in position localization because the straightness of sound waves is not guaranteed due to the temperature distribution of seawater.

It is suitable to use the acoustic navigation in the medium and short distance range, because the light does not reach anywhere except the immediate vicinity in the sea. The temperature distribution of seawater exists in the depth direction, but is generally uniform in the horizontal direction. When positioning with a target using a transponder, the azimuth in the horizontal direction can be grasped relatively accurately, but the error in the vertical direction increases as the angle with the vertical direction increases. If the sound wave propagation is more than 20° away from directly above or below, the sound wave will not reach the target reliably.

[0264] The principle and implementation method of the acoustic navigation **228** in FIG. **15** are shown in FIG. **17**B,C. The acoustic sensors A **231**, B **232**, C **233**, and D **234** are installed on the surface **292** of the traveling direction of the deep sea crane **001**. A Sound generator **230** is installed at the center of them, and when the acoustic navigation section **091** is entered, a sound is generated periodically. When the transponder installed at the arrival target (seafloor landing position) returns an echo, there is a time lag in arrival of the echo signal with respect to each of the sound sensors, as shown in FIG. **17**B,C. In FIG. **17**B, the echo from the transponder **236** reaches the acoustic sensor C **233** on the acoustic propagation front **1 237** and reaches the acoustic sensor A **231** on the acoustic propagation front **2 238**, causing a time shift. FIG. **18** shows this situation three-dimensionally. It shows that the transponder azimuth vector **239** is obtained by calculation from the deviation of the arrival time of the echo signals to the four acoustic sensors A to D **231-234** surrounding the origin O on the XY plane. The distance to the transponder **236** can also be obtained from the difference between the sounding time and the arrival time of each echo. If the sound source is a point, the calculation is not easy, but if the sound source is sufficiently far compared to the distance between the acoustic sensors, it can be treated as a sound source of the plane, and it is relatively simple to calculate its direction and distance. Acoustic distance measurement uses the same principle as active sonar, but firstly it is not necessary to create an image of the target, and secondly a transponder can be installed on the target, and thirdly the purpose is to guide directly below or above the target, and fourthly system simplification and lower output power are possible because the precise target orientation is left to optical navigation.

[0265] FIG. **20** shows the configuration and operation of a device used in acoustic navigation.

In FIG. **20**B piezoelectric ceramics are widely used in active sonars as the sound-sensors A to D **231-234** and the acoustic generator **230** for the acoustic navigation device. Recently, high-power piezoelectric ceramics have been marketed as general consumer demand. A vibration transmission signal pattern in constant frequency and voltage in FIG. **20**A is applied to the piezoelectric vibrator to oscillate a sound wave. In FIG. **20**B, the vibration transmission and the vibration reception are performed by different piezoelectric elements, but they may be shared. In order to control the deep sea crane **001**, the acoustic navigation system in FIG. **20**B is installed in the deep sea crane **001**, and the transponder in FIG. **42** is installed on out side of the surface command ship **010**. The operation of the acoustic navigation is as described in the processing sequence of FIG. **20**C, and the acoustic navigation device performs (2) signal vibration according to the vibration command from the navigation control system. After the forward propagation time, the transponder detects (3) vibration reception and immediately transmits (4) echo vibration. After the return propagation time, (5) to (8) Ch**0** to **3** echoes are received by the acoustic navigation device **141**. Immediately after transmitting the vibration, the CH**0-3** data is recorded waiting in (9). Correlation between the recording data while waiting and the transmitted source signal is performed in (10) and (11) to obtain the propagation delay time for each of the acoustic sensors (FIG. **20**D to **20**F) Processing flow **1** to **3**)

[0266] FIG. **19** is a processing flow describing the operation of the acoustic navigation system using the acoustic navigation device. In FIG. **20**, processing block **546** and processing block **550** acquire the round-trip sound wave propagation delay of each acoustic sensors A, B, C, and D, and processing block **551** obtains the distance from the target from the average delay time of each sensor and the sound velocity in the sea.

A case where the sound source is approximated by a surface sound source will be described in detail with reference to FIGS. **18**A to **18**C.

In FIG. **18**A, the transponder azimuth vector **239** indicates the sound wave intrusion direction, and the angle formed with the XY plane is φ, and the angle formed with the projection on the XY plane with the X axis is θ. In FIG. **18** AB is the arrival direction of the acoustic wave, and FIG. **18**B is a view seen from above the Z axis. FIG. **18**C is a sectional view of FIG. **18**B taken along a plane including the acoustic wave arrival direction AB and the Z axis, and shows the relationship between the acoustic wave propagation path and the delay time with respect to the acoustic sensors A to D **231** to **234**.

If the sound reception time (seconds) of the acoustic sensors A to D **231-234** are ta, tb, tc, and td, respectively, and the sound velocity in the sea is s m/sec, Then, based on

the propagation distance between the acoustic sensors A and C due to the time difference of propagation, and

the propagation distance between the acoustic sensors B and D due to the time difference of propagation, the followings are obtained.

[equation 02]

$$(t_c - t_a)s = r\cos\varphi\cos\theta$$

$$(t_d - t_b)s = r\cos\varphi\sin\theta$$

$$\cos\varphi = \pm\frac{s}{2r}\sqrt{(t_c - t_a)^2 + (t_d - t_b)^2}$$

$$\sin\theta = \pm\frac{(t_d - t_b)}{\sqrt{(t_c - t_a)^2 + (t_d - t_b)^2}}$$

[0267] Then, the processing block **551** is obtained. In Equation 02, cos φ=0 and sin θ cannot be obtained unless there is a propagation delay time difference with respect to the sound sensor. cos φ=0 means that the control purpose is achieved because the transponder is directly below or above. In processing block **552**, the transponder azimuth is corrected based on the attitude data obtained from the inertial sensor, and in processing block **553**, the position of the deep sea crane **001** on the sound generator side, which is the control target, is obtained from the known transponder position.

6 Optical Navigation

[0268] Especially on the seabed, the reaching distance of light is shortened by the mud that rolls up, but since accurate positioning is possible at a short distance of 10 to several meters or less, LED light emitting devices can be used for precise position control. The principle of optical navigation will be described with reference to FIGS. **21** (*a*) (b) (c) (d).

When the imaging device **235** detects the light emitted from the light emitting devices A to D **240** to **243** of the capture ring **037** by the imaging device **235** at the tip of the lifting hook **047** of the cargo room **005** of the deep sea crane **001**, then the process shifts to optical navigation **229**. Since the capture rings of the light emitting devices A to D **240** to **243** are used for pulling up the seabed mineral ores collecting device **015** (electric power shovel) and the seabed mineral ores collecting container **034**, it may be assumed that they are in the vertical relationship as shown in FIG. **24**E.

The imaging devices **235** are installed above the lifting hook **047** of the cargo compartment **005** of the deep-sea crane **001**, and are installed in a horizontal plane at a right angle of 90 degrees apart so that one of the four imaging devices **235** can capture light emitting devices A to D **240** to **243**.

When the central axis of the imaging device **235** is shifted;

(1) to the light emitting devices AB side, then (d**3**) in FIG. **21**C is imaged.

(2) to the light emitting devices BC side, then (d**4**) in FIG. **21**C is imaged.

(3) to the light emitting devices CD side, then (d**1**) in FIG. **21**C is imaged.

(4) to the light emitting devices DA side, then (d**2**) in FIG. **21**C is imaged.

When the central axis is not displaced, the image of (d**0**) in FIG. **21**C is obtained.

[0269] FIG. **21**B shows the principle of optical navigation. The imaging device **235** installed at the tip of the lifting hook **047** is an ordinary electronic camera, and it is assumed that the viewing angle is 90° at 1000×1000 to 4000×4000 pixels. FaFbFcFd in FIG. **21**B is the imaging surface **293**, and the images of the light emitting devices A to D **240** to **243** are formed as shown in FIG. **21**C.

In the optical navigation in FIG. **21** and FIG. **22** using the following data from (1) to (7);

(1) Pixel positions of images of the light emitting elements A to D **240** to **243** on the imaging surface **293**

Light emitting device A (Ha, Va), light emitting device B (Hb, Vb), light emitting device C (Hc, Vc), light emitting device D (Hd, Vd) in FIG. **22**C

(2) Identification information of light emitting elements A to D **240** to **243**

(3) Focal length Lf **155** of the image pickup device **235**

(4) Vertical and horizontal angle of view (aV, aH) and number of vertical and horizontal pixels (Vmax, Hmax) of the imaging device **235**

(5) Angle β formed by the line AC connecting the light emitting devices A and C **240** to **243** with the XY plane

(6) The angle γ formed by the line BD connecting the light emitting elements B and D**240** to **243** with the XY plane

(7) Angle δ that straight line BD makes with the Y-axis

Then, the following data (A) and (B) can be obtained by the method described below, where the above (1) and (2) are measurement data of the imaging device 235, and (3) and (4) are unique data of the imaging device **235**, which are all known.

(A) Position of deep sea crane **001** (latitude/longitude (LatT, LonT), depth (DpT))

(B) Posture of deep sea crane **001** (pitch pb, yaw yb, roll rb)

[0270] The above (A) and (B) are determined using quaterion.

Using the reference coordinate system, with XYZ axis; X axis: horizontal Y axis: vertical Z axis: front and rear, the position of the imaging device **235** is defined as P, and using a coordinate system (XbYbZb), the posture of the imaging device **235** is defined as Pb.

It is assumed that the capture ring aim **068** in FIG. **21**B is rotated by the quaterion Qt with respect to the reference coordinate P and becomes the view coordinate Pt of the target direction vector **310**.

$$P_t = Q_T P Q_T^*$$ [equation 03]

[0271] The capture ring aim **068** in this coordinate system is projected on the imaging surface **293** to obtain the image in FIG. **21**C. Since the capture ring aim **068** is on a plane orthogonal to the Z axis of the reference coordinate P and is located at a position deviated from the Z axis of the reference coordinate P, the plane formed by the target orientation vector **310** and the capture ring aim **068** is not vertical. Details of the PAC and PBD of FIG. **21**B are shown in FIG. **22** A,B.

[0272] A indicates the presence of the light emitting device A **240**, and the same applies to BCD. M is the intersection of AC and BD. FIG. **22**C shows the image forming coordinates of the imaging surfaces **293** of A, B, C, and D. In the HV coordinates, the upper left is (0,0) and the lower right is (Hmax, Vmax). The coordinates of the intersection M of the line AC connecting the light emitting devices A and C and the line BD connecting the light emitting devices B and D are given below.

$$\begin{bmatrix} H_m \\ V_m \end{bmatrix} = \begin{bmatrix} V_b - V_d & -H_b + H_d \\ -V_a + V_c & H_a - H_c \end{bmatrix}^{-1} \begin{bmatrix} H_d V_b \\ H_c V_c \end{bmatrix} \qquad \text{[equation 04]}$$

In FIGS. **22**A and **22**B, when the angles for expecting line segments AM and MC are α and β and the angles for expecting line segments BM and MD are γ and δ from the viewpoint P, they are given by Equation 03. Here, R is the distance from the viewpoint P to the intersection M of AC and BD, r is the distance between the light emitting element and M, and ω and φ are the angles formed by the line segments AC and BD with respect to the plane orthogonal to the line-of-sight vector PM. Then, it is given by Equation 05.

$$\tan\alpha = \frac{r\cos\omega}{R - r\sin\omega}$$

$$\tan\beta = \frac{r\cos\omega}{R + r\sin\omega}$$

$$\tan\gamma = \frac{r\cos\varphi}{R - r\sin\varphi}$$

$$\tan\delta = \frac{r\cos\varphi}{R + r\sin\varphi}$$

$$R = \frac{r(\tan\alpha + \tan\beta)}{\sqrt{(\tan\alpha - \tan\beta)^2 + 4\tan^2\alpha\tan^2\beta}}$$

or

$$R = \frac{r(\tan\gamma + \tan\delta)}{\sqrt{(\tan\gamma - \tan\delta)^2 + 4\tan^2\gamma\tan^2\delta}}$$

taking the average

$$R = \frac{1}{2}\left(\frac{r(\tan\alpha + \tan\beta)}{\sqrt{(\tan\alpha - \tan\beta)^2 + 4\tan^2\alpha\tan^2\beta}} + \frac{r(\tan\gamma + \tan\delta)}{\sqrt{(\tan\gamma - \tan\delta)^2 + 4\tan^2\gamma\tan^2\delta}}\right) \qquad \text{[equation 05]}$$

$$\sin\omega = \frac{R}{r}\frac{\tan\alpha - \tan\beta}{\tan\alpha + \tan\beta}$$

$$\sin\varphi = \frac{R}{r}\frac{\tan\gamma - \tan\delta}{\tan\gamma + \tan\delta}$$

On the other hand, since α, β, γ, and δ are obtained from the coordinates of the image of the light emitting devices on the imaging surface **293** as in Equation 05, the values of R, ω, and φ in Equation 06 are determined.

$$\alpha = \sqrt{\left\{\frac{(H_a - H_m)\alpha_H}{H_{max}}\right\}^2 + \left\{\frac{(V_a - V_m)\alpha_V}{V_{max}}\right\}^2} \qquad \text{[equation 06]}$$

$$\beta = \sqrt{\left\{\frac{(H_c - H_m)\alpha_H}{H_{max}}\right\}^2 + \left\{\frac{(V_c - V_m)\alpha_V}{V_{max}}\right\}^2}$$

$$\gamma = \sqrt{\left\{\frac{(H_b - H_m)\alpha_H}{H_{max}}\right\}^2 + \left\{\frac{(V_b - V_m)\alpha_V}{V_{max}}\right\}^2}$$

$$\delta = \sqrt{\left\{\frac{(H_d - H_m)\alpha_H}{H_{max}}\right\}^2 + \left\{\frac{(V_d - V_m)\alpha_V}{V_{max}}\right\}^2}$$

$$\tan\rho = \frac{V_a - V_c}{H_a - H_c}$$

[0273] It should be noted that ρ represents a rotation around the line-of-sight vector PM with respect to the reference coordinates. In Equation 05, the capture ring aim **068** is assumed on the XY plane, but it is generally inclined with a certain posture angle. As shown in FIG. **21**A, when the X* axis is inclined by a with respect to the horizontal and the Y* axis is inclined by β with respect to the horizontal, r cos ϵ and r cos τ may be used instead of r.

[0274] From FIG. **22**C, the relationship between Pb and the view coordinate Pt of the target direction vector **157** (Equation 007) can be obtained in the coordinate system (XbYbZb) representing the attitude of the deep-sea crane **001**. The definitions of Pitch, Yaw, and Roll follow the definition in FIG. **23**.

$$\text{Roll} = \frac{H_m - \frac{H_{max}}{2}}{H_{max}}\alpha_H \qquad \text{[equation 07]}$$

$$\text{Pitch} = \frac{V_m - \frac{V_{max}}{2}}{V_{max}}\alpha_V$$

$$\text{Yaw} = \tan^{-1}\left(\frac{V_a - V_c}{H_a - H_c}\right)$$

[0275] If the rotation quaterion of (Equation 007) is Qt, then (Equation 008) is obtained.

$$P_t = Q_t P_b Q_t^* \qquad \text{[equation 08]}$$

[0276] Equation 09 is obtained from Equation 08 and Equation 03, and the posture of the imaging device **235** with respect to the reference coordinates P is obtained.

$$P_b = Q_t^{-1} Q_T P Q_T^* Q_t^{*-1} \qquad \text{[equation 09]}$$

[0277] The processing block **561** in FIG. **21**D is obtained from Equation 05 and Equation 06, and the processing block **562** is obtained from Equation 08. As a result of the optical navigation **229** in FIG. **15**, the command value is calculated to the control system in the processing block **523** of FIG. **15**, and the deep sea crane **001** is brought close to the capture ring aim **068** by the control system of FIG. **14**.

III Control System

1. Control Principle

1.1 Control System Configuration

[0278] FIG. **14** is a block diagram showing the control logic.

The measured values of the navigation sensor **113** including the inertial position sensor, the depth gauge, the acoustic sensor, the optical sensor, and the geomagnetic sensor are input to the position/speed control system **216**. Pitch, yaw, and roll signals from the attitude sensor **214** are input to the attitude control system **217**. The navigation control system **212** gives a navigation command **404** to the position/speed control system **216** according to the navigation mode selected in the processing block **522** of FIG. **15**.

The navigation command **404** is a time function of the target position, and includes the seabed landing position that is the arrival target position, and the moving trajectory that is the time function between the current position of the deep-sea crane **001** and the control target position.

The attitude control system **217** can practically ignore other than the rotation around a vertical axis as the deep sea crane **001** in which a cargo room **005** is suspended in a buoyancy tank **002** has a similar shape to balloons (FIGS. **1**A and **31**).

In the case of the inertial navigation **227** and the acoustic navigation **228**, the position/speed control system **216** calculates the control order by Equation 015 and Equation 016, and individual thruster controllers **221** send out control order to each control wings. In these cases, braking and rotation or horizontal thrust is obtained by controlling the opening angle and rotation angle of the control wings and landing leg attached to the cargo room as shown in FIG. **26**A,B.

When performing precise position/velocity control by optical navigation **229**, the position/velocity control system **216** calculates the control order by Equation 015 and Equation 016, and the individual thruster controllers **221** output the command signals to the individual thrusters. When performing the precise position/velocity control by the optical navigation **229** in FIG. **15**, the precise position control is performed by adding precision control attachments with thrusters added to the cargo compartment **005** as shown in FIGS. **24**B and **44**B.

The precise control is performed only when the rendezvous control is needed in order to hoist the capture ring **037** of the seabed mineral ores collection device **015** (electric power shovel) and the seabed mineral ores collection container **034** by the lifting hook **047**. Other than that, the potential energy is passively used for the round-trip between the sea surface and the seabed without using thrusters.

The deep sea crane **001** is navigated by controlling the individual thrusters and the command orders to the control wings. Since this is common to all of the following operation modes (inertial navigation, acoustic navigation, optical navigation), the integrated control **215** changes the components of the diagonal matrix A of Equation 016 corresponding to the state variables, and the feedback coefficient of Equation 016 so as to realize the each control mode commonly, corresponding to each of the position/speed control system **216** and the attitude control system **217**.

[0279] The navigation control system **291** shown in FIG. **14** is described below in detail. The structure and coordinate system are as shown in FIGS. **23** and **24**.

FIG. **23**B,**24**C, and FIG. **44**C model the external force vectors acting on the cargo compartment **005** of the deep-sea crane **001**.

As the shape of the deep-sea crane is axisymmetric, the attitude control is mainly the rotation about the vertical axis When hoisting the container **034**, it is necessary to face the capture ring **037** of the rendezvous target (FIG. **24**E, FIG. **44**E). There are the following two measures as this solution.

(1) Since the shape of a deep-sea crane is axisymmetric, the attitude control is focused to the rotation control in the axial direction, however it is absorbed by the twist of the suspension rope and it is difficult to control the rotation in the cases of suspension types of FIG. **31**A,B. Therefor no rotation control is performed. The capture ring **037** of the rendezvous target (FIG. **24**E) can be directly faced regardless of the axial rotational position. For example, four imaging devices **235** having a viewing angle of 90 degrees apart are arranged orthogonally, and four lifting hooks **047** are provided so as to face the center of the visual field of one of the imaging device **235**. In FIGS. **24**B and **24**D, the imaging device **235** suspended in the cargo compartment **005** keeps the entire circumference in view.

Of these, the imaging device **235** that captures the rendezvous target (FIG. **24**E)) is selected to perform precise position/speed control. In this case, the horizontal thruster of FIG. **24**A is not provided with a thruster for rotating the cargo room **005** around its axis.

(2) The policy is to control the rotation around the axis of the deep-sea crane **001**, and if the suspension method as shown if FIG. **31**D is employed, the rotation is absorbed by the buoyancy tank connector **060**. No problem due to the rotation of the hanging rope occurs,

Thus the imaging device **235** suspended in the cargo compartment **005** is rotationary controlled to image the capture ring **037** of the rendezvous target (FIG. **44**E) within the field of view is generated. In FIGS. **44**A and **44**B, thrusters e and f are provided for rotating the cargo compartment **005** around an axis.

1.2 Position and Speed Control

[0280] In the case of inertial navigation **227** and acoustic navigation **228**, braking and lateral thrust are obtained by controlling the degree of opening and rotation angle of each of the four control wings **006** shown in FIG. **23**A. The degree of opening and rotation are same for the control wing/leg a and c, and same for b and d.

$$Ra=Rc$$

$$Rb=Rd$$

The components of the above vector are defined as follows.

$$R_a = \begin{bmatrix} 0 \\ R_{ay} \\ R_{az} \end{bmatrix} \quad R_b = \begin{bmatrix} R_{bx} \\ 0 \\ R_{bz} \end{bmatrix} \qquad \text{[equation 10]}$$

The drag force is defined by the following parameters.

Wing opening angle: α_a (subscript is wing ID)

Wing rotation angle: ρ_a (subscript is wing ID)

Ascending/Descending force $S=W-F$

Cargo compartment weight W

The function Fxy is an empirical formula that generates a thrust component with respect to the horizontal plane.

The function Fz is an empirical formula that generates a thrust component in the vertical direction. Since the vertical thrust is generated by the passive resistance vanes, it acts only as a resistance that counteracts the difference between buoyancy and gravity.

$$R_{ay}=F_{xy}(S,W,\alpha_a,\beta_a)$$

$$R_{az}=F_z(S,W,\alpha_a,\beta_a)$$

The following is obtained by integrating each component.

$$T=2\begin{bmatrix} R_{bx} \\ R_{ay} \\ R_{az}+R_{bz} \end{bmatrix} \quad \text{[equation 11]}$$

1.3 Precision Control of Position/Speed

[0281] When the precise position/velocity control is performed by the optical navigation **229**, FIG. **24**C and FIG. **44**C show forces acting on the deep-sea crane **001**.

Before performing the precise position/speed control, the ballast is adjusted to balance the buoyancy and gravity of the deep-sea crane **001**, and the crane is once stopped before moving to rendezvous operation by the precise position/speed control. The position and speed of the cargo compartment **005** is controlled in FIG. **24**A,B,C and FIG. **44**A,B,C and the cargo compartment **005** is suspended by a rope from buoyancy tanks.

It is not necessary to control the posture of the lifting hook **047** and the imaging device **235** due to their structure. In FIG. **44**, the attitude control is performed so that the lifting hook **047** and the imaging device **235**, which are suspended from the cargo compartment **005**, can face the rendezvous target (FIG. **44**E).

In the precise position/speed control, the thrusts of the vertical thrusters A to D in FIG. **44**B are TA, TB, TC, TD, and the thrusts of the horizontal thrusters a to f are Ta, Tb, Tc, Td, Te, and Tf. (In the case of FIG. **24**B, Te=Tf=0)

Since the control in the vertical direction is performed while maintaining the horizontal posture, the thrust of the vertical thruster is the same.

$$Tz=TA=TB=TC=TD$$

Expressing the components of the above vector,

$$T_z=\begin{bmatrix} 0 \\ 0 \\ T_z \end{bmatrix} \quad \text{[equation 12]}$$

[0282] Since the thrusters in the horizontal direction are on the X-axis or Y-axis, the thrust are same for each axis because of the horizontal movement

$$Ta=Tc$$

$$Tb=Td$$

$$Te=-Tf$$

Vector notation,

$$T_a=\begin{bmatrix} T_a \\ 0 \\ 0 \end{bmatrix} \; T_b=\begin{bmatrix} 0 \\ T_b \\ 0 \end{bmatrix} \quad \text{[equation 13]}$$

The following is obtained b integrating each component.

$$T=\begin{bmatrix} 2T_a \\ 2T_b \\ 4T_z \end{bmatrix} \quad \text{[equation 14]}$$

If there is attitude control and the z-axis torque is Rz, Rz=2Te·b, where b is the distance from the z axis of the thruster.

Rendezvous Mechanism

[0283] The precise position/velocity control is also used to lift the seabed mineral ores collection device **015** (electric power shovel) and the capture ring **037** of the seabed mineral or collection container **034** by the lifting hook **047** of the cargo compartment of the deep sea crane **001**. The rendezvous mechanism of FIG. **24**D,E and FIG. **44**D,E is specially prepared for this purpose. Passing through the capture ring **037** through the hanging hook **047** and hang it up.

[0284] The capture ring is located above the object to lift and has a light-emitting device with four LEDs on the upper part. The imaging device **235** on the upper part of the lifting hook **047** captures the capture ring **037** in the visual field. The deep-sea crane **001** is guided by an optical method to lift the capture ring **037** by the lifting hook **047**. The height of the light emitting LEDs is set so that the imaging device **235** can easily capture them.

1.4 Control Law

[0285] The deep sea crane **001** has a specific gravity of around 1.0, a low moving speed of about 1 m/sec, and a low resistance symmetrical shape. However, with respect to movement in the x-axis, y-axis, and z-axis directions, the deep sea crane **001** receives water resistance which is a function of speed, here approximated as linear. R is a water resistance coefficient and the equation of motion can be expressed by Equation 015.

$$T(t)=M\ddot{X}(t)+R\dot{X}(t)$$

$$r(t)=m\ddot{\omega}(t)+s\dot{\omega}(t) \quad \text{[equation 15]}$$

[0286] Here, M is the mass of the deep sea crane **001**, R is the resistance coefficient, and X (t) is the position of the center of gravity in the reference coordinate system. T (t) is the thrust in the reference coordinate system obtained from the navigation control system and the levitation control system for the deep-sea crane **001**. Where, r is the torque around the z-axis, m is the rotation moment, and s is the resistance torque against rotation. (r(t) is considered only when attitude control is performed). A control system is configured for the dynamic characteristics of Equation 015. The control law is to find T(t) that minimizes the following. When performing attitude control, also obtain r(t).

Then minimizing the next equation,

$$\int (W(t) - W_T(t))^T A((W(t) - W_T(t)))dt$$

Where,

$$W(t) = \begin{bmatrix} X(t) & 0_{3\times 3} \\ 0_{3\times 3} & \dot{X}(t) \end{bmatrix}$$

$$W_T(t) = \begin{bmatrix} X_T(t) & 0_{3\times 3} \\ 0_{3\times 3} & \dot{X}_T(t) \end{bmatrix}$$

[0287] When attitude control is performed, the next equation is minimized.

$$\int (r(t) - r_T(t)))^2 dt \qquad \text{[equation 16]}$$

[0288] A is a 6×6 constant matrix whose diagonal elements are aij>0 i=0,5. The lower right subscript in WT (t), XT (t), and rT (t) in (Equation 016) indicates the target value, and the upper right subscript indicates the transposed matrix.

VI Supervisory Control System

[0289] The equipment that composes the seabed mineral ores collection has been described above, All of these activities are monitored and controlled by the supervisory control system **283** from the surface command ship **010**.

[0290] Considering that the surface command ship **010** uses a standard ore carrier ship, which is changed to the surface command ship with a PC-based small-sized portable system to facilitate effective operation.

(1) Navigation control
(2) Controlling the seabed mineral ores collection devices
(3) Managing acoustic position markers
(4) Power control
(5) Controlling the surface command ship

The supervisory control system **283** includes a part relating to the deep-sea crane control system **284** shown in FIG. **35** and a part relating to the seabed mineral ores collecting device (electrical power shovel) **015** shown in FIG. **30**.

[0291] In the part relating to the deep sea crane control device **284** shown in the monitoring control system of FIG. **35**, the deep sea crane console **210** on the surface command ship **010** performs the next monitoring control of the deep sea crane **001** via the optical interface **211**.

(1) The state of the deep-sea crane **001** is monitored, the landing to and lifting from the seabed is controlled, the operation management such as ore loading, and the ballast control information are managed and controlled.

(2) The images from the imaging device **235** are monitored when the precise speed position control is active, and manual control is performed if necessary. In addition to the functions related to the deep sea crane control device **284**, the deep sea crane console **210** of the supervisory control system in FIG. **35** performs the following.

(1) Based on the GPS positioning data **402** captured by the supervisory controlled control system **283**, a speed and steering command for canceling the influence of ocean current and wind are imposed to the surface command ship **010** in order to maintain a fixed point.

(2) Managing the identification numbers (IDs) of the acoustic position markers set by the position marker ship **070**, the latitude and longitude, and the installation time are collectively managed. Every time the acoustic position marker is installed and collected, the information is updated by the acoustic position marker control device (FIG. **38**, FIG. **47**) of the position marker ship **070** using media. Since the acoustic position marker is driven by a battery, the battery consumption is managed. The position marker ship **070** is provided with the information for floating recovery.

(3) As the submarine equipment management, information such as the identification number (ID), the latitude and longitude, and the installation time of the seabed mineral ores collecting device **015** (electric power shovel) and the seabed mineral ores collecting containers **034** are managed.

(4) Collect and manage geographic information (video information, resource excavation information) on the seabed.

[0292] In the part relating to the seabed mineral ores collection device control device **285** shown in the supervisory control device of FIG. **30**, the deep sea crane console **210** on the surface command ship **010** performs the next monitoring control of the seabed mineral ores collection device **015** via the optical cable **268**.

(1) While watching the image of the ultrasonic high-definition video camera **050** on the display **255**, the seabed mineral ores collecting device **015** is operated with the joystick **270**. When the seabed visibility is good, the imaging device **235** is also used.

(2) According to the instruction of the deep sea crane console **210**, the mineral loading target is selected and performed.

(3) The seabed mineral ores collecting device **015** is remotely controlled by the joystick **270** and the resource collecting device console **441** via the optical cable **268**.

The power switchboard **251** controls the power generator **470** by the power supply monitoring system **250** shown in FIG. **35** to perform the following.

(1) Power is supplied to the seabed mineral ores device power mechanism **267** of the mineral collection device **015** through the power transmission interface **253** and the undersea power cable **269**.

(2) Power is supplied to the deep-sea crane control system **284** via the power transmission interface **253** and the undersea power cable **269**. The attachment for detailed position/speed control has a thruster and requires electric power for driving, but there is also a method of mounting a high-performance secondary battery and omitting the undersea power supply cable **269**.

The power supply device monitoring control system **250** controls the charging device **252** via the power supply control panel **251** to charge the acoustic position markers and the secondary battery for the deep sea crane control device **284**.

The seabed mineral resource collection system of the present invention can collect and unload mineral ores distributed on the seafloor, but since the components do not contain gas and are composed only of liquid and solid, the internal pressure and seawater pressure of the component device can be equalized at any seafloor depth without having a special pressure resistance mechanism.

Moreover, since it does not include pumping of fluid, there are no mechanical restrictions. Since the buoyancy is used to lift the seafloor mineral resources with being slightly lighter than the specific gravity of the surrounding seawater, the energy required for the lift does not increase with depth.

[0293] That is, it can be operated from a depth of less than 1000 to a depth of more than 6500 m in which seafloor mineral resources exist. Since the operation is flexible in this way, it is possible to selectively move and collect sea areas with high-grade minerals, which has a great profitable effect. The numbers shown in the examples are for feasibility and can be scaled up or down.

What is claimed is:

1. A seabed resource lifting apparatus comprising;

a deep sea crane;

a seabed mineral ores collecting device;

a surface command ship;

acoustic position markers; and

seabed mineral ores collection containers;

wherein the deep-sea crane is characterized by including all or part of the following four items:

first, buoyancy tank in which containing liquid including n-cyclopentane or gasoline, which is in liquid phase at room temperature and has lower specific gravity than water, is hermetically filled,

second, a cargo compartment to collect seabed mineral ores from the seabed,

third, a mechanism for connecting the cargo compartment to buoyancy tank,

fourth, a control device including control wings and landing legs for landing the cargo compartment on the seabed and controlling the position and attitude in the sea;

wherein the deep sea crane is configured to descend to the sea floor by making the specific gravity of the entire deep sea crane including the ballast mounted in the cargo compartment larger than seawater, then after landing on the seabed, the ballast mounted in the cargo compartment is exchanged for seabed mineral ores,

then finally, the specific gravity of the entire deep-sea crane is made smaller than that of surrounding seawater, and the seabed mineral ores are collected by floating on the sea surface by buoyancy; and

wherein the deep sea crane is made of solid and liquid to equalize the internal pressure of the deep sea crane with the ambient seawater, thereby avoiding mechanical stress due to high pressure.

2. The seabed resource lifting apparatus according to claim **1** wherein the deep sea crane is characterized by the following three items;

firstly, with a gap in the lower part of the buoyancy tank, the cargo compartment having a structure capable of smoothly dropping the seabed mineral ores from above void space by gravity is suspended in water,

secondly, the seabed mineral ores collecting device puts the seabed mineral ores from the above void space into the cargo compartment,

thirdly, the gravity of the seabed mineral ores is used to push the ballast loaded in the cargo compartment downward and to discard the ballast, thereby exchanging the ballast with the seabed mineral ores;

wherein in order to realize these points, the following items are featured:

firstly, a ballast discharge mechanism including a passage blocking function is provided at the lower end of the cargo compartment, and in order to prevent mixing of ballast brought in from the sea surface and collected mineral ores thrown in from above on the sea floor, providing a membranous or stretchable and movable partition mechanism, which is movable on the upper surface of the ballast when descending from the sea surface,

secondly, the ballast can be dropped and discharged by the ballast discharge control mechanism at the lower end of the cargo compartment,

thirdly, weighing scales for measuring the load on the seabed are installed on a part or all of the control wings and landing legs for landing, and the underwater weight of the entire deep-sea crane is constantly monitored from the measured value in order to control the amount of ballast within a range in which the cargo compartment can continue landing on the seabed in accordance with the weight of the seabed mineral ores fed from above the cargo compartment,

fourthly, after the loading of the collected mineral ores into the cargo compartment is completed, the ballast discharge is controlled to make the deep-sea crane float from the seabed by means of controlling the specific gravity of the deep-sea crane smaller than that of the surrounding seawater.

3. The seabed resource lifting apparatus according to claim **1** wherein the control wings and landing leg of the deep-sea crane are configured by the following features, and the horizontal movement and the ascending/descending speed of the deep-sea crane can be controlled;

first, on the outer peripheral portion of the upper part of the cargo compartment, it is provided the control wings and landing legs which can individually control the opening degree in the horizontal direction from the vertical direction toward the outer periphery in the radial direction,

secondly, it is provided the control wings and landing legs the rotation of which can be controlled individually around the support pillar of each control blade and landing leg.

4. The seabed resource lifting apparatus according to claim **1** wherein the deep sea crane includes a route guidance control function for guiding and controlling a movement route between a seabed landing point and the surface command ship, and includes the following features:

first, when the deep sea crane descends from the sea surface, inertial navigation and acoustic navigation can be switched according to the positional relationship with the seabed landing point, which is the target point when descending,

secondly, when the deep-sea crane rises from the seabed landing point, inertial navigation and acoustic navigation can be switched according to the positional relationship with the surface command ship, which is the target point when rising;

wherein the depth data and inertial navigation data are used in the range where sound waves do not reach due to the temperature distribution in the sea or the propagation straightness is not sufficient to measure the target direction, and the depth data and sound are used in the range where acoustic measurement is sufficient to measure the target direction;

wherein, an acoustic transponder is installed at the seafloor landing point and the surface command ship, and the acoustic transponder generates an echo in response to a acoustic oscillator installed in the deep-sea crane to measure the round-trip time of the acoustic signal;

wherein, when the deep-sea crane is ascending, the distance between the deep-sea crane and the surface command ship is measured, and the direction of existence of the surface command ship is detected from the phase difference between the vibration receiving elements installed at different points at the deep-sea crane; and

wherein, when the deep sea crane descends, the distance between the deep sea crane and the seafloor landing point is measured, and the direction of seafloor landing point is based on the phase difference between the vibration receiving elements installed at different points at the deep sea crane.

5. The seabed resource lifting apparatus according to claim **1** wherein the buoyancy tank of the deep-sea crane is divided into three or more equal-volume balls and is made of a lightweight and tough material including carbon fiber resin;

wherein, in order to disperse the suspension stress on each sphere, a net is squeezed from the upper part of each sphere to the side surface to cover the rope, and the cargo compartment is suspended by the rope from each sphere;

wherein, the deep-sea crane is configured to operate as follows;

when collecting the collected mineral ores on board, the cargo compartment is caught by the onboard crane of the surface command ship from the gap in the center of each of the balls while the balls are floating on the sea surface,

when descending to the seabed, the ballast is mounted in the cargo compartment and lifted down from the gap at the center of each of the balls floating on the sea surface by the onboard crane of the surface command ship, connected to each of the balls, and descends to the seabed.

6. The seabed resource lifting apparatus according to claim **1** wherein the acoustic position marker is an acoustic position marker installed on the seabed in correspondence with the latitude and longitude, and includes the following three features:

first, the acoustic position marker is set immediately below a marker ship whose latitude and longitude are measured on the sea surface by GPS;

secondly, on the surface of the sea, oscillate an acoustic signal from the apexes of the polygon that encloses the marker ship with different latitude and longitude surrounding the marker ship, and measuring deviation from the vertical line directly under the marker ship by the principle of triangulation of the acoustic wave or inertial guidance to steer each wing of the acoustic position marker to eliminate the deviation from the vertical line to reach the point directly below the sign ship;

third, after the acoustic position marker has landed on the seabed, the acoustic marker functions as a transponder in response to an interrogation signal from the deep-sea crane.

7. The seabed resource lifting apparatus according to claim **1** wherein the surface command ship includes a supervisory control device which supplies power to the seabed mineral ores collecting device, performs communication by optical fiber, and controls the descending of the deep-sea crane from the surface command ship to the seabed landing point, and controls the ascending of the deep-sea crane from the seabed landing point to the surface command ship; wherein the power generation device of the surface command ship supplies power to the deep-sea crane by power transmission or charging its rechargeable battery,

wherein, the supervisory control device of the surface command ship controls transferring the mineral ores collected from the deep-sea crane to the surface command ship.

8. The seabed resource lifting apparatus according to claim **1** wherein the Seabed mineral ores collection containers or the seabed mineral ores collecting device that can be separated and connected to the cargo compartment of the deep-sea crane,

wherein, when the deep-sea crane descending from the sea surface to the sea floor, the ballast being loaded in the cargo compartment for dumping, and the seabed mineral ores collection device or one or more of the seabed mineral ores collection containers being suspended,

and the specific gravity of the deep-sea crane being set larger than that of seawater;

wherein, after the deep-sea crane has landed on the seabed, the seabed mineral ores collection device or the seabed mineral ores collection container is installed on the seabed after the suspension from the cargo compartment is released;

wherein, when the deep-sea crane lifts the seabed mineral ores collection device or the seabed mineral ores collection container loaded with the collected mineral ores on the sea surface,

a mechanism for lifting including a ring provided in the seabed mineral ores collecting device or a mechanism for lifting including a ring provided in a shroud of the seabed mineral ores collection container, and a mechanism for lifting including a hook at the lower part of the cargo compartment being provided;

wherein the seabed mineral ores collecting device is same as a power shovel of the construction machine used on land of which hydraulic mechanism is driven by electric motors instead of an engine, and is remotely operated from the surface command ship using an image monitoring apparatus including an ultrasonic high-definition video camera, and the collected mineral ores are loaded in the seabed mineral ores collection container; and

wherein the underwater weight of the seabed mineral ores collection container can be monitored when should stop loading the collected mineral ores into the seabed mineral ores collection container.

* * * * *