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Using Multi-Function Fishing Tool Strings to Improve Efficiency and Economics of Deepwater Plug and Abandonment Operations

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Abstract

This paper discusses procedures and tool systems developed to optimize the efficiencies and economics of subsea plug and abandonment (P&A) operations. The tools and techniques described in the paper address removal of intermediate casing strings and final removal of the subsea wellhead. Included in the discussion is a new deepwater plug and abandonment system. This system employs a string of multi-function fishing tools that work cooperatively to minimize the number of trips required for casing and wellhead recovery (significantly reducing pipe-cutting time) and to prevent wellhead damage without the use of motors.

Before the development of multi-function fishing tools, recovering a subsea wellhead required three or more drillpipe trips to remove each string of intermediate casing. This was followed by another trip to cut and recover the wellhead. During the 1990s, cut-and-pull technology consolidated cutting and recovery of the wellhead into a one-trip procedure. However, multiple trips were still required for each intermediate casing string. Given today's rig rates for deepwater work and the amount of time required to cut the large-diameter, thick-walled casing that ties into subsea wellheads, it is easy to see why any opportunity to improve the efficiencies of subsea P&A operations is welcome. The new systems and procedures addressed in this paper rely on proven technology to reduce risk and minimize field training required for successful deployment.

This paper compares time and costs for old and new methods. It describes a universal wellhead retrieval system and a unique procedural sequence in which casing is cut before seals are extracted. The system results in the ability to cut and recover the wellhead in a single trip without damaging the wellhead. The paper explains the safety, environmental, and economic advantages of eliminating motors and explosives and cutting the wellhead in tension. Case histories quantify results obtained in deepwater operations in the Gulf of Mexico and West Africa.

Introduction

Rig costs and other factors associated with extreme water depths make any opportunity to improve efficiencies and economics of subsea P&A operations most welcome. Now, newly developed multi-function fishing tools offer the ability to save hundreds of thousands of dollars by minimizing the number of trips required during casing and wellhead recovery. A new deepwater plug and abandonment system saves trips, reduces pipe-cutting time and prevents wellhead damage. The system consists of a Universal Wellhead Retrieving tool and the high-strength Hercules Multi-String Cutter combined with an advanced hydraulic casing spear and combination marine swivel/seal extractor. Operators in West Africa and the Gulf of Mexico are already reaping the time saving advantages of this new multi-function system.

Reducing Trips and Cost

Before the development of the multi-function fishing tools, recovering a subsea wellhead was very time-consuming and thus cost-intensive. Typically, three or more drillpipe trips were required to remove each intermediate casing string. The first trip retrieved the casing hanger seals from the wellhead. The casing was cut with a second trip. A third trip was then required to remove the casing and casing hanger from the well. This three-trip process would be repeated for each intermediate casing string to be recovered. Following recovery of all intermediate casing strings, the conductor strings were cut just below the mudline and the wellhead was recovered.

During the past decade, advances in "cut-and-pull" technology have consolidated cutting and recovery of the wellhead into a one-trip procedure. Still, multiple trips have been required for each intermediate casing string. Rig time consumed by these trips is a function of water depth. In deepwater operations, 8 to 10 hours per round trips are common. Added to that is time required for pipe cutting operations. Pipe cutting for the large-diameter (20- to 36-in.), thick-walled (1-1/2-in.) conductor casing that ties into subsea wellheads often requires 7 to 10 hours using conventional cutting equipment. Currently, day rates for deep water rigs are in the $200,000-

250,000 range, over $8,000 per hour. Thus, the potential savings from eliminating one trip are in the range of $75,000. For a typical subsea well with two intermediate strings to recover, elimination of two trips per string can save $300,000. This is a significant saving for an overhead operation with no revenue generation.

Intermediate Casing String Recovery Tools

Tools for intermediate casing string recovery include the casing cutter, a hydraulic casing spear and a combination marine swivel/hanger seal extractor. Although each is a discrete tool, they have been designed to work as a system that provides an efficient service.

Hercules Multi-String Casing Cutter

The cutters used to cut the intermediate casing strings are designed to cut the casing strings quickly. The Hercules multi-string cutter, Figure 1, is an improvement to a basic design that has been in service for three decades. The cutter is equipped with knives that are pivoted into the pipe to sever the casing. Circulation through the cutter produces a pressure differential across a large piston in the cutter. The resulting force acts on a cam surface on the inner end of the knives, pivoting them into the casing. Improvements to the cutter provide an increased cross-section in the knives to handle greater bending moments and improvements to the hydraulic “tattle-tail” feature. This provides a surface indication once the knives have extended far enough to complete the prescribed cut.

Knives of different lengths are available to cut a single pipe string or to progressively cut multiple strings. An adjustable internal stop is set to control the maximum knife-cutting diameter.

The most reliable and rugged knife dressing is the generally cylindrically shaped, sintered tungsten, carbide button referred to as MetalMuncher™. Development of the button configuration has been refined to consistently produce small cuttings that are easily circulated out of the well bore and minimize the risk of interfering with tool operation.

Specifically targeted at the wellhead recovery system, the updated cutter employs a solid body design that allows for a more robust knife design. The cutter can also be fitted with a special large OD sleeve to provide maximum stabilization when run to cut the larger diameter conductor strings[1]. Stabilization is the key to providing speed and endurance for maximum performance. The sleeve also eliminates the need for added stabilizers in the workstring.

Combination Marine Swivel/Seal Extractor

The swivel design is one of the key trip-saving elements of the intermediate casing string recovery system. The swivel, shown in Figure 2, allows pinpoint accuracy in locating the casing cut, and provides a stationary position during the cutting process. The swivel is equipped with a seal-pulling adapter according to the wellhead manufacturer’s specification, allowing for seal removal after the cutting process is completed. The swivel can be equipped to accommodate any 18-3/4” wellhead straight-pull release hanger seal.

The design allows the casing string to be cut with the hanger seals locked in to the wellhead, preventing the hanger from moving after the cut is made. Such movement can scar and damage the inside of the wellhead. With the seal unlocked and retracted, the hanger can be pulled and recovered in the same trip.

The swivel is equipped with robust radial and axial thrust bearings. A pressure compensator equalizes the pressure on the bearing lubricant, equalizing the pressure across the bearing seals. Porting in the lower housing allows unrestricted circulation during the cutting operation.

Hydraulic Casing Spear

The hydraulic casing spear is the final key component of the one trip cut-and-pull system for intermediate casing string recovery. The spear, shown in Figure 3, is hydraulically operated and therefore eliminates the need for right- or left-hand rotation to set or release the spear. A high load spring maintains the slips fully retracted until engagement of the casing is required. After the casing string is cut and the workstring is elevated, releasing and pulling the hanger seals if applicable, the hydraulic spear is positioned just below the casing hanger.

Proper loading of the cutter knives depends on the opportunity to control the circulation rate through the cutter. Since engagement of the casing with the spear is also a function of circulation rate, it is necessary to ensure that the flow required to perform the cut will not activate the spear. This is accomplished by providing a metering sleeve that is lubricated down the work string after completion of the cut.

Once the metering sleeve is set, fluid circulation at a predetermined rate sets the spear. With the casing securely engaged, the workstring is elevated once again and the casing is then pulled free to the rig floor. The spear is run one joint above the cutter so that no timely stripping is required once the casing is set in the slips at the rig floor. Simply dropping a ball and pressuring the workstring releases the spear. The casing is then laid down.

Slips are available for all casing sizes from 9-5/8” to 13-3/8”. Changeout of the slips is readily accomplished on the rig although normal practice is to have a different spear on hand for each casing size to be recovered.

Operation Sequence-Casing String Recovery

The operating procedures are as follows for the intermediate casing string recovery. Figure 5 illustrates the sequence of operations.

The bottom hole assembly is made up consisting of:

- Casing cutter
- Stabilizer
- One joint of drill pipe
- Hydraulic casing spear
- Drill pipe as needed to space cut below wellhead
- Marine swivel/seal extractor
- Long stroke bumper jar
- Drill pipe to surface as needed.

Trip in hole until the marine swivel/seal extractor lands in the wellhead on top of the casing hanger seals. When landed, the seal extractor ring automatically engages the seal assembly for eventual retrieval with a straight pull.

Slack off half the stroke of the bumper jar, then start rotation of the workstring. Circulate to maintain the pressure required to activate the casing cutter. A loss of backpressure and torque will indicate that the cut is complete. Stop circulating and pick up on the workstring. This will release the hanger seals and retract the cutter knives.

Pick up and position the hydraulic spear just below the casing hanger. A metering sleeve is now dropped into the workstring and seated in the hydraulic spear with circulation. Once the plug has seated, a predetermined pump rate is established, depending on the mud weight and properties to set the spear slips into the casing. Pick up on the workstring and stop circulation. Pull out of hole with the casing string. A ball can be dropped prior to or after the casing is set in the slips at the rotary table. Once the casing load is set in the rig slips, the spear is released by pressuring up on the drill pipe. Next, the released hydraulic spear and casing cutter are laid down. The casing can then be laid down. This process is repeated for each intermediate casing string to be recovered.

Universal Wellhead Recovery System

The Universal Wellhead Retrieving System (UWRS) is a combination latching tool and marine swivel[2]. The UWRS, shown in Figure 4, is run above the multi-string cutter to secure the wellhead during the cutting process and recover the wellhead once it is severed from the cemented conductor strings. The UWRS is designed to catch all manufacturers' 18-3/4" subsea wellheads with minor reconfiguration.

Earlier wellhead recovery tools relied on wellhead-specific adapters to engage proprietary profiles on the wellhead housing or wickered slips to engage the bore of the wellhead. These designs have proven troublesome. They must provide precisely mated engaging hardware for a variety of wellhead designs that employ the profile engagement style. Certain damage can also occur to the polished bore for wellheads using the slip style engagement.

With the UWRS, a shoulder beneath the wellhead polished bore is engaged in tension with a collet system. A J-slot in the top of the UWRS controls setting and releasing of the collet from the wellhead. The UWRS is run with the J-slot latching the collet in the release position. With the tool shouldered on top of the wellhead, one quarter turn rotation to the left allows the inner mandrel to release from the run-in position and to be raised, locking the collet into the wellhead. An overpull can then be taken on the drillstring. If the toolstring must be recovered prior to completely severing the wellhead, slacking off on the drillstring disengages the collet. When the inner mandrel is lowered, it will automatically re-engage the J-slot to maintain the collet in the released position.

Once set in the subsea wellhead, the Universal Wellhead Retrieving System allows tension to be maintained on the workstring during the cutting process. The thrust bearings in the UWRS are rated for an overpull of up to 300,000 pounds during rotation to cut the pipe. To recover the wellhead, which may be seated with considerable friction to the seabed, the UWRS is rated for 1,240,000 pounds of static pull.

Severing of the 20-inch casing below the wellhead and 30" or larger conductor string is accomplished with the previously described multi-string cutter. For this operation, the multi-string cutter is fitted with knives of sufficient length to cut both pipe strings. During the cutting process, the pipe cross-section being cut increases substantially. To achieve optimum performance from the cutter, it is therefore important to be able to raise the force applied to the cutter as the cut proceeds. This is accomplished simply by increasing the fluid circulation rate, which in turn increases the differential pressure across the piston in the cutter and the force exerted against the knives.

Operational Sequence Wellhead Recovery

The operational procedures are as follows for Subsea Wellhead recovery. Figure 6 illustrates the recovery sequence.

The bottom hole assembly is made up consisting of:

- Hercules style casing cutter
- Bumper jar
- Pony collar or spacing as needed
- Universal Wellhead Retrieving System
- Long stroke bumper jar
- Drill pipe as needed.

Trip tools to top of wellhead in open water and stab tools into wellhead. A remotely operated vehicle (ROV) is normally provided to assist stabbing the tools into the wellhead. Shoulder the UWRS stop ring on top of wellhead. Apply one quarter of a turn of left-hand torque to the tool. Pick up and take an overpull of 50,000 to 300,000 pounds. A nominal tension of 50,000 pounds is adequate to maintain the UWRS firmly engaged to the wellhead, but additional tension may be desirable to better manage whip and fatigue of the drillstring in open water. Start rotation of workstring; maintain circulation to produce the prescribed differential pressure to operate the cutter. A loss of weight or pump pressure will signal that cut is complete. Pull wellhead and tools to surface.

Tool Performance

All of the equipment described herein with the exception of the seal extractor was rigorously tested on the company's drilling rig prior to release for field use. Since a major goal of this equipment is efficient operation in the field, in-house rig testing is essential to prove field worthiness before sending new equipment designs offshore. The marine swivel/seal extractor was put through a factory acceptance test with a wellhead manufacturer to confirm the functionality of the tool with their seal assembly.

Field Operations and Benefits

Operators in West Africa and in the Gulf of Mexico have been the first to realize the benefits of the new deepwater P&A system. In two recent applications in 2,500-ft (763 m) waters in West Africa, the UWRS was used with 100% success. In one well using the UWRS and a conventional cutter, a single string was cut in just 8 minutes of cutter operation.

An operator in the Gulf of Mexico used the UWRS and the Hercules cutter to successfully cut two strings of casing in 2 hours and 8 minutes. The 20 in. and 36 in. diameter fully cemented casings were cut and the wellhead removed in one trip as part of a P&A operation in 4,500 ft. (1,373 m) water. Where no cement is present between the two strings, substantially more rotating time may be required to complete the cut.

Another operator in the Gulf of Mexico has successfully used all four of the new tools in 4,600 ft of water. The 13 5/8" casing string was cut with the casing hanger seals locked into the wellhead. The casing string and seals were then pulled with the marine Swivel Seal Extractor and hydraulic spear all in one trip. On the next run, the Hercules cutter, along with the UWRS, was run in and the wellhead engaged. Three casing strings (20", 26", and 36"), were then cut in what we believe was a record breaking time of 2 hours and 54 minutes. The casing and wellhead were then recovered in the same trip.

We have also had another successful run of all the tools on a well in 4,100 ft. waters. The 20" and 36" casings were cut in 1 hour and 15 minutes.

Different practices among operators and well conditions can impact the opportunity to achieve full benefits of the system. Good well records are essential to planning the total job, and correct preparation of the tools contribute to success as well.

No Motors or Explosives Required

All components for both Casing String Recovery and Wellhead Recovery systems use rotary drilling practices. Consequently, neither downhole motors nor explosives are required. Avoiding explosives significantly reduces safety and environmental risks. Eliminating the need for downhole motors reduces costs associated with equipment and breakdowns and enhances operational reliability.

Other systems that use downhole motors also use a hydraulically operated cutter similar to the multi-string cutter described herein. Operation of these multi-string cutters is dependent upon supplying circulation at a prescribed rate to activate the cutter. For a single string cut, the fluid requirement does not vary significantly during the cut. However, to cut two or more casing strings, the differential pressure required at the cutter increases as the cut progresses.

Using rotary drilling as with the Casing String and Wellhead Recovery system, the rotation of the cutter is independent of fluid circulation rate. Therefore, both the rotation speed and the circulation rate can be varied independently to maintain the optimum cutter velocity, torque and cutting pressure against the pipe. By contrast, with the use of a downhole motor the relationship between rotary speed, available torque, and cutter force are all dependently linked to the circulation rate. Consequently, it is more difficult to optimize cutting parameters with a system that uses a downhole motor to power the cutters.

Preventing Wellhead Damage

Properly recovered, subsea wellheads can be redressed and re-used. Minimizing damage to the polished bore was a key design criterion for all equipment run into the wellhead in both recovery operations. The casing recovery system allows the hanger seals to remain installed while the casing is cut. This reduces the tendency of the hanger to "jump", damaging the polished bore with the final release of strain energy when the casing string is severed. This risk is directly proportional to the depth below the wellhead of the cut. Because the UWRS utilizes a lift shoulder to engage an internal upset in the wellhead instead of wickered slips, the risk of damaging the polished bore is minimal.

Advantages of Cutting the Wellhead in Tension

The UWRS and multi-string cutter work together to keep the work string in tension while cutting. The ability to cut in tension creates less pipe fatigue due to bending in the workstring. Cutting the casing in tension also provides a more efficient cut as it ensures that the weight of the dutchman never slacks off onto the cutter knives.

Conclusions

The four tools introduced to improve efficiency of subsea P&A operations are meeting their design goals of improved operational efficiency and high reliability. They have proved to be operationally safe and cost efficient.

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2. Davis, J.P., Wellhead Retrieving Tool, U.S. Patent No. 6,059,049, May 2, 2000.

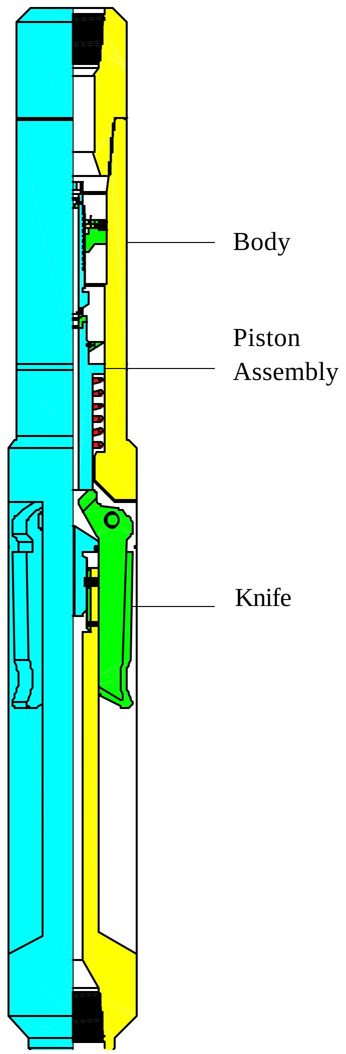

Figure 1. Multi-String Cutter

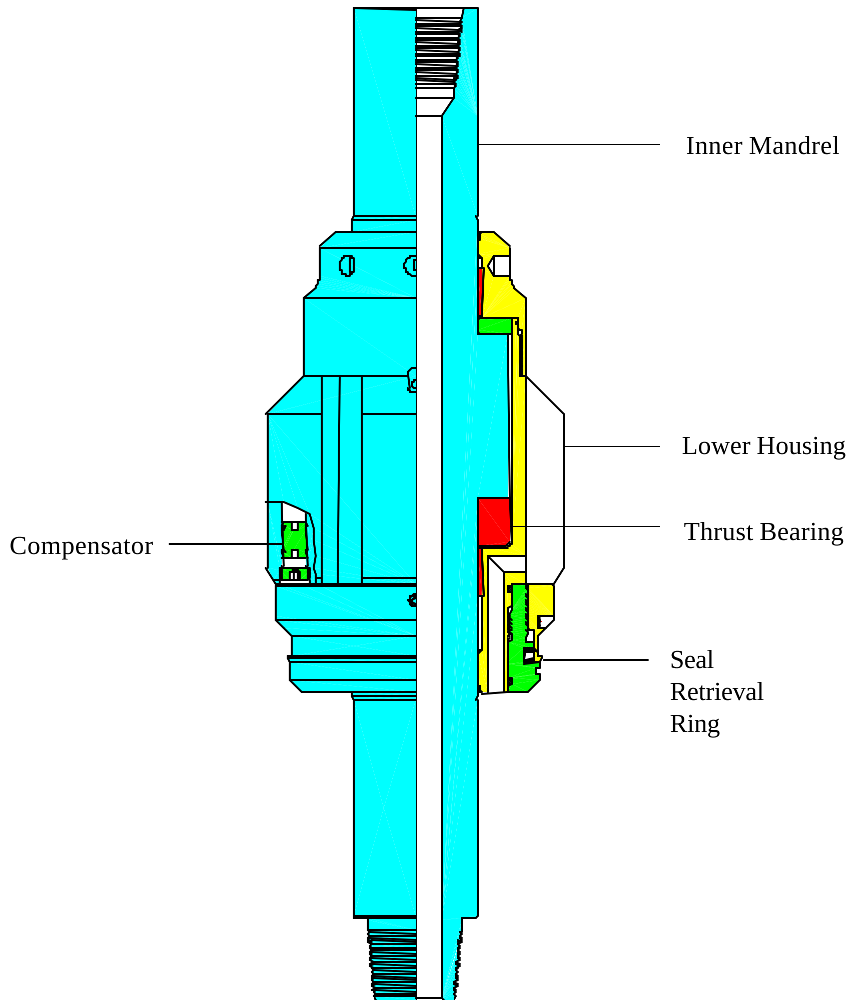

Figure 2. Marine Swivel/ Seal Extractor

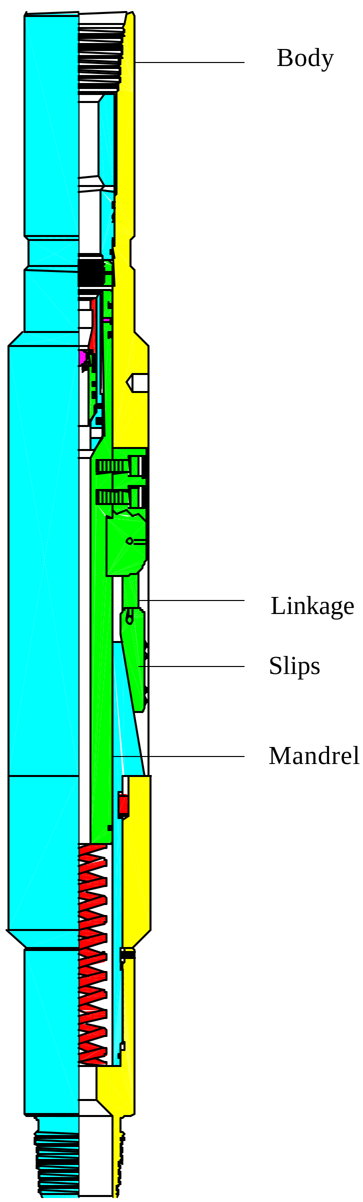

Figure 3. Hydraulic Casing Spear

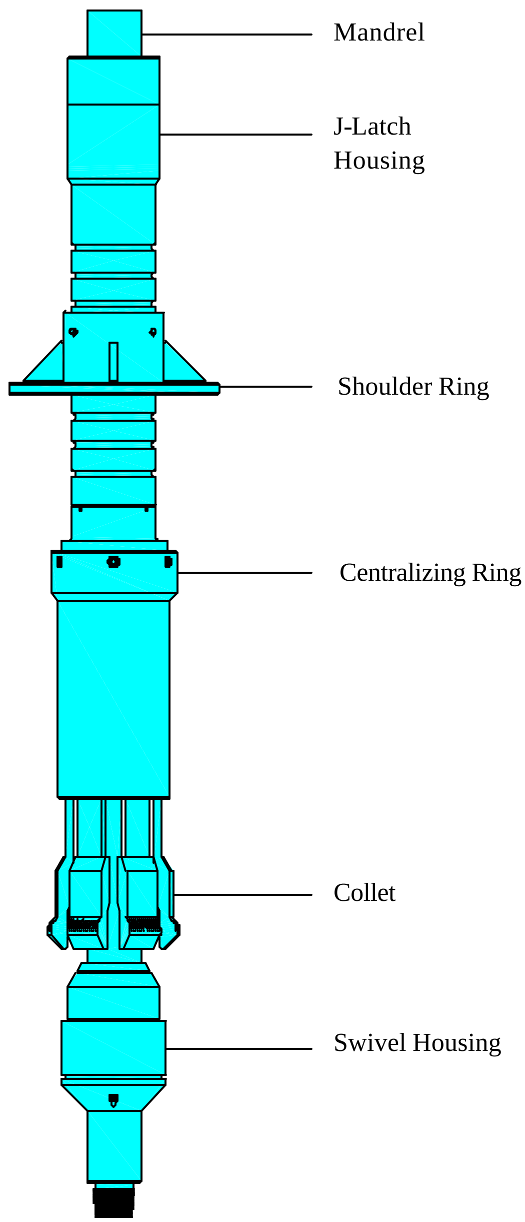

Figure 4. Universal Wellhead Retrieving System

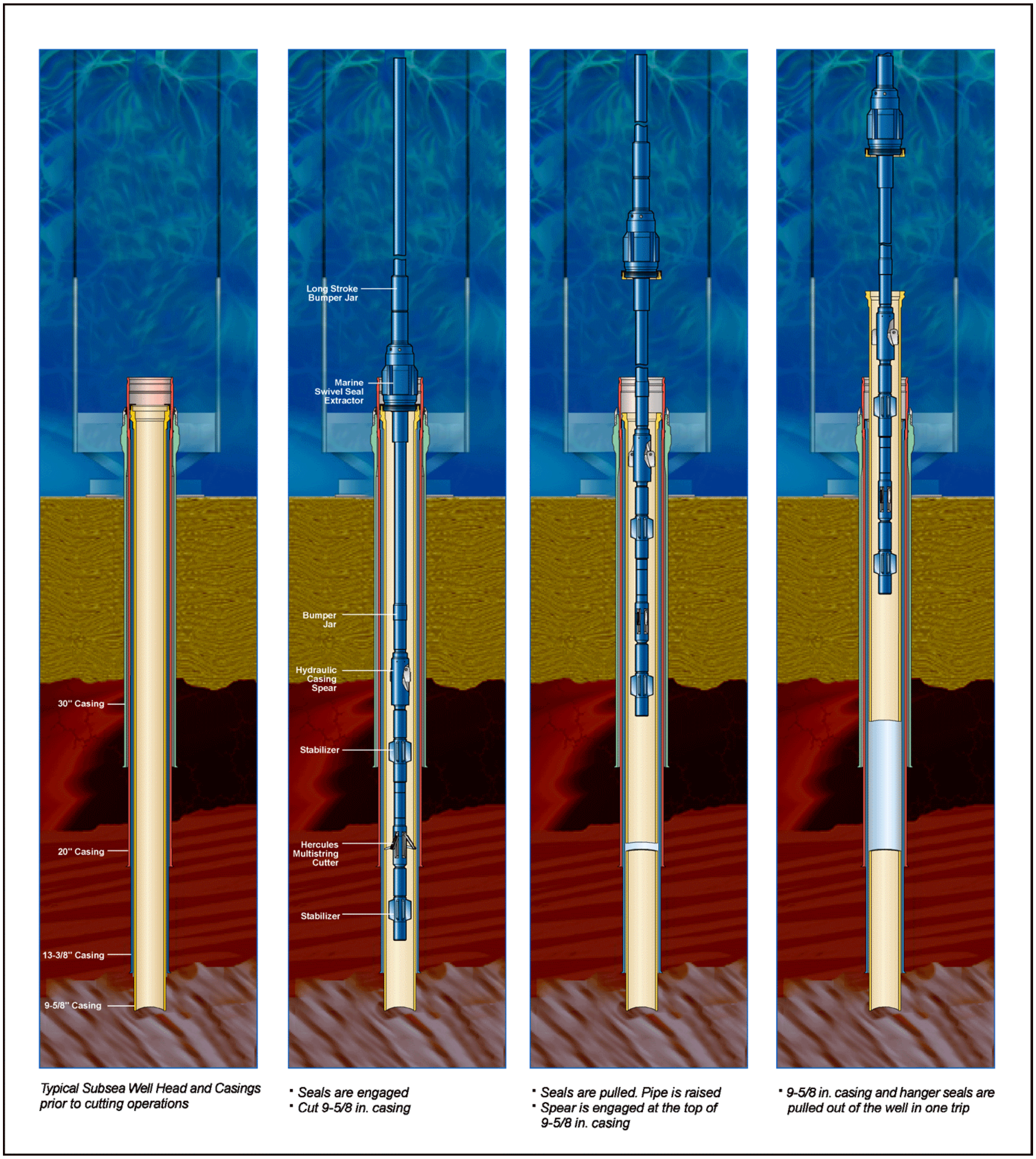

Figure 5. Intermediate Casing String Retrieval Sequence

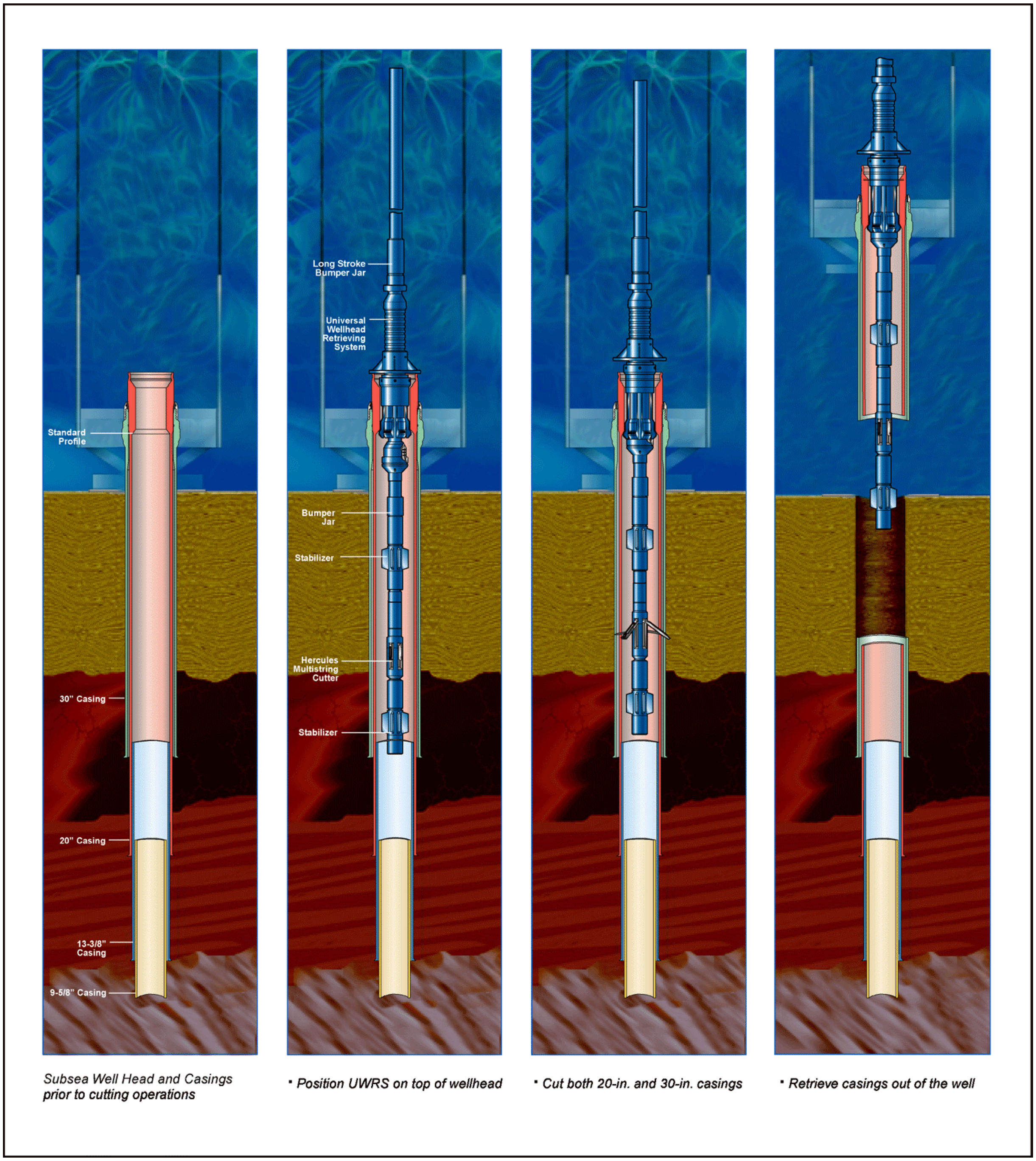

Figure 6. Wellhead Recovery Sequence.