

Device for removing sea bed

The invention relates to a device for removing sea bed having a conveying line operated according to the airlift method or using feed pumps, which is at least partially surrounded by sea water and by which removed sea bed can be transported in the conveying direction to the surface.

The "airlift method" is understood as the known method for transporting removed sea bed; it provides a supply of compressed air into the bottom area of the conveying line. The air bubbles that rise on the inside of the conveying line create the effect of an upward flow on the inside of the drilling line that transports removed sea bed to a marine unit above the water line.

In particular, when such a conveying apparatus is employed for transporting mineral raw materials, specifically manganese nodules, for example, from a water depth of approximately 5,000 m, the volume part of the material that is transported inside the conveying line can be up to 10% of the internal volume of the conveying line. The same has an inside diameter of 40 cm, for example.

If feed pumps are used, it is regularly possible to generate a stronger upward flow. The volume fraction of the conveyed material is greater in that case, and the method tends to be even more susceptible to clogging.

If the conveying operation of removed sea bed comes to a standstill – irrespective of the reason - the sea bed material that is inside the conveying line sinks very quickly to the bottom, because it has a considerably higher density than sea water. Assuming a water depth of 5,000 m and a volume fraction of removed sea bed of 10%, the result is a 500 m long plug clogging the line. Freeing the conveying line of the plug by regular means is at this point no longer possible at all, or it is only possible with great difficulty. Similarly, it is

no longer possible to salvage the conveying line, due to the large mass of the plug, which can be as much as 1,500 to 2,000 t in the present example. In the worst case scenario, this means that the conveying line may have to be abandoned following such an interruption of the conveying operation.

A reason for such an interruption can be, in particular, a failure of the transport of flow inside of the conveying line. Such a failure can be caused by deposits of removed sea bed on the interior lining of the conveying line, which gradually increase until they create a blockage of the complete internal cross-section or of the conveying line. Another conceivable reason for a blockage is an energy supply failure or a compressor failure, whereby the compressed air that is necessary for the operation of the airlift process is no longer blown into the conveying line. If the sea bed is first pumped via solid-material pumps from a clearing vehicle to an interim station, that is also referred to as a "buffer," and transported from there via the conveying line to the marine unit above the water line, defects on the submarine unit can also result in a failure of the transport of flow. Moreover, extreme environmental events are conceivable as that have the propensity of causing an interruption in the transport of flow.

DE 2008384 A discloses a dual pipe conveying facility that has an annular pipe line with pipes that are routed as a sink pipe from the ocean surface down to the ocean floor and as a lift pipe for the transported material back up to the ocean surface. Pressurized water preferably circulates inside this annular pipe line as a transport fluid; wherein the pressurized water is circulated by pumps. The conveyed material is fed into the annular pipe line via a pressure lock on the ocean floor. The pressure of the pressurized fluid is dimensioned such that the conveyed material that is fed into the annular line is raised inside the lift pipe, all the way to the water surface.

It is therefore the object of the present invention to improve a device, as was described in the introduction, in such a way that the clogging risk by the formation of a plug, as described previously, accompanied by an interruption of operations or a failure of the transport of flow is at least substantially reduced.

This object is achieved with the apparatus according to claim 1.

The conveying line of this device comprises an emergency emptying means by which removed sea bed, which is transported counter to the conveying direction, can be discharged from the conveying line and into the sea water. This measure helps to avoid the removed sea bed, which is present inside the conveying line at the time of the interruption or the failure of the transport flow, from forming a plug of the kind as described in the introduction that becomes deposited in the line and clogs the bottom end of the conveying line.

In one preferred embodiment of the device according to the invention, the emergency emptying means comprises at least one emergency emptying means that can be opened and closed and through which removed sea bed material moving against the direction of transport can be discharged into the surrounding sea water.

To further accelerate such a discharge in order to further reduce down-times and any residual clogging risk, a plurality of emergency emptying openings are preferably provided and preferably disposed approximately at regular intervals over the length of the conveying line.

The openings are preferably spaced every 200 m to 700 m, particularly preferred at 400 m and 500 m intervals. Assuming that the removed sea bed inside the conveying line typically sinks at 0.5 m/s following such a disruption of flow, the emergency emptying openings would have to remain open in particularly preferred cases for 13 to 17 minutes to ensure an almost complete evacuation of removed sea bed from the inside of the conveying line.

In one preferred embodiment of the device according to the invention, an emergency emptying door is provided on each emergency emptying opening. The same can be displaced into the interior of the conveying line in such a manner that any removed sea bed

moving counter to the conveying direction can be discharged by the action of the emergency emptying door through the emergency emptying opening and into the sea water.

A piston/cylinder apparatus that can be operated by water-hydraulic means is preferably provided for actuating the displacement of the emergency emptying door between the open and the closed positions. The essential advantage of a water-hydraulic actuation is the fact that it is environmentally safe. Accordingly, if leaks occur, they will not cause an escape of hydraulic oil that could damage the environment. Moreover, it is possible to omit a closed system for circulating hydraulic fluid altogether, because, when pressure is to be relieved, the water is simply discharged into the environment and any return by way of a separate return line into the pressure reservoir can be omitted. The water-hydraulically operated apparatus can therefore be conceived as having only a single, central hydraulic supply for the totality of all piston/cylinder devices.

To avoid having to apply continuous pressure to the water-hydraulically actuated piston/cylinder devices during the conveying operation, the piston/cylinder devices are spring loaded such that they cause the emergency emptying doors to move to their closed positions, when no water-hydraulic pressure is in effect. This means only one pressure application to the piston/cylinder devices is necessary, when the transport of flow inside the conveying line comes to a halt due to a malfunction.

In a particularly preferred embodiment, the hydraulic line is connected to a water reservoir that supplies the water-hydraulic pressure. The same can also include a closed water tank that is filled with compressed air above the water level. To this end, it is possible to connect the tank to a compressor that maintains the internal pressure inside the tank at a preset value.

The hydraulic line that is preferably connected to a water reservoir preferably includes a free end that is closed by a check valve. The check valve is disposed such that it opens against the pressure that is present inside the hydraulic line. Using this hydraulic line, the

piston/cylinder devices are connected for the purpose of actuating them against the spring force.

A switching valve is preferably disposed between the water reservoir and the hydraulic line that is able to execute the following switching positions:

- Separation of the water reservoir from the hydraulic line by means of a check valve that opens against the water-hydraulic pressure provided by the water reservoir. This is the switching position of the switching valve during normal operation of the device; meaning, when the desired conveyed flow is present inside the conveying line.
- Connection of the water reservoir to the hydraulic line. In this switching position that can be manually actuated as well as - provided the corresponding sensors are present – automatically actuated in the event of a failure, the pressure that is applied by the water reservoir to the water in the hydraulic line causes actuation of the piston/cylinder devices against the spring pressure, whereby the emergency emptying doors are displaced to the inside of the conveying line for the purpose of discharging removed sea bed to the outside.
- Separation of the water reservoir from the hydraulic line and simultaneous closing of the water reservoir as well as opening of the hydraulic line to the environment. The switching valve is brought in this position, when the conveying operation must be restarted after a disruption in the conveying operation has been remedied, and/or after the material that is inside the conveying line was discharged into the surrounding sea water by opening the emergency emptying openings.

The invention will be described in further detail below based on the drawings. Shown are as follows:

Fig. 1 is a - schematic - representation of a view of a region of the conveying line around an

emergency emptying opening, seen in a partial longitudinal section; and

Fig. 2 is a representation of the hydraulic diagram of an embodiment of the device according to the invention.

The embodiment of a device according to the invention, as depicted in the drawing, comprises a conveying line 1, a section of which is shown in Fig. 1. Said line is approximately pipe-like with an internal diameter of 2 to 40 cm. The conveying line serves for transporting removed sea bed to the surface using the so-called "airlift method." In particular mineral raw materials are conceivable as removable sea bed, such as, for example, manganese nodules that are mined at an underwater depth of approximately 5,000 m. Correspondingly, the length of the conveying line is approximately 5,000 m.

Using the airlift method, an upward fluid flow is created on the interior 3 of the conveying line 1, as symbolically indicated by the arrow S.

To avoid that large quantities of removed sea bed become impacted at the lower end of the conveying line 1 and form a plug, should the operation be interrupted due to a failure in the transport of flow, emergency emptying means 4 are provided, respectively spaced at 500 m intervals.

The functionality of these emergency emptying means shall be described in further detail below in reference to Fig. 1, which depicts said emergency emptying means in the activated state.

In section B, which is where the emergency emptying opening 5 is located, the conveying line has an approximately oval cross-section. Below the emergency emptying opening 5, a bearing means 7 is provided on the outside of the wall 6 of the conveying line 1, where the door of the emergency emptying means 8 is connected in an articulated manner and can be pivoted about a hinge axis T that is arranged transversely relative to the longitudinal extension L of the conveying line 1. Said door can be pivoted from a closed position, in

which the emergency emptying opening 5 is completely closed and the door is substantially flush with the wall 6 of the conveying line 1, to an open position, as depicted in Fig. 1, in which the door rests by the remote edge 9 thereof relative to the hinge axis T internally against the wall 6 on the side that is opposite the emergency emptying opening 5, therein forming an opening angle α of approximately 30° with opening plane.

A water-hydraulically powered piston/cylinder apparatus 10 is provided for the pivot actuation between the closed and the opened positions. It engages by the piston rod 12 thereof via a lever 11, which protrudes approximately perpendicularly from the surface of the emergency emptying door 8, with the emergency emptying door 8. The cylinder-side end of the piston/cylinder apparatus 10 is fastened to a bearing projection 13, again on the exterior of the wall 6.

A compression spring 15 is disposed in the annular space between the piston rod 12 and the cylinder space 14. It causes the piston rod to be supported in the retracted position thereof, when the emergency emptying door 8 is flush with the wall 6, and thereby sealing the emergency emptying opening 5, when no pressurized water is applied to the cylinder space.

In the position of the emergency emptying door as depicted in Fig. 1, removed sea bed is guided in the form of solid material particles 16, which are symbolized by the circles as presently shown in Fig. 1, while sinking consequent to a malfunction or interruption of the transport of flow within the meaning of the arrows P, and discharged toward the outside into the surrounding environment of the conveying line 1. Due to the fact that a typical sink rate of the removed sea bed - as described previously - is approximately 0.5 m/sec, an accumulation of the sunken sea bed material in the ambient area surrounding the bottom end of the conveying line 1 can be precluded, because even small ocean currents that are in effect outside of the conveying line will cause the material to be distributed over a large terrain.

The apparatus that is provided for the water-hydraulic actuation of the piston/cylinder

apparatus 10 and the emergency emptying door 8 shall be described in further detail below in reference to Fig. 2.

In Fig. 2, O designates the sea water surface. For actuation purposes, the cylinder chambers 14 of the piston/cylinder devices 10 are connected to a hydraulics line 18 via the supply lines 17. As can be seen in the schematic sectional representation in Fig. 2 of the piston/cylinder devices 10, the compression spring 15 operates in an embodiment according to Fig. 2 with an effect on the floor of the piston on a side that is opposite of the piston rod 12. The cylinder volumes are correspondingly formed by the annular space that surrounds the piston rod. This configuration, that is reversed in relation to the embodiment according to Fig. 1, has the advantage of a lesser cylinder volume filled with hydraulic fluid, such that, due to the return displacement of the pistons that is effected by the compression springs 50 as well as for the displacement of the pistons due to the water-pneumatic pressure, only smaller amounts of water must be transported, whereby it is possible to reduce the actuation times.

The hydraulic line 18 is hydraulically connected to a water reservoir 20 by way of a switching valve 19. A measurement means 21 is disposed between the switching valve 19 and the water reservoir 20 by means of which it is possible to measure the amount of the flow-though and the pressure that the water is subject to within the hydraulic line 18.

The water reservoir 20 comprises a pressure tank 22. Said tank is filled with water to a filling level 23. A freely movable piston 38 is disposed above the filling level 23, and a compressed air cushion is in effect acting upon the same, whereby the air cushion is generated with the aid of a high-pressure piston compressor 24 that is connected via the high-pressure air accumulator 25 to the pressure tank 22, which is also referred to as the "piston accumulator." A pressure measurement instrument 26 and a pressure relief valve 27 are activated in the supply line to the pressure tank 22. The pressure line that runs between the high-pressure piston compressor and the high-pressure air accumulators is also provided with corresponding means 28.

The water reservoir 20 further comprises a fresh water tank 29 from which, via a line, which is protected with the aid of a check valve 30 against reflux, the high-pressure water pump 31 pumps pressurized water into the pressure tank 22 to achieve and/or maintain the desired filling level 23. A bypass 32 is switched between the high-pressure water pump 31 and the hydraulic line 18 that leads to the fresh water tank 32, which is connected to this line via a stop cock 33 and a pressure relief valve 34.

If a malfunction or interruption of the transport of flow is detected in the conveying line 1, triggering an emergency switch 35 that engages the switching valve 19, actuated manually or via suitable sensors, which are not shown in the present drawing, and that measures the transported flow inside the conveying line 1 results in the switching valve 19 being moved into the switching position III. In this switching position, the hydraulic line 18 is connected to the pressure tank 22. Due to the pressure increase, water flows into the cylinder volumes 14 of the piston cylinder devices 10 actuating the same against the effect of the compression springs 15, thus causing the emergency emptying doors to open. Sinking solid material particles are deflected laterally through the emergency emptying openings to the outside, as described above.

To close the emergency emptying openings, employing suitable means, the switching valve 19 is moved into switching position II. In this position, the supply line from the pressure tank 22 is closed by the hydraulic line 18. The hydraulic line is open toward the environment and/or a fresh water reservoir, which can be a fresh water tank 29. Due to the retractive forces generated by the compression springs 15, the emergency emptying doors 8 are moved to the closed position with the aid of the piston rods 12. After reaching said position, the switching valve 19 is moved into the resting position I as depicted in Fig. 2, when the hydraulic line 18 is connected by a check valve that opens against the water-hydraulic pressure as provided by the water reservoir with a fresh water reservoir 29.

The hydraulic line 18 includes an end 36 that is free relative to the environment. It is closed via a check valve 37 that must be opened against the pressure that is present inside the hydraulic line 18.

List of reference numerals

1	Conveying line
2	Inside diameter
3	Internal
4	Emergency emptying means
5	Emergency emptying opening
6	Wall
7	Bearing means
8	Emergency emptying door
9	Edge
10	Piston/cylinder apparatus
11	Lever
12	Piston rod
13	Bearing projection
14	Cylinder chamber
15	Compression spring
16	Solid particle
17	Supply lines
18	Hydraulic line
19	Switching valve
20	Water reservoir
21	Measurement means
22	Pressure tank
23	Filling level
24	High-pressure piston compressor
25	Air accumulator
26	Pressure measurement device
27	Pressure relief valve

28	Means
29	Fresh water tank
30	Check valve
31	High-pressure water pump
32	Bypass
33	Stop cock
34	Pressure relief valve
35	Emergency switch
36	End
37	Check valve
α	Angle of opening
F	Direction of transport
L	Longitudinal extension
O	Surface
P	Arrows
S	Arrow
T	Hinge axis

Claims

1. A device for removing sea bed,
having a conveying line (1) that is at least partially surrounded by sea water and
through which removed sea bed (16) can be transported to the surface (O) in the
conveying direction,
characterized
in that the conveying line (1) comprises an emergency emptying means (4) by
which removed sea bed (16) moving counter to the conveying direction (S) can
be discharged from of the conveying line (1) into the sea water.
2. The device according to claim 1, **characterized** in that the emergency emptying
means (4) comprises at least one emergency emptying opening (5), which can be
optionally opened or closed and through which removed sea bed (16) moving
counter to the conveying direction (F) can be laterally discharged from the
conveying line (1) into the sea water.
3. The device according to claim 2, **characterized** in that a plurality of emergency
emptying openings (5) is provided, preferably disposed as distributed at regular
intervals over the length of the conveying line (1).
4. The device according to claim 3, **characterized** in that the openings are spaced
every 200 m to 700 m, preferably 400 m to 500 m.
5. The device according to any one of the claims 2 to 4, **characterized** in that a
displaceable emergency emptying door (8) is provided at each emergency
emptying opening (5) for opening the same toward the interior of the conveying
line, such that removed sea bed (16) moving counter to the conveying direction
can be discharged by the action of the emergency emptying door (8) though said
emergency opening (5) into the sea water.

6. The device according to claim 5, **characterized** in that a water-hydraulically actuated piston/cylinder apparatus (10) is provided for displacing the emergency emptying door (8).
7. The device according to claim 6, **characterized** in that the piston/cylinder apparatus (10) is spring-loaded such that it effects the closed position of the emergency emptying door (8), when no water-hydraulic pressure is applied.
8. The device according to claim 6 or 7, **characterized** in that a water reservoir (20) is envisioned that provides the water-hydraulic pressure.
9. The device according to claim 8, **characterized** in that the water reservoir (20) comprises a hydraulic line (18) with preferably one free end that is sealed by a check valve (37) connecting the piston/cylinder apparatus (10) for the purpose of actuating the same against the force of the spring.
10. The device according to claim 9, **characterized** in that a switching valve (19) is provided between the water reservoir (20) and the hydraulic line (18) that causes the activation of the following switching states:
 - Separation of the water reservoir (20) from the hydraulic line (18) by means of a check valve that opens against the water-hydraulic pressure as provided by the water reservoir;
 - Connection of the water reservoir (20) with the hydraulic line (18);
 - Separation of the water reservoir (20) from the hydraulic line (18) and closing the water reservoir (20), as well as opening of the hydraulic line (18) to the surrounding environment.