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Underwater Seafloor Drilling Rig

Adel Sheshtawy, AADE, USDR Inc.

Abstract

The **U**nderwater **S**eafloor **D**rilling **R**ig (USDR7) system is an innovative, safe, efficient, lower initial cost and lower operating cost deepwater drilling system. The USDR is currently in the final stages of engineering design and technical evaluation of its system components.

The benefits of the USDR drilling system are:

1. The USDR will eliminate the long and massive riser and all the associated negative effects of the mud column circulating through the riser.
2. The USDR will not experience shut down due to surface waves or strong current.
3. The USDR construction cost is less than 20% of the construction cost of a deep water drill ship and will require less than 6 months of shipyard time to build.
4. The USDR has no water depth limit, it can perform drilling, well service (workover) or completion of oil or gas wells in 10,000 feet water depth or deeper.

The conceptual design, research, engineering and selection of USDR system components span a three year period.

Introduction

The conventional deepwater floating drilling vessels, drillships and semis, are simply an adaptation of land drilling operations and equipments to perform under offshore conditions which they were not designed for. The support surface for this equipment, the water surface, is not static as in a land operation. The development of the motion compensator and riser slip joint enable the drilling operation to continue up to a certain wave height. When the wave height approaches the riser slip joint stroke length, then the drilling operation must be suspended. The surface current in certain areas of the open water may drift the floating drilling vessel off location causing the ball joint angle between the marine riser and subsea **B**low**O**ut **P**reventor (BOP) to exceed a safe operating limit thus suspending drilling operations. The shut down of the drilling operations, will occur regardless if the floating drilling vessel is anchored to the bottom or dynamically positioned. In some areas of deepwater drilling operations, the shut down due to waves and currents can approach 50% of the time the floating drilling vessel is on location.

The effect of the mud column circulating in the deep water riser forces the drilling engineer to plan deepwater wells with multiple shallow surface casings.

The current worldwide planned exploration and development in deep water exceeds the number of available floating drilling vessels. The imbalance between supply and demand of deep water floating drilling vessels results in the following:

1. Rapid increase in the daily rate of the deep water drilling vessels (ex. from. $192,000 per day in 2005 to $520,000 per day in 2007).
2. The delayed development of promising deepwater discoveries.
3. Expiration of deepwater leases due to non-availability of deep water floating drilling vessels.

The deepwater offshore drilling units, ships and semis, have drilled very few wells in approximately 10,000 feet water depth. The author believes that 10,000 feet water depth is the technical and economical limits of the current floating drilling vessels.

Our principal effort is to design and construct a deepwater drilling system which is safe, efficient in performing drilling, completion and workover operations at any water depth. The USDR system must receive the approval of the American Bureau of Ships (ABS), DNV, loyde, Coast Guard and other major international agencies and bodies. We are confident based on initial investigations and our planed approach, that the certification of the USDR system will be granted.

From the inception of the USDR concept, we intended to utilize proven components and technologies from both the drilling industry and submarine vessel knowledge bases [1, 2, 3.]

The expected non-productive time of the USDR due to waves or surface current will be minimal [4], if any. The elimination of the long marine riser will reduce the number of casing, liner strings and will lower the overall cost of drilling a deepwater well.

USDR System Components

The two main components of the USDR are:

1. A submersible drilling capsule designed to withstand the hydrostatic head pressure of the salt water column (0.447 psi/ft) with an acceptable safety factor for its operating water depth.
2. A small support vessel to provide electric power, air, drilling mud, control signal and accommodation for the operating crew of the USDR.

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The Submersible Drilling Capsule (SDC)

The SDC will have a relatively small outside diameter of approximately 20 ft and a length of 110 feet. The SDC will have a middle cylindrical section with a semi spherical top and bottom sections as shown in Figure 1. The SDC will be double hulled with the space between the hulls pressurized to half the hydrostatic head pressure to further increase the collapse safety factor of the SDC [5], three thin wall support capsules are attached to the outside diameter of the SDC, in order to increase the live load capacity of the SDC and control the buoyancy from neutral to positive or negative. Using compressed air [6], the volume of water inside the support capsules will be controlled to either descend, rise, or stop the SDC at any water depth. The SDC and support capsules will have up to 1.4 million pounds of lifting capacity or live load. Inside the SDC, a rack and pinion mast or hydraulic ram rig with top drive will be placed. Also, an iron roughneck, automatic pipe handling system, mud pumps, mud handling equipments and air scrubber to remover carbon dioxide (CO_2) plus emergency electric power, air and hydraulic sources will be installed inside the SDC. A conventional subsea Blowout Preventors (BOP) stack will be attached to the lower end of the SDC. A double spherical BOP, pipe ram and blind ram will be attached to the top end of the SDC to allow tripping of the drill string in and out of the hole in sections up to 5,000 feet in length. Two emergency evacuation capsules will be attached to the SDC, to function as life boats in a floating drilling vessel.

Purified air rich in oxygen will be continuously circulated from the support vessel to the SDC through the umbilical bundle. The air will be sucked form the SDC lower section and pumped to the mud return line that will reduce the horsepower required to pump the return mud to the surface.

The Support Vessel

The USDR Support Vessel can be a quarter of the size of 5th generation deep water drilling vessels. Initially, the support vessel could be a production spar, tension leg platform or small scientific coring vessel. The support vessel will have mud mixing and pumping capabilities, electric power generation, and accommodation for the USDR operating crew. The electric power, drilling mud, air and control signals will be transmitted from the support vessel to the SDC through hoses and cables bundled with enough length to permit a wider range of the surface support vessel position, relative to the fixed position of the SDC at the sea bottom. Figure 2 shows the range of the support vessel displacement, relative to the subsea well location, in comparison to floating vessel limited displacement. The USDR operation can be controlled from the support vessel or from the SDC. Emergency power, air and hydraulic sources will be located in the SDC.

The USDR Operation Procedures

The SDC will move using its own power or with the help of a tug boat accompanied with the support vessel from one well site location to a new well site, at the water surface or 50 feet below the water surface to avoid surface waves (Fig. 3). At the new location, the BOP stack, surface casing with the drill string inserted in it, the well template and the umbilical bundle will be attached to the SDC (Fig. 4). By control flooding of the buoyancy tank, the SDC will change from the horizontal to the vertical position and start a controlled descent to the sea bottom. When the end of the surface casing is approximately 100 ft, from the sea bottom, the SDC will assume neutral buoyancy, stop its decent. The SDC will adjust its lateral position by using its thruster, relative to three sonars placed at the sea bottom (Fig 5). At the exact well location, the SDC will continue it's decent and apply a pre-determined weight on the surface casing sealed shoe, to cause its maximum penetration into the soft sea bottom. The pipe rams will open but the hydril will remain closed. The drill string will slide downward to open the surface casing shoe and start rotating and circulating sea water to drill and underream the surface hole (Fig. 6).

The buoyancy of the SDC will be adjusted to generate adequate downward thrust on the surface casing. The surface casing will slide in the drilled and underreamed hole until the well template rests on the sea floor (Fig. 7).

The surface casing will be cemented in place; a transport capsule will pull the drilling string out of the hole through the hydril at the top section of the SDC (Fig. 8). The transport capsule will rack the drill string a safe distance from the SDC on the seafloor while waiting on cement (Fig. 9). At the same time, another transport capsule will bring the drilling tools, (bits, MWD, LWD stabilizer, etc.) to the SDC for drilling the next hole section, and afterwards recover the drilling tools for the previous section. After waiting for cement to set, the drilling string transport capsule will insert the stored drill pipe section in the SDC and drilling will proceed to the next casing shoe depth. Additional drill pipe will be supplied to SDC by a transport capsule.

After conditioning the drilled hole for logging, logging will be performed from the surface vessel through a pressure controlled stuffing assembly commonly used for logging live wells. When the logging operation is completed, the second string of casing will be run using a transport capsule (Fig. 10) and cemented in the hole. The drilling operation will continue in the same sequence until the planned total depth of the hole.

The SDC will disconnect from the completed well leaving only the template and connector for the subsea well head and move to the next well location. A transport capsule will install the subsea well head to the completed well.

The Safety Approach to Prove the USDR

The **S**ubmersible **D**rilling **C**apsule (SDC) will be designed to operate at up to 10,000 foot water depth. The standard inspection of submarine fabrication for weld areas and steel plate will be used, x-ray, sonic…etc. The double hull design will allow the pressure testing of the materials and welds to a predetermined percentage of the steel yield strength. The USDR will go through extensive sea trial before its first job.

The SDC will be used for drilling test holes in less than a 1,000 feet water depth. The USDR operating water depth will incrementally increase to pre-determined water depth. With every incremental increase in the USDR operating water depth, the stresses and strain in the SDC will be measured and recorded.

The USDR will initially be used unmanned to drill the conductor pipe using the floating drilling vessel or the production platform as the source of power, air, and mud. Manned operation for the hole sections below the surface conductor casing will be carried out only after proving the safety of the USDR components and operating system under actual field conditions.

Historical safety data from the year 1905 to 2000 for military and civilian submarines with operating water depth ranges from 700 ft to 2460 ft (Sierra Class, Russian Submarine) is impressive [8] (Table 1). There is no reported accident for a deep dive research submarine from 1934 to 2005 with water depth ranges from 1000 feet to 35,800 feet (Triesta). Examining Table 1 shows that all lost submarine accident are related to factors like collision with other vessels during military maneuvers, explosion due to malfunction of ammunition, nuclear power generator failure, and mutiny. These factors will not exist in the USDR operation schedule. Examining the above two statements indicates that the SDC will be safer than driving your car on any major city highway or flying from Houston to San Francisco.

Conclusions

- The current deepwater drilling vessels, ships and/or semi submersibles, have reached their technical and economical limits at 10,000 feet water depth.
- The Underwater Seafloor Drilling Rig (USDR) represents the first safe, practical method to improve the performance and the economics of deepwater drilling.
- I recognize human race strive to keep their head above water and every operator in the petroleum industry wants to be number two in any new drilling technology application. We will work hard to over come that.

Acknowledgments

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Nomenclature

ABS = *American Bureau of Ships*
CO_2 = *Carbon Dioxide*
DNV = *Det Norske Veritas*
LWD = *Logging While Drilling*
MWD = *Measurement While Drilling*
BOP = *Blowout Preventors*
SDC = *Submersible Drilling Capsule*
USDR = *Underwater Seafloor Drilling Rig*

References

1. Allmendiger, E., Irish, J.D., et Al "Submersible Vehicle Design" The Society of Navel Architects and Marine Engineers. 1990
2. Burcher, R, Raydill, L "Concepts in Submarine Design" Cambridge Ocean Technology Series, Cambridge University Press, Cambridge, England, 1994
3. Brayton, H., "Submarines", A Political, Social, and Military History, Berkley Books, Press, NY 1997
4. Prager, E., Earles, S., "The Oceans" McGraw-Hill Publisher 2000
5. Sikora, J., Devine, E., "Guide Lines for the Design of Advance Double Hull Vessels" Navel Surface Warfare Center, 2002
6. Craven, J., Former Chief Scientist, U.S Navy Special Project, "The Silent War" Simon Schuster, 2001
7. Gerth, W., "Chamber Carbon Dioxide and Ventilation" Navy Experimental Diving Unit, Navel Sea System Command, November 2004
8. Hutchinson, R., "Submarines War Beneath the Waves, From 1776 to Present" Harper Collins Publishers, 2001

Table 1
Submarine Accident 1905-2000

	UK	Russia	USA	France	Germany	Other	Total	Percent
Total Sub Accident	57	34	30	28	27	30	203	100%
Total Sub Lost	26	20	14	13	25	16	114	56.16%
Collision	28	9	7	9	16	17	86	42.36%
Diving	11	3	4	5	2	6	31	15.27%
Explosion	5	6	8	6	0	3	28	13.79%
Mechanical Failure	3	7	7	3	1	4	25	12.32%
Flooding	4	2	2	5	1	4	18	7.44%
Mutiny	1	1	1	0	4	1	8	3.91%
Unknown	3	5	0	0	3	1	12	4.91%

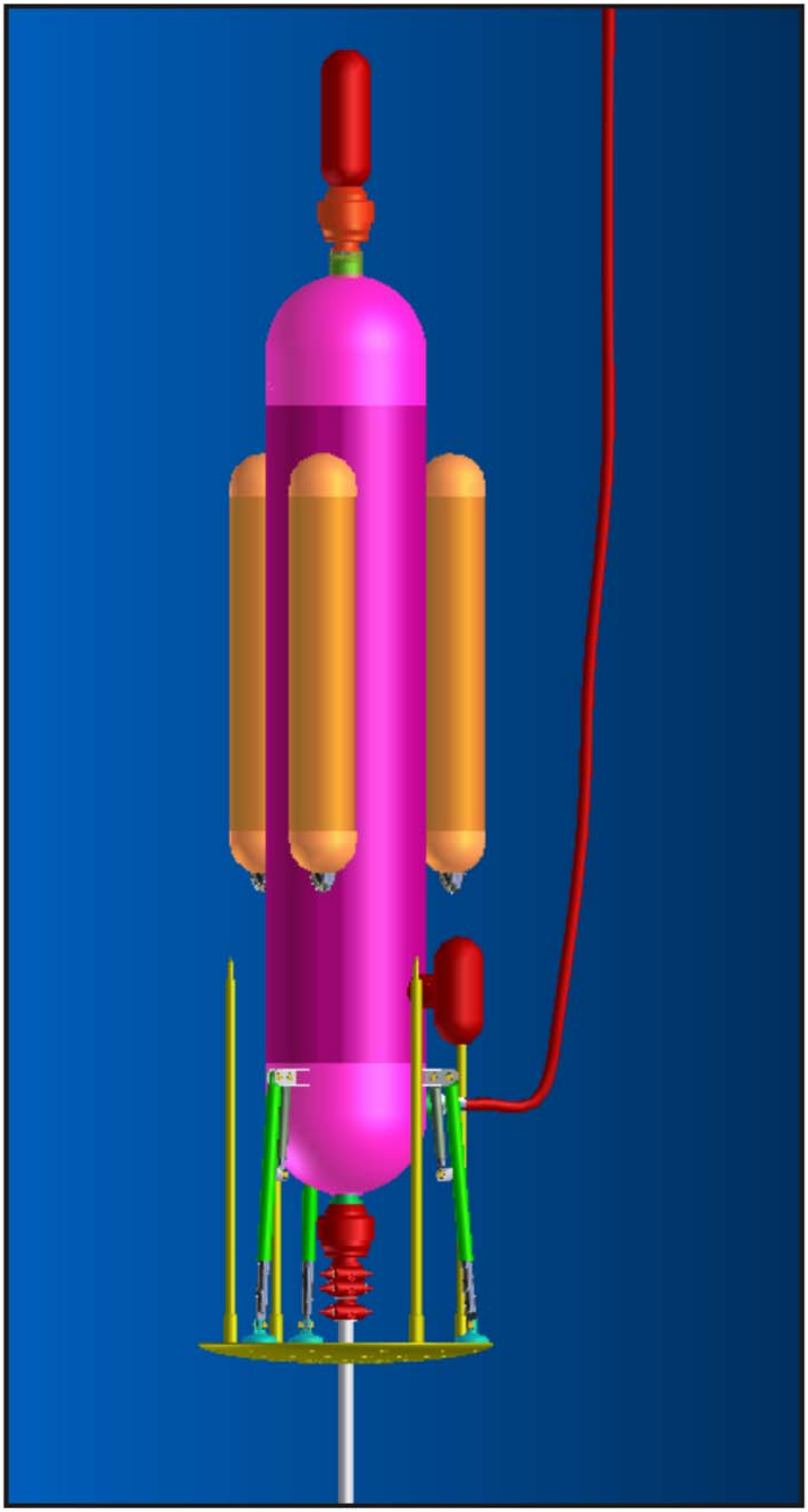

Figure 1 - Submersible Drilling Capsule (SDC).

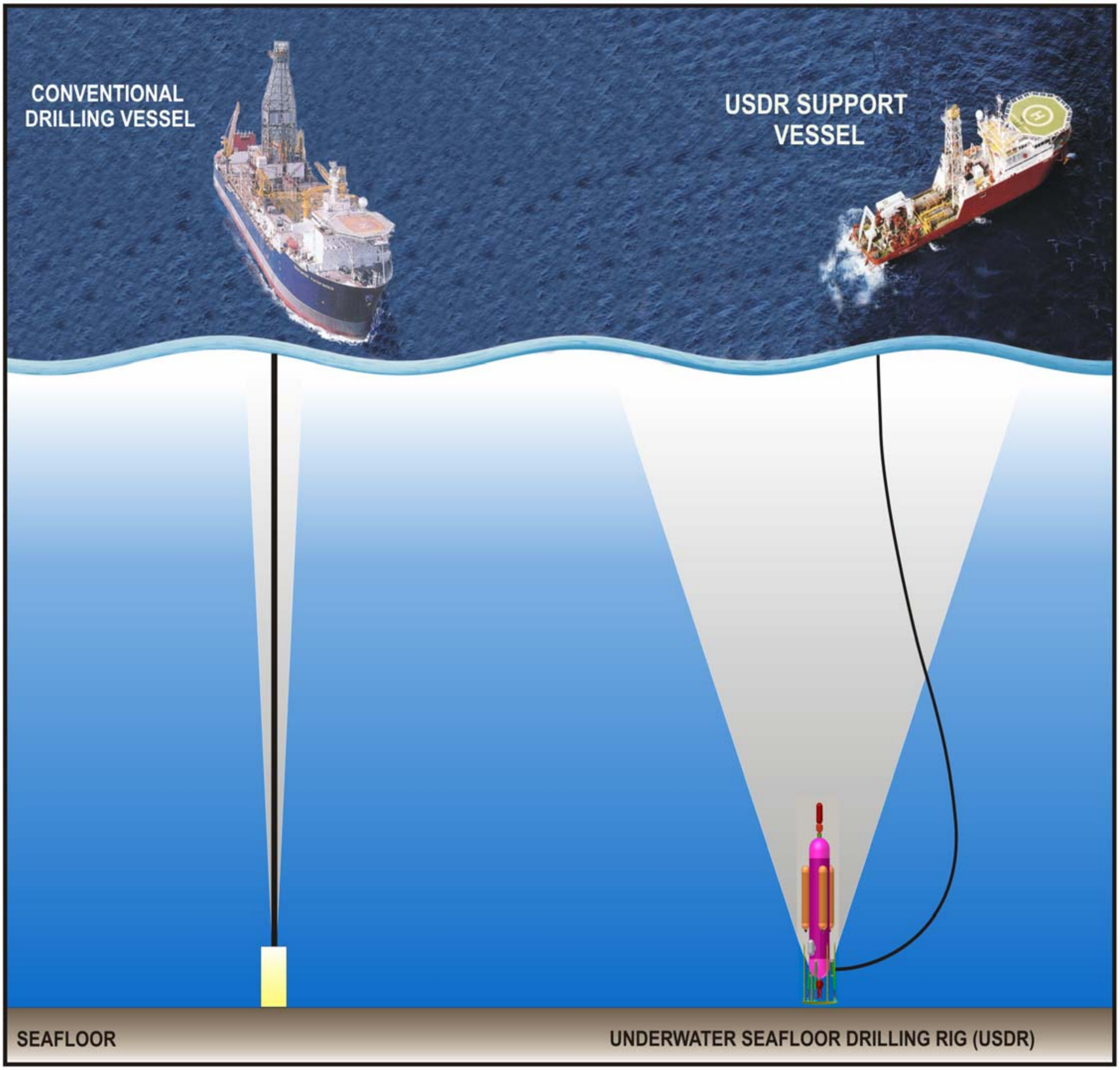

Figure 2 - USDR vs. Floating Drilling Vessel.

Figure 3 - USDR moving to new location.

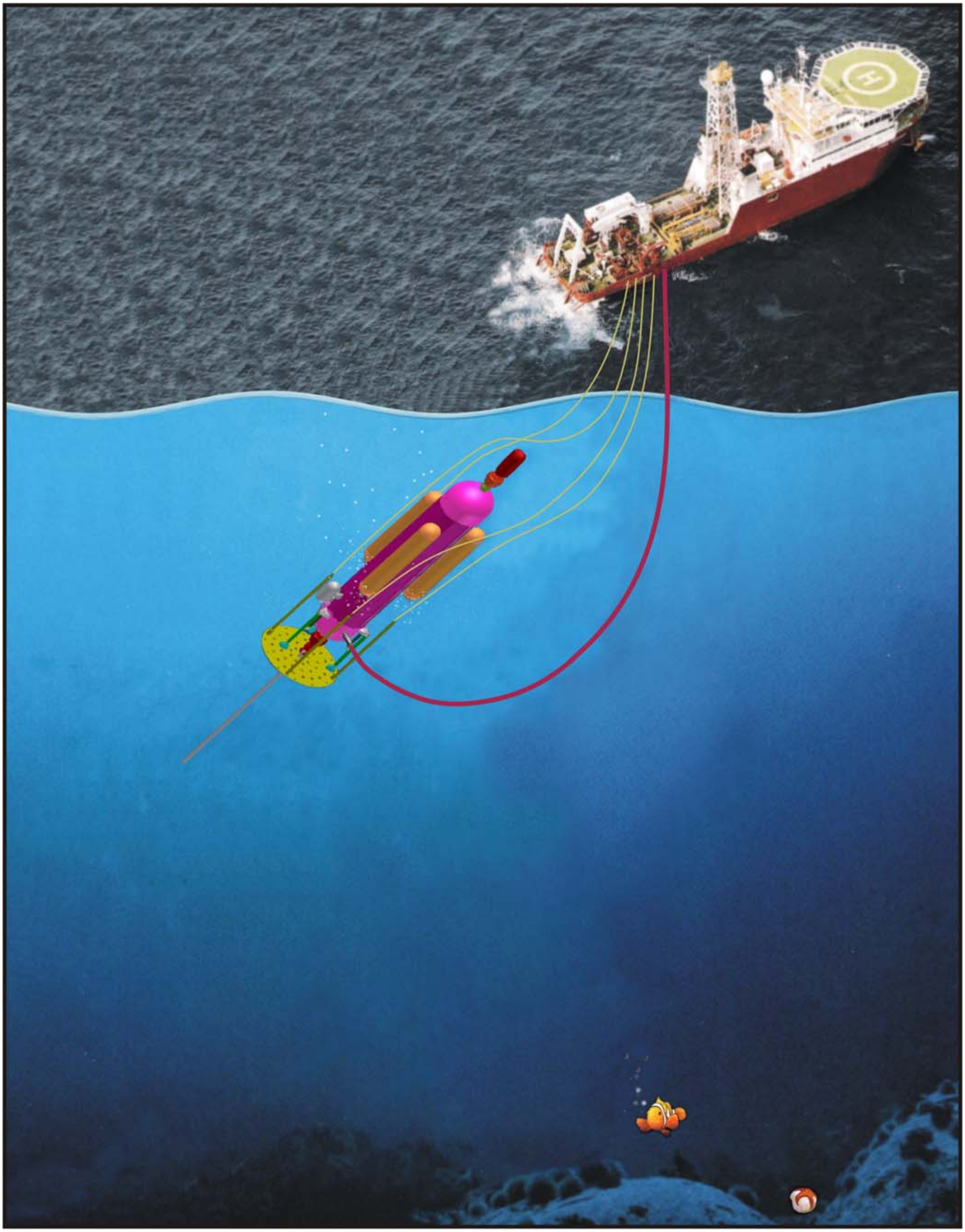

Figure 4 - USDR initial descend to seafloor.

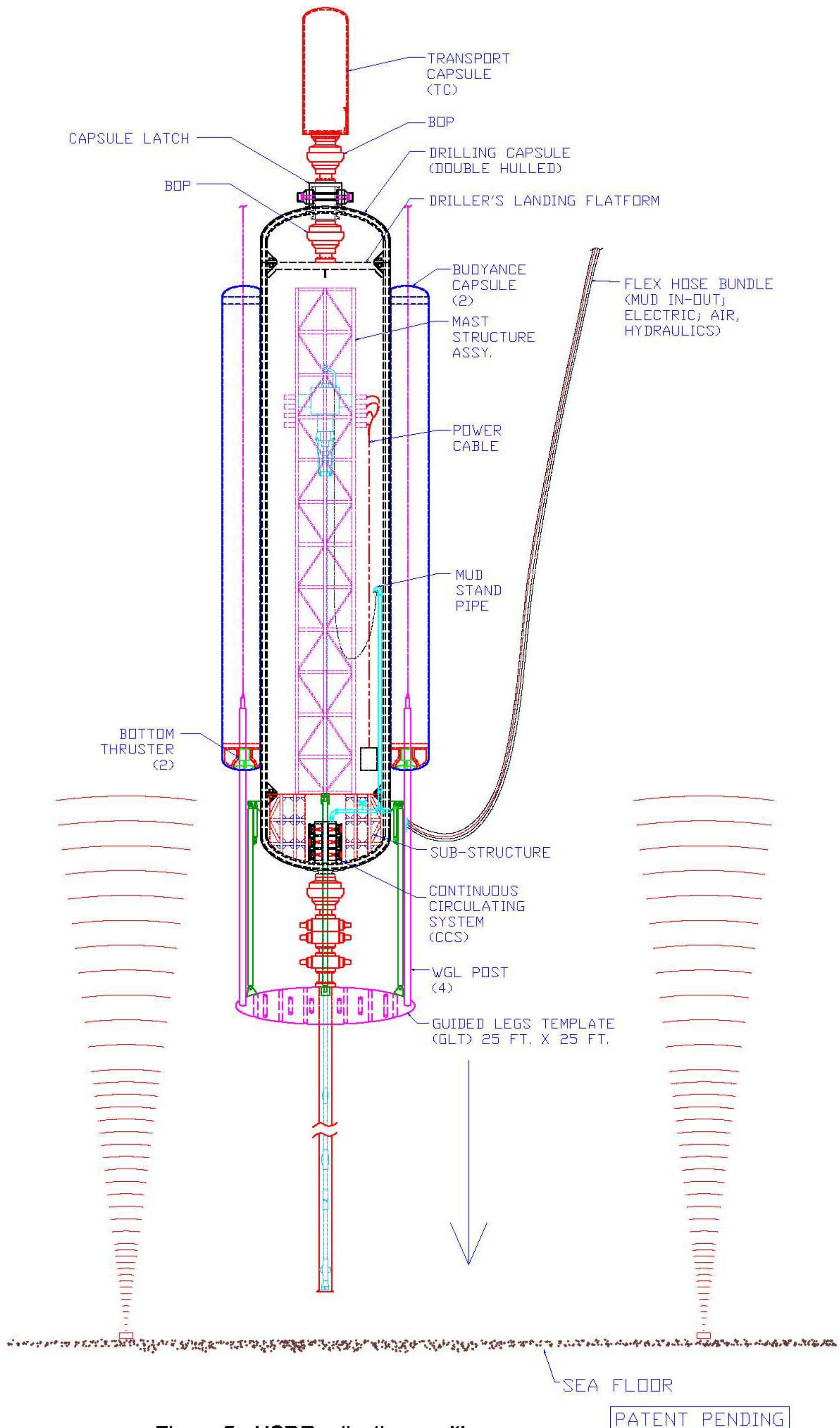

Figure 5 - USDR adjusting position.

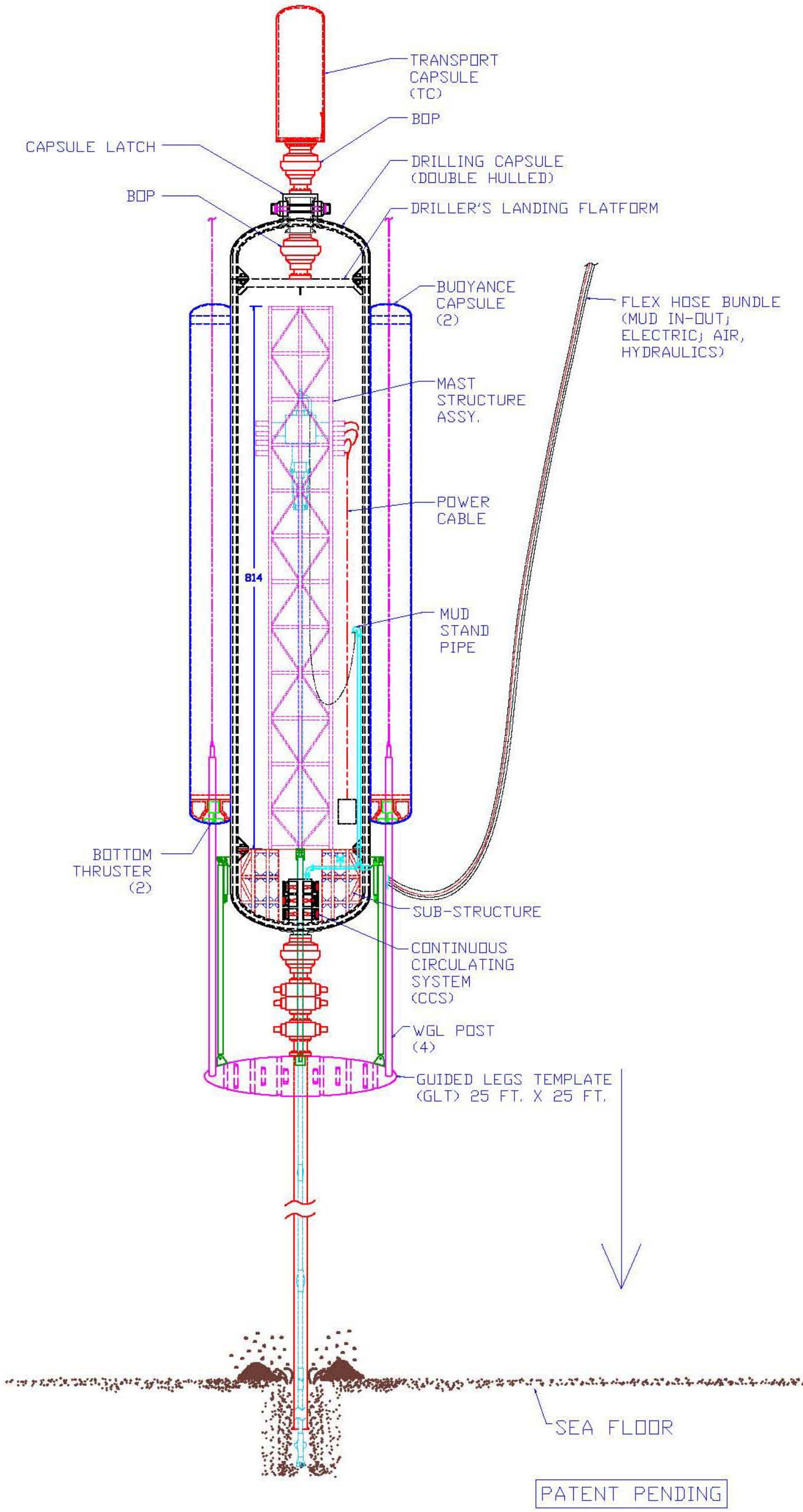

Figure 6 - Drilling the surface hole.

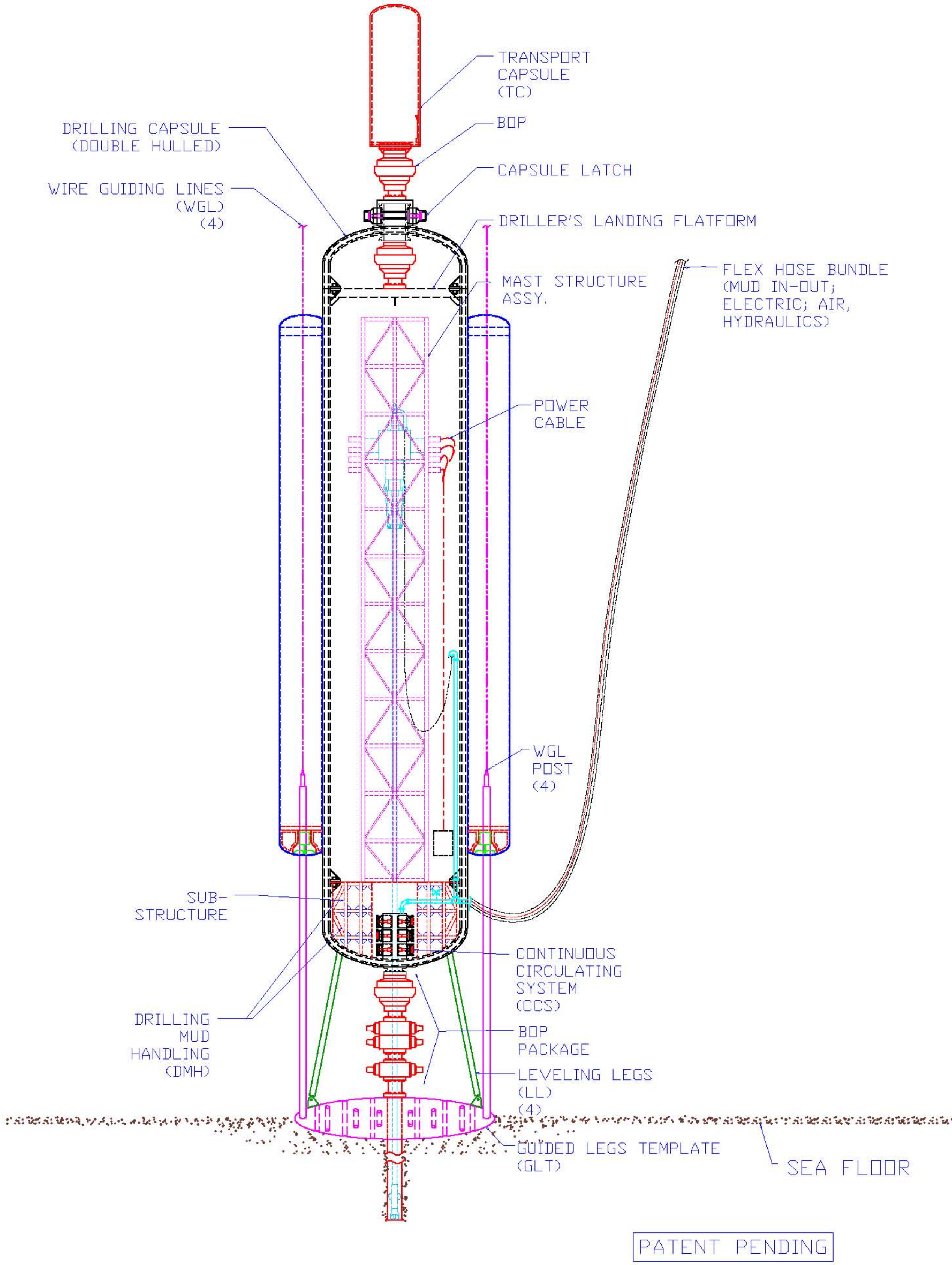

Figure 7 - Finish drilling the surface hole.

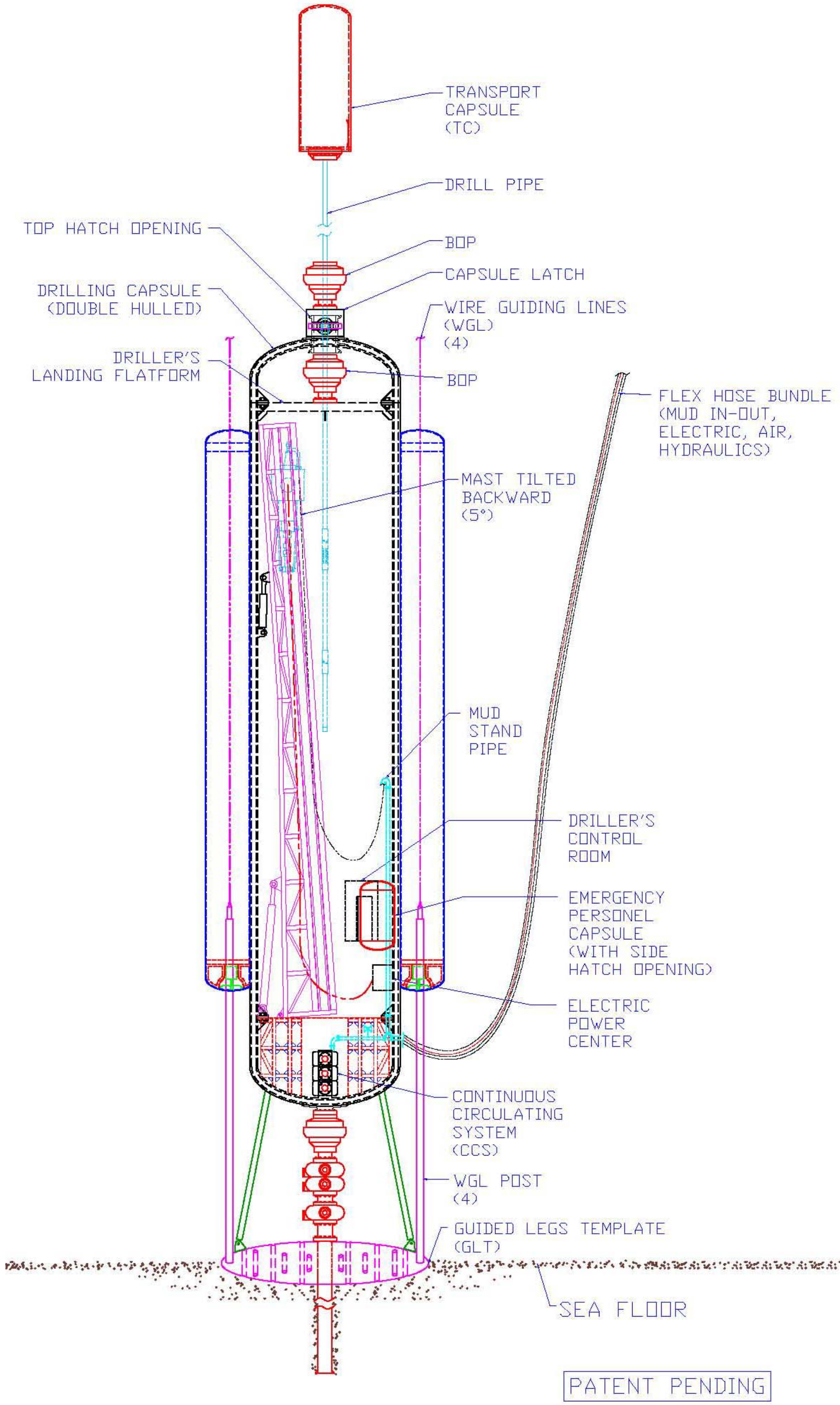

Figure 8 - Pulling out of the hole.

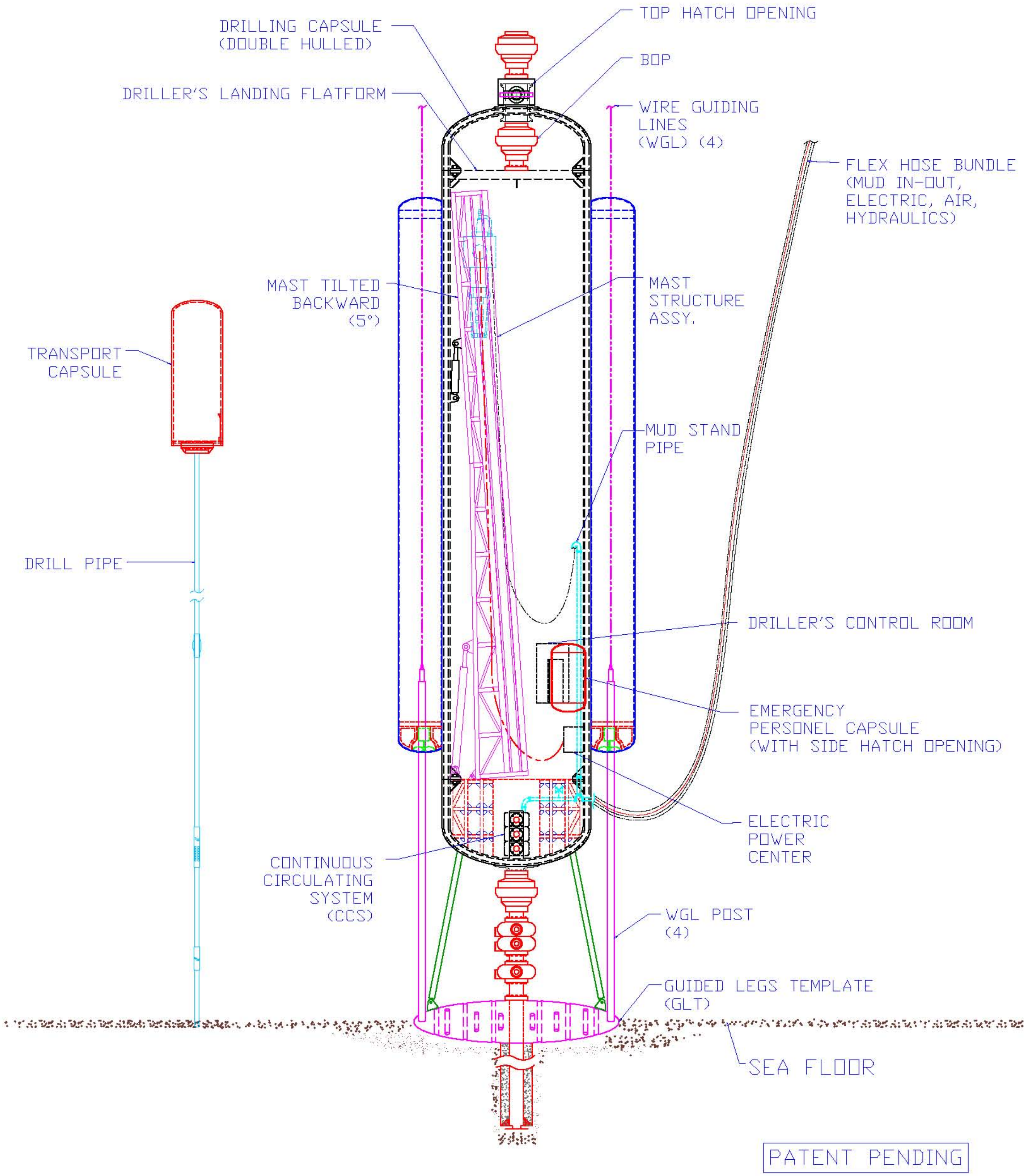

Figure 9 - Racking the drill string on the sea bottom.

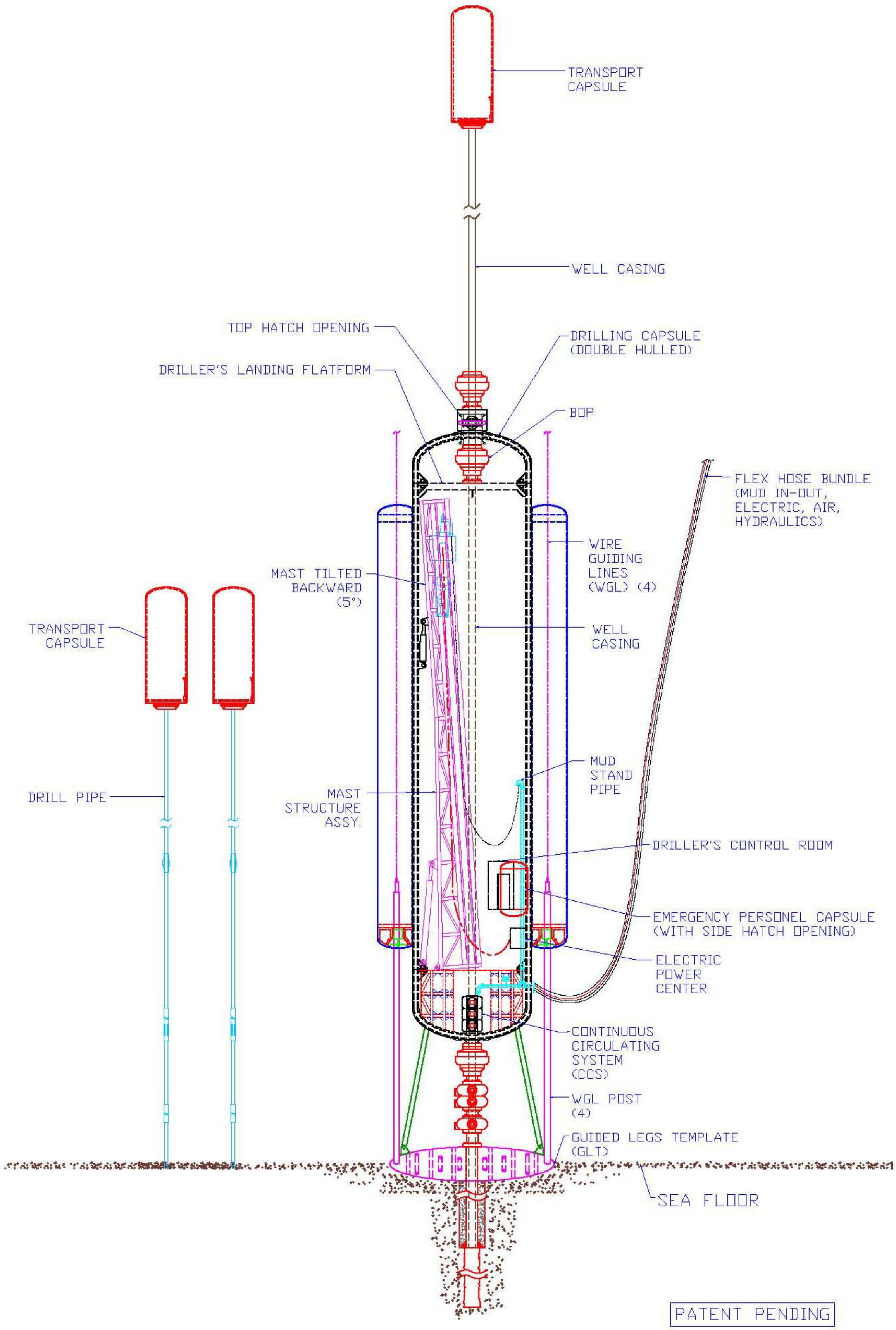

Figure 10 - Running the second casing string.