United States Patent

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[54] **UNDERWATER COLLECTING AND LIFTING DEVICE**
7 Claims, 2 Drawing Figs.

[52] **U.S. Cl.** **61/69,** 37/56, 73/425.6, 222/386.5
[51] **Int. Cl.** **B63c 11/00,** G01n 1/14, E02f 3/88
[50] **Field of Search** 37/54, 56, 58, 195; 61/69; 175/5, 6, 226; 222/386.5, 216; 73/425.6

[56] **References Cited**

UNITED STATES PATENTS

687,830	12/1901	Kirk	37/56 X
813,935	2/1906	Avery, Jr.	37/56
958,615	5/1910	Fitzgerald et al.	61/69
975,534	11/1910	King	61/69
1,097,722	5/1914	Lake	37/56 UX
2,735,589	2/1956	Milster et al.	222/386.5
2,927,776	3/1960	Hildebrandt et al.	175/226
3,063,507	11/1962	O'Neill et al.	37/54 UX
3,343,422	9/1967	McSmith	73/425.6
3,354,659	11/1967	Lehmann	61/69
3,367,191	2/1968	Richard	73/425.6
3,369,368	2/1968	Wilson	61/69
3,415,068	12/1968	Casey, Jr. et al.	37/56 X

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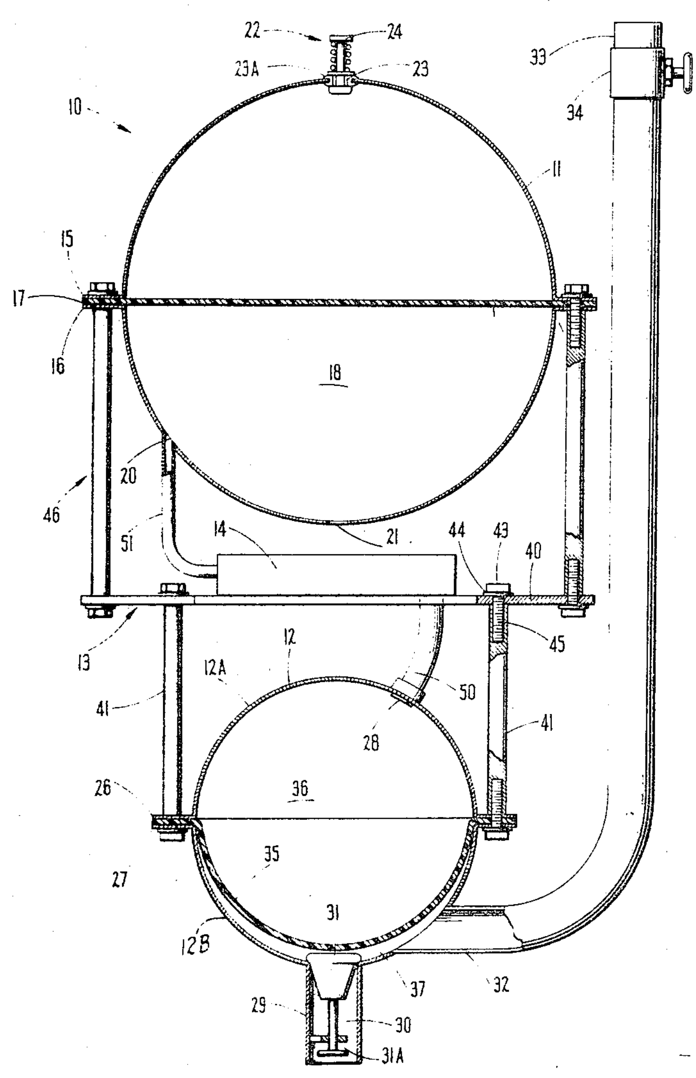
ABSTRACT: An underwater collecting and lifting device for use in obtaining material from below the earth's surface, such as the floor of the ocean, has a first chamber for raising and lowering the device in a body of water and a second chamber for collecting the material and transporting it. A diaphragm divides the second chamber into two compartments and is movable so as to change the volumes of the two compartments inversely to each other.



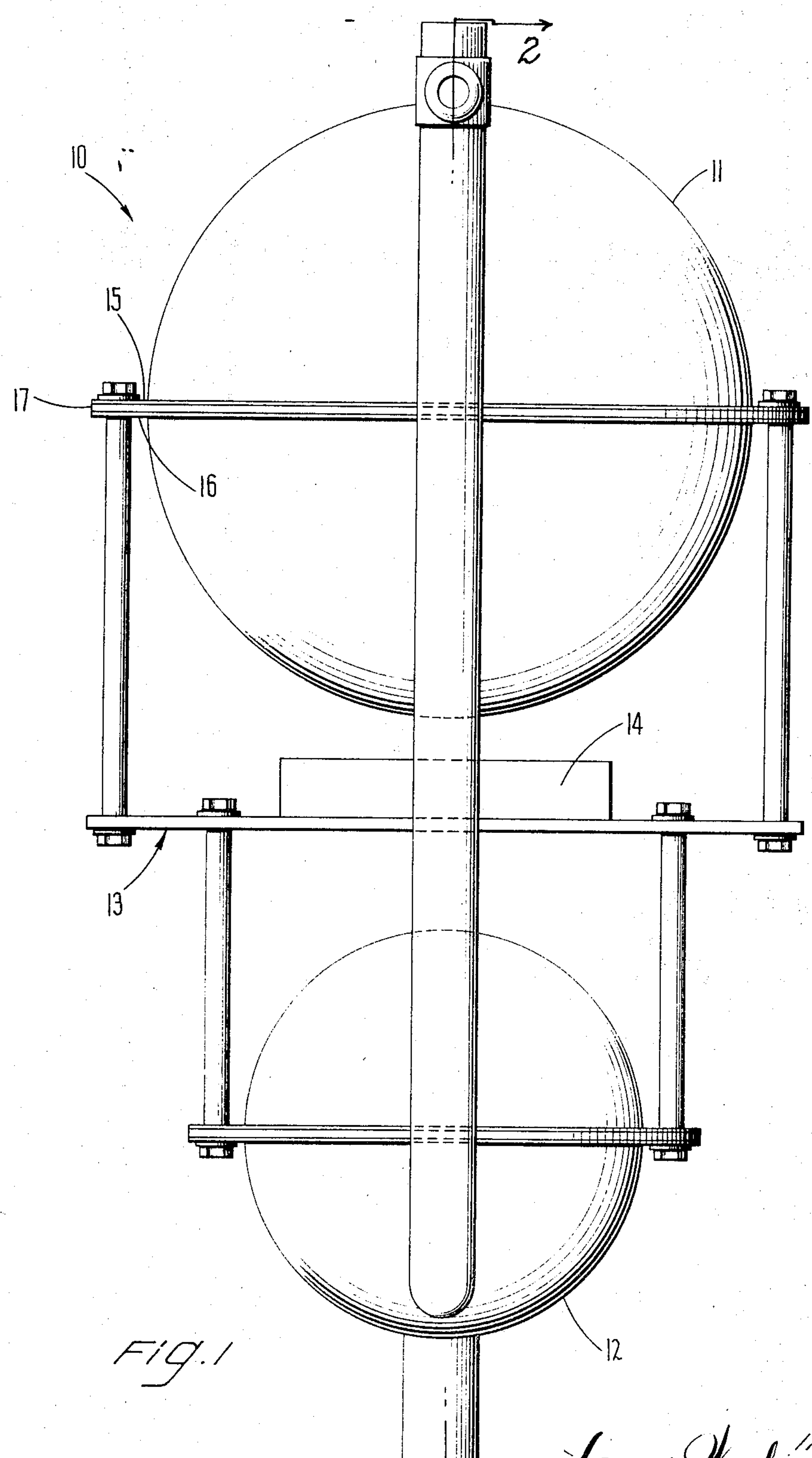


Fig. 1

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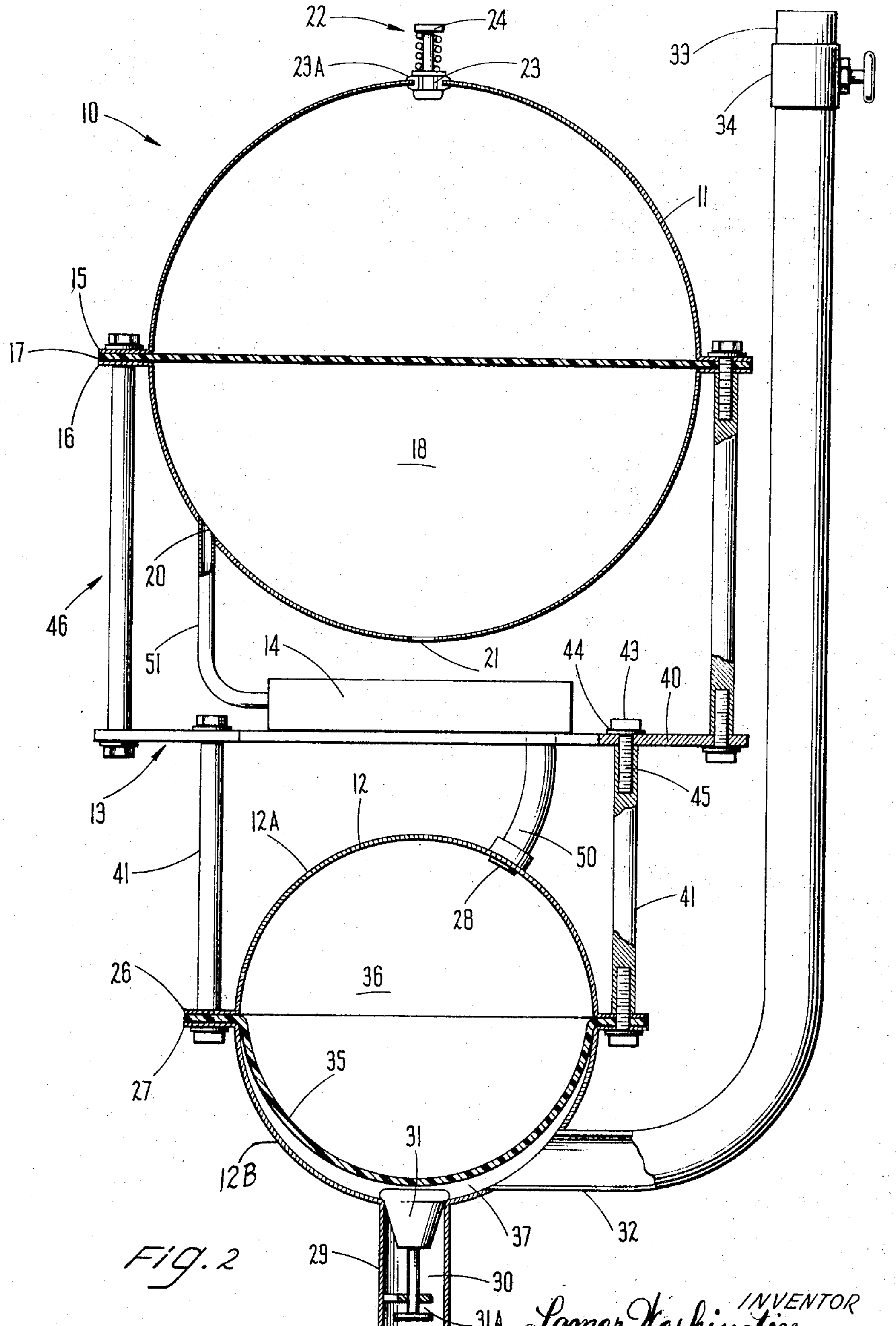

Fig. 2

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UNDERWATER COLLECTING AND LIFTING DEVICE

BACKGROUND OF THE INVENTION

Many devices have been proposed or used for obtaining benthic material, i.e., materials or objects on or below the water earth interface of a large body of water such as the ocean. Commonly such devices are linked to a surface station by a cable and are limited in size and load capacities. Limitation occurs because of the fact that the cable necessary to support extremely heavy weights must have an extremely large radius. The large radius greatly complicates winding and unwinding of such cables. Even where cable radii are not severely limiting factors, limitations occur due to the complicated and costly collecting devices commonly used to obtain samples from great depths.

SUMMARY OF THE INVENTION

According to the invention, an underwater collecting and lifting device for use in obtaining objects from great depths is provided. The device has means defining a first chamber adapted to be filled with water to cause lowering of the device and means defining a second chamber for collecting objects such as benthic materials by the use of a pressure differential between the second chamber and a surrounding environment. Preferably the first and second chambers are mounted on means interlinking the means defining the two chambers.

The collecting device which comprises the means defining the second chamber is preferably divided into two compartments by a diaphragm constructed and arranged to be movable so as to increase the volume of one of the compartments while simultaneously decreasing the volume of the other compartment and vice versa. The collecting device can act to collect benthic materials and other sample objects and also to aid in causing the collecting and lifting device to pass downwardly in a body of water such as the ocean.

It is a feature of this invention that the novel and advantageous collecting device can be constructed at low cost with high reliability. The collecting and lifting device of this invention can be used without attachments of any kind to the surface of the body of water in which it is operated. Large volumes of sample materials can be obtained easily permitting large scale underwater sampling and/or mining.

Preferably the collecting and lifting device acts as a hoist in that the first chamber has a predetermined volume as compared with the volume of the second chamber so that extremely large and/or heavy loads contained within the second chamber can be raised to the surface when the first chamber is made buoyant. Buoyancy of the fist chamber is easily accomplished by filling the first chamber with a gas which displaces the water therein. Preferably displacement of the water is automatically carried out after means interconnected with the second chamber have been activated to cause a pressure differential between compartments of the second chamber whereby one of said compartments becomes enlarged and fills with material or objects to be collected.

In the preferred embodiment, the second chamber is carried on a mounting platform so that it can be easily removed from the means defining the first chamber as is desirable in certain operations.

Accordingly, it is an important object of this invention to provide a novel and improved underwater collecting device.

Another object of this invention is to provide an underwater collecting device in accordance with the preceding object which is mounted in a collecting and lifting structure which permits ease of lowering the device to great depths and raising of said device to the surface of a large body of water.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features and objects of the present invention will be better understood from the following description when read in conjunction with the accompanying drawings in which:

FIG. 1 is a semidiagrammatic front view of a collecting and lifting device in accordance with the preferred embodiment of the present invention; and

FIG. 2 is a semidiagrammatic cross-sectional view thereof taken through line 2–2 of FIG. 1.

DESCRIPTION OF PREFERRED EMBODIMENTS

With reference now to the drawings, a preferred embodiment of the lifting and collecting device is illustrated generally at **10** and has a first or major sphere **11** connected to a second or minor sphere **12** by a mounting and connection means **13** on which a control means **14** is positioned.

The major sphere **11** which acts to raise and lower the device is constructed of two hemispherical sections each having mating outwardly extending annular flanges **15** and **16** hermetically sealed together by a compression O-ring or gasket **17** preferably formed of a resilient rubber material. The sphere **11** defines a chamber **18** closed to the surrounding environment except at orifice **21** located at the lower portion of the sphere. Valve **22** provides an upper passageway **23** between the chamber and the environment. Valve **22** can be any check valve which is normally closed but can be opened when desired. The spring-loaded valve illustrated is preferably used and is maintained in place by a conventional grommet **23*a***. The passageway of the valve is closed through the use of a conventional plug **24** which is firmly urged in place as pressure within the chamber **18** increases.

The minor sphere **12** is formed as is sphere **11** of two identical rigid, structurally strong hemispherical members **12*a*** and **12*b*** each carrying an annular outwardly extending flange **26** and **27** having predrilled holes for mechanical connection together. An orifice **28** is provided for connection with a pump as will be described. A collection snout comprising a pipe **29** extends outwardly from the lower hemispherical member **12*a*** defining a passageway **30** connected with the interior of the sphere **12**. A frustoconical check valve member **31** operates to close or open passageway **30** as will be described. The check valve member **31** has an attached rod with an encircling slip ring member **31*a*** mounted on the inside of passageway **30** which prevents it from being raised off its seat (as shown in FIG. 2) beyond a predetermined distance. Other means for limiting travel of member **31** to prevent its misalignment or displacement in chamber **37** can be used.

A pipe **32** interconnects the interior of the sphere **12** with an outlet nozzle **33**. Preferably a second check valve **34** is positioned at the outlet end **33**. It is preferred that the outlet end **33** extend above the uppermost portion of the upper sphere **11** since in operation in water, the device **10** will be positioned as indicated in the drawing with spheres **11** and **12** symmetrical about a vertically extending central axis. The uppermost position of the outlet end allows ease of connecting a suitable receptacle to the device to transfer materials from the collecting sphere **12** to a surface station.

A resilient rubber diaphragm **35** has an annular outer portion thereof clamped between flanges **26** and **27** to seal the inside of the sphere from the surrounding environment. The diaphragm **35** is capable of resiliently moving within the interior of the sphere **12** to define two entirely separated compartments **36** and **37** of variable volume. Thus when the diaphragm is in its lowermost position as shown in FIG. 2, compartment **36** is substantially nonexistent while compartment **36** occupies substantially the entire volume of the sphere **12**. However, the diaphragm is capable of movement when pressures in compartment **37** exceed those in compartment **36** to an uppermost position adjacent the inside of hemispherical portion **12*a***. In FIG. 2, a small space is shown between portion **12*b*** and diaphragm **35** to aid in understanding of the invention. However, in the lowermost position, diaphragm **35** abuts the portion **12*b*** and is thus supported against rupture due to excessive pressure as is the case when the diaphragm is in its uppermost position.

The mounting and connection means **13** has a disc-shaped flat platform **40** which mounts a series of supporting rods **41** attached thereto at first ends and engaging flanges **26** and **27** at second ends as best shown in FIG. **2**. Preferably rods **41** are uniformly spaced about the circumference of the sphere **12**. In the preferred embodiment, four rods **41** are used although the number and size of the rods can vary. The rods **41** are anchored by bolts **43** which have underlying washers **44** and screw-threaded shanks **45** passing through the platform **40** or flanges **26**, **27** screw-threaded into female threaded ends of the rods as best shown in FIG. **2**. Preferably the

Rods **46** are identical to rods **41** and mount the major sphere on the platform **40**. In the preferred embodiment, four rods **46** are used.

Also mounted on the platform **40** is a control box **14** which is connected with the minor sphere at orifice **28** by pipe **50** and interconnected with the major sphere at orifice **20** through pipe **51**. The control box preferably includes a gas-generating mechanism of any conventional type for generating gas when desired and passing it through pipe **51** into the chamber **18**. The generated gas is used to remove water from the chamber **18** and render the entire lifting and collecting device buoyant.

Another part of the control box is a conventional fluid pump which is used to pump water or other fluids to or from compartment **36**.

Turning now to the method of operation of this invention, the device **10** starts its operational cycle at the interface between the atmosphere and the surface of the ocean or other body of water. Valve **22** preferably at the top of the major sphere **11** is opened and water enters through the opening **21** decreasing the buoyancy of the device **10**. simultaneously, in the minor sphere **12**, the upper compartment **36** is flooded through pipe **50** with water pumped from the control box. Fluids in compartment **37** are removed through end **33**. The flooding results in the diaphragm **35** being distended downwardly and allows water to fill the entire minor sphere with compartment **36** encompassing substantially the entire sphere. The device **10** then starts to accelerate downwardly maintaining its position as shown in the drawing as the gravitational force overcomes the buoyant force due to the entrance of water into chamber **18** and compartment **36**. The device comes to rest on the interface between the water and the ocean floor with the snout **29** in the benthic material to be collected.

A second operational phase now begins. The water inside the upper compartment **36** of the minor sphere **12** is rapidly pumped out through pipe **50** and the diaphragm **35** rises since the pressure in compartment **36** becomes lower than the pressure in compartment **37** and pipe **32**. A pressure differential, between the external ocean and the minor sphere's compartment **37**, causes the compartment **37** to be filled with benthic material. As the benthic material rises in the snout, it opens the valve **31** whose density is preferably greater than that of the benthic material so that a self-closing system is formed when the flow of benthic material ceases. In the second operational phase, valve **34** which is preferably a conventional pressure-sensitive, normally closed valve is closed. Valve **34** is opened either manually or by a pressure differential when the pressure at the inside of pipe **32** is greater than that of the surrounding ocean.

When the minor sphere is filled so that the pressure differential across valve **31** diminishes, the valve **31** closes and the entire system enters its third operational phase. After compartment **37** is filled with the benthic material, the gas generator within the control mechanism **14** is activated and forces gas to enter into the chamber **18** and displace the water contained therein to give the device **10** a net positive buoyancy. The valve **22** is closed as it can be opened only when the external pressure is greater than that inside the major sphere or it is manually opened. The locked valve **22** retains the gas and prevents its escape. Thus, when the camber **18** is filled with gas, the water therein displaced and the sphere **12** is filled substantially with the benthic material, there exists a system which has collected material from beneath the water-ocean interface and which is capable of delivering the material to the surface by positive buoyancy. The device returns quickly to the surface.

When the device **10** is ascending, certain types of benthic material may expand due to a reduction in pressure in the surrounding sea as higher levels are reached. Thus, the benthic material may flow up pipe **32**. When the valve **34** is an internally activated pressure-sensitive check valve it can open and allow excess benthic material to flow over the side of the device **10**. Since the major sphere **11** is open to the external ocean through opening **21**, a flux exists to counteract and equalize internal and external pressures. Therefore, the structure of the device **10** is such that an increase or decrease of external pressure is no threat to the physical integrity of the system. Of course water samples or other materials can be collected by the device **10** above the water-ocean interface if desired.

Once at the surface, the benthic material collected in the collecting sphere **12** can be removed by pumping water into the compartment **36** to expand the compartment **36** while reciprocally contracting the volume of compartment **37** forcing the collected material through pipe **32** and out the end **33** into a suitable receptacle such as a land station, ship or another pipe.

Although the size, weight and dimensions of the lifting and collecting device **10** can vary greatly, the size of the sphere **11** is always directly related to the size and weight of the sphere **12** and the weight of the material to be collected. Thus, the sphere **11** must be sufficiently large to create a buoyant force when the sphere **12** is filled with benthic material. The minor sphere may be only 1 foot in diameter with volume of 0.52 cubic foot of benthic material when loaded. In a larger device **10**, such as one that might be used for mining materials from the ocean bed, the minor sphere **12** could for example be 100 feet in diameter with a volume of 5.2×10^5 cubic feet.

In a specific example, if we assume the benthic material to be collected to have a density of 100 pounds per cubic foot, the minor sphere having a diameter of 100 feet would weigh about $5\times\times10^7$ pounds or 26,200 tons. Since the purpose of the major sphere is to provide positive buoyancy to the entire device **10** when fully loaded, there is a need for a calculation of the minimum size of the major sphere which is determined as follows.

In making the calculation to determine the size of the major sphere **11**, the weight of the gas used to displace the water in the major sphere must be considered. At standard temperature and atmospheric pressure conditions, the density weight of a gas is about 1.3 grams per liter. At depths of several thousand feet at which the device **10** is capable of operating, tens of atmospheres increase the pressure which compresses the gas to a density weight of a third of the density weight of water or to about 20 pounds per cubic foot.

Another factor which must be taken into account is temperature as there exists a temperature gradient between the surface and the lower interface. However, since the proportion is based on absolute (Kelvin) temperature, the factor does not vary significantly when compared to the pressure factor and can be ignored for first order approximations.

In determining the minimum size needed for a steel major sphere **11**, the following formulas and weights are used:

Volume of a sphere $=(4/3)(\pi)(r)^3$
Volume of a shell $=(4)(\pi)(r)^2((\Delta r)$
Weight of water = 64 pounds per cubic foot
Weight of benthic material = 100 pounds per cubic foot
Weight of steel = 490 pounds per cubic foot
Weight of gas under compression in first order approximation = 20 pounds per cubic foot steel

For a minor sphere of radius of **50** feet and steel shell thickness of one-half inch (one twenty-fourth of a foot), the buoyancy function is dependent upon the radium of the major sphere, the radius of the minor sphere having been fixed. For this approximation, the associated equipment, including platforms, pumps, connectors, etc., will be disregarded.

Buoyancy as a function of radius $(r) = (\pi)(4/3)(r)^3(64-20) + (\pi)(4)(1/24)(r^2)(64-490) + (\pi)(4/3)(50)^3(64-100) + (\pi)(4)(1/24)(50)^2(64-490)$

$$B(r) = (4/3)(\pi)(44)(r^3) - (\pi/6)(426)(r^2) - (4/3)(\pi)(36)(125\times 10^3) - (\pi/6)(426)(25\times 10^2)$$

$$B(r)=184.3\,r^3-223\,r^2-1.93\times 10^7$$

$$B(r)=r^3-1.21\,r^2-1.05\times 10^5$$

The radius (r) should be such that $B(r)$ is positive. For our first order approximation, 60 feet radius (20 percent over the radius of the minor sphere) is enough for the entire system, fully loaded, to be delivered a net positive vuoyancy when the major sphere has a steel shell thickness of one-half inch.

While specific embodiments of the present invention have been shown and described, it should be understood that many variations thereof are possible. For example the spheres can be integral units rather than formed of two-part hemispheres. In some cases, cylindrical or other shaped chambers may be used although the spherical shape is preferred to increase the strength of the chambers. During the second operational phase, the velocity of flow through the snout must be great enough to establish and maintain two-phase flow in order to take in the benthic material. Otherwise, only water will be taken into the compartment **37**. The velocity of flow through the snout is a function of its cross-sectional area and of the pump capacity in gallons per minute.

The spheres are preferably made of high-strength steel materials although various other structurally strong materials can be used. It is a feature of this invention that pressures on the spheres are minimal during descent and rising since the spheres are filled with fluid when lowered and can be filled with a sample material collected (minor sphere) and a gas under pressure (major sphere) when raised. Thus, the spheres do not have to withstand high unbalanced outside pressures. Although platform **40** is provided with the specific connection means shown, other types of devices can be used to connect the spheres together. Similarly, the particular discharge pipe **32** can vary as can the snout **29** and the particular valves shown. In some cases, a mechanically operated auger can be positioned within the snout to aid in collection of benthic materials.

In some cases, it may be desirable to attach a guiding cable to the device **10** from the surface of the body of water although this is not necessary. Similarly it may sometimes be desirable to mount the control means **14** on a surface station or surface vessel and control gas generation and pumping from the surface. However, conventional pumps and gas-generating apparatus can be used mounted directly on the platform as shown and sequenced for timed operations which can be predetermined to determine the length of time of each phase of operation of the device **10**.

It is also possible to use the collection means exemplified by the sphere **12** with other means for positioning at a site where sample objects and materials are to be collected. It is also possible to surround the device **10** above the snout **29** with a hydrodynamically shaped casing to aid in effecting lowering of the device **10** by gravity substantially along a vertical axis coincident with the axis of the snout **29**.

The sphere **12** can also be used for depositing material underwater. **34** locked, chamber **37** can be filled with cement, valve **34** locked, the sphere lowered underwater, valve **31** opened by suitable means and gas or water pumped into chamber **36** to force the cement out snout **29**. Alternatively, the material to be deposited can be forced out of end **33** in the device **10**.

The diaphragm **35** is preferably of rubber although any material having sufficient strength and resiliency can be used. In face, the diaphragm **35** need not be elastic or resilient in the sense of an ordinary rubber diaphragm. In some cases, a folded resilient or rigid plastic sheet or other means can be used as long as it is capable of being moved to vary the compartments **36** and **37** inversely proportioned to each other with the compartments being hermetically sealed.

In view of the many modifications possible, which will be apparent to those skilled in the art, this invention is to be limited only by the spirit and scope of the appended claims.

What I claim is:

1. A submergeable underwater collecting and lifting device comprising
   A. a first chamber having a normally closed venting valve at a normally uppermost end thereof and having a fluid passage at an opposite end thereof,
   B. a materials collecting and storing second chamber mounted with and normally below said first chamber,
   C. a diaphragm element dividing said second chamber into first and second compartments normally vertically arranged with said second compartment above said first compartment,
   D. a normally closed pressure-responsive valved port for controlling the passage of material between the environment of said device and said first compartment of said second chamber, and
   E. control means carried with said chambers for selectively releasing buoyant fluid to said first chamber and for selectively pumping liquid into and out of said second compartment for charging the volume of said first compartment.

2. A collecting and lifting device as defined in claim **1** further comprising overflow and evacuating port means coupled at one end thereof with said first compartment of said second chamber and having a second end normally disposed above said one end thereof.

3. An under water collecting and lifting device as defined in claim **1** in which said venting valve opens in response to a greater pressure outside said first chamber than within it, and in which said valved port opens in response to a pressure outside said first compartment greater than the pressure within it.

4. A submergeable chambered device for carrying material in an underwater environment and for transferring material between the chamber interior thereof and the environment outside it, said device comprising
   A. a first chamber for controlling the buoyancy of said device and having valve means for controlling fluid passage between the first chamber interior and said environment of said device,
   B. a materials transferring and storing second chamber mounted with said first chamber,
   C. a diaphragm element dividing said second chamber into first and second compartments normally of relative volumes such that there is a minimal pressure differential thereacross,
   D. a valved port for controlling the passage of material between said environment of said device and said first compartment of said second chamber in response to the pressure differential between the interior of said first compartment and said environment, and
   E. control means carried with said chambers for selectively releasing buoyant fluid to said first chamber and for selectively pumping liquid into and out of said second compartment for changing the volume of said second compartment inversely relative to the volume of said first compartment.

5. A device as defined in claim **4** in which said control means withdraws fluid from said second compartment to draw said diaphragm increasingly into said second compartment and produce a pressure differential across said valved port, thereby opening said valved port for drawing material from the environment into said first compartment.

6. A devices defined in claim **4**
   A. in which said valve means in said first chamber comprises a pressure-responsive valve for venting buoyant fluid from said first chamber in response to a greater pressure outside said first chamber than within it, and
   B. further comprising a port for passing ballast fluid between said first chamber and said environment.

7. A device as defined in claim **4** in which the volume of said

first chamber is significantly larger than the volume of said second chamber, and said chambers and said fluid-releasing means and said control means are arranged to maintain said first chamber more buoyant than said second chamber such that said device normally maintains an orientation in water with said first chamber above said second chamber.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,593,533 Dated July 20, 1971

Inventor(s) Lamar Washington

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 63, before "is substantially" change "36" to --37--.

Column 3, line 8, delete "screw-threaded" and insert therefor --and--.

Column 3, line 9, delete "Preferably the".

Column 3, line 43, after "snout 29" insert --embedded--.

Column 4, line 41, change "$5xx10^7$" to --$5x10^7$--.

Column 4, line 70, after "per cubic foot" delete "steel".

Column 4, line 73, "radium" should be --radius--.

Column 5, line 14, "vuoyancy" should be --buoyancy--.

Column 5, line 38, after "Although" insert --a--.

Column 5, line 64, delete "34 locked" and insert therefor --Thus--.

Column 5, line 72, "face" should be --fact--.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,593,533 Dated July 20, 1971

Inventor(s) Lamar Washington

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 6, line 25, "charging" should be --changing--.

Column 6, line 25, after "volume of said" insert --second compartment inversely relative to the volume of said--.

Column 6, line 68, "devices" should be --device--.

Signed and sealed this 3rd day of October 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents