REDUCING UNCERTAINTY IN SUBSEA FIELD DECOMMISSIONING

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Abstract

In an industry that demands savvy engineering and rapid advancements in technology, it is often far too easy to overlook the simplest approach to the path forward. As many of the technological “advancements” in the oil & gas industry will attest, simplicity simply never wins the spotlight. Now that older generations of subsea wells, PLETs, and manifolds are reaching the end of their 15 to 20 year design lives, decommissioning projects have started to earn their share of the yearly budget. Fortunately, decommissioning fields need not be costly or excessively challenging – and many of the lessons learned from brownfield deconstruction may lead to cost-savings in future developments… if simplicity can once again be seen for its elegance.

Background

The dawn of the 21st century does not seem like a very long time ago, but the historians among us may recall that the late 1990s and early 2000s were a time before many people had a dial-up modem let alone a dedicated broadband connection. In fact, a basic smart phone today has 10x more processing power than a PC did back then. Fax machines and copiers went through paper without remorse, whereas now the boxes of binders a project engineer once took offshore have been replaced by laptops and external hard drives.

In fact, the transmission and storage of information now is so effortless as to be trivial in the grand scheme of things. While the document control process is certainly far from trivial, the passing of information from one gatekeeper to another is no longer a process involving paper cuts, cardboard boxes, file cabinets, or folders – well, at least not as many. Documents and drawings can be easily archived to “the cloud” for convenient storage and retrieval. A mere ten years ago, boxes of original documents (and their draft copies) would be shipped weekly to corporate storage facilities where they were quickly forgotten. In some instances, this archaic practice is still being implemented today; old habits indeed die hard.

Imagine the frustration when ~20 years after a PLET (pipeline end termination) or a rigid jumper has been installed - and - spoiled by the luxury of new technology – an exhaustive search for archived information only results in an old scan of hand sketch, a rudimentary fabrication drawing, and a few photos of the structure taken at the fabrication yard. Unfortunately, the handful of people who may have known where to find the coveted information are no longer with the company, and even if they were – it would take several weeks rummaging around a storage facility for one of them to find it, even if it existed at all.

So begins the process of engineering a decommissioning project, and each of these types of projects will come with its fair share of surprises. The initial incompleteness of the information that the project team will have at its dispense (and the questionable accuracy of the information) is the first hurdle to overcome. This was the case on a 2015 project in which our project team oversaw the engineering and offshore operations for the decommissioning of several rigid jumpers, flying leads, and other subsea architecture.
An excellent starting point when it comes to tracking down information is the BSEE website. Here a wide range of information may be discovered, including as-built drawings and field layouts with relevant segment numbers. It is important to note that BSEE records can only be as complete as the information they are given. In our case, our search for information only started with BSEE. It took a small archaeological expedition to find the rest of the information, if it existed at all.

The aforementioned project will be drawn upon for much of the information presented in this paper, thus the following is a brief explanation of the work that was performed. The project consisted of the disconnection and recovery of three rigid jumpers, several hydraulic flying leads (HFLs) and a few electrical flying leads (EFLs) to enable the trees to be recovered.

![Figure 1 – General Field Layout for Decommissioning of Jumpers A&B](image)

Two of the rigid jumpers (Jumpers A&B) were connected to their respective hubs via flanged connections and were installed in the 1990s by divers in 1,500 ft. water depth using an Oceaneering International, Inc. one atmosphere diving suit (ADS).

Following the disconnection of the flanged jumpers, flanged pressure caps were installed on the empty flanges to provide isolation from the environment.

The third jumper (Jumper C) had diverless vertical connectors (DVC). The empty PLET and tree hubs were isolated from the environment with modified hub pressure test clamps following the recovery of the jumper. Typically, purpose-built pressure caps would be used, but these could not be fabricated to meet the project timeline.

One consideration worth highlighting when it comes to decommissioning projects is that they are never a simple matter of reverse engineering. In all likelihood, the components of a subsea field were not designed or installed with the intent to return 20 years later and recover everything. Furthermore, in many cases there may be other wells as part of the development that share common flowlines, PLETs, hydraulic and electrical controls. These wells/trees may remain in service, so additional care is required to prevent field shut-ins beyond what is required for the decommissioning scopes of work.
The Path Forward

Jumpers A&B were installed roughly around the time that vertical connectors first entered the market. While the purpose of this paper is not to educate the reader on the history of vertical connector and ROV innovation, it bears mentioning that the tasks that were once a challenge for ROVs gave birth to innovations such as the diverless vertical connector; however, more dexterous ROV manipulators, more horsepower, and better ROV pilots make it possible to perform tasks that were typically allocated to divers 20 years ago. Prior to vertical connector innovation, the tried and true flange was the only way to connect subsea jumpers and spool pieces. Needless to say, divers were the best-suited means to successfully guide eight bolts into their respective holes and ensure that they were torqued to the proper value. As offshore exploration moved into deeper waters, it became apparent that a diverless vertical connector solution was the way forward. In fact, you would be hard-pressed to find a modern subsea development that did not use vertical connectors of some kind.

The century of collective experience that our project team had at its dispense actually did include prior ADS projects; however, in the time that had elapsed since the initial installation of Jumpers A&B, atmosphere diving systems are typically not rated for use commercially at depths greater than 1,200 fsw. The only remaining option was to perform the work with an ROV. Initially, this seemed like a daunting task, but only for lack of certainty and experience in that it had not been done before. Our project team reduced this uncertainty by closely overseeing the design of the tooling and equipment procured from Oceaneering. This included the flanged pressure caps, ROV-operated torque wrenches, ROV-operated bolt cutters & nut extractors, and contingency bolt-retaining collars (that we hoped we would never use). The existing PLETs and trees to which Jumpers A&B were connected were installed with bolt-retaining collars already in-place. Our plan was to re-use the existing bolts, but we did not have full confidence in the integrity of the ~15 to 20-year old collars. As such, in the event that the existing collars failed, we would be forced to replace it subsea with the ROV. The following figure presents sketches and photos of the pressure caps and nut-retaining collars that were designed and fabricated to the same specification of the original jumper flange connections.
Factory Acceptance Testing (FAT) was conducted upon the completion of all fabricated equipment at Oceaneering’s testing facility in Houston, TX. System integration and function was performed to demonstrate equipment manufacturing and operation meet design requirements. Lessons learned were captured and minor modifications to the equipment and tooling were made as necessary to improve functionality and future offshore success.
Photos from FAT:

**Figure 6:** Bolt retention collar (yellow) installed around a flange test hub that was manufactured to match the existing subsea flange connection on the offshore tree. Alignment of bolt retention collar with flange bolt holes was checked using a fork tool (white), which would also be used by the ROV when installing the collar.

**Figure 7:** The engineered pressure clamp assembly (yellow) fitted over the flange test hub and the final connection between both flanges was made using a retrofitted hydraulic torque wrench.

**Figure 8:** A back seal test of the annulus between the gasket and flange was performed along with a complete bore test to prove pressure containment and manufacture design requirements respectively.
To gain further confidence in the equipment and procedures an underwater SIT (System Integration Test) was performed in Oceaneering’s test pool at the NASA Neutral Buoyancy Laboratory in Houston. (Yes, NASA, Houston – as in “Houston, we have a problem.”) For two days we worked alongside astronauts simulating our respective missions, missions that would later take place over 230 miles apart in equally remote conditions.

Figure 9 – Entrance to the Neutral Buoyancy Laboratory – Did you know they filmed Armageddon here?

Figure 10 – Photo of NASA Neutral Buoyancy Laboratory with ROV shown in far left. (Photo taken by S. Penney)

When it comes to installation, existing procedures are typically used for “inspiration” as cut & paste “go-bys” that may not evolve much from project to project. However, a decommissioning project is likely going to start from a blank slate, as was the case with the decommissioning of Jumpers A&B. Over the course of two days, engineered task plan methodology was preformed with an ROV to simulate actual offshore operations to prove the execution process and equipment functionality. The underwater SIT proved invaluable, as the ROV maneuvered, installed and function tested all equipment several times. Operational lessons learned were applied to the procedure, and the equipment was modified as necessary to improve future offshore success.
The following figures present a few snapshots taken from the underwater SIT.

Figure 11: ROV installing bolt retention collar (yellow) around a flange test hub that was manufactured match the existing subsea flange connection on the offshore tree. This proved to be less challenging to accomplish with the ROV than previously expected.

Figure 12: ROV landing the engineered pressure clamp assembly (yellow) over the flange test hub. The clamp was designed and fabricated to the same specification of the original jumper flange connections.

Figure 13: ROV installing and spinning down the bolts using a T-handles socket tool. A retrofitted hydraulic torque wrench was used to make the final connection been both flanges. A back seal test of the annulus between the gasket and flange was preformed to prove pressure containment.
Offshore Execution

The underwater SIT was successful in that it increased confidence in our tooling and methodology. With the exception of one unexpected discrepancy in the configuration of one of the tree hubs and its existing nut retaining collar, the offshore execution of the work went well. A discrepancy was discovered during the attempted installation of a pressure cap on one of the empty tree hubs. The pressure cap’s guide funnel was designed to fit over the existing bolt retaining clamp on the structure, which was expected to be clamped onto the piping directly underneath the flange itself. In the case of the hub in question, the nut retaining collar actually clamped around the flange. Note that this revelation would have been unlikely discovered until after the jumper had been removed. This is an excellent example of what was found verses what was expected. In this case, the change had never been recorded in as-built documentation that was readily available or accessible to the project team.

Figure 15 – All documentation that was obtained pointed to this configuration: nut retaining clamp positioned directly underneath the flange.

Figure 16 – This configuration was unexpected when encountered offshore. In this case, the nut retaining collar can be seen clamped around the outer diameter of the flange. This had not been reported in any as-built documentation.
As a result of all the extensive research, physical trials, detailed planning, and a few minor infield modifications, the work was executed flawlessly. The average time for the disconnection of a single flanged connection was roughly 30 minutes. Installation of the tree and PLET pressure caps was achieved in tandem, as both ROVs worked simultaneously, each at its own hub. Using the manipulator-held socket tool, it took an average of 40 minutes to wind down all eight bolts. The final make-up torque required three passes with the hydraulic torque wrench in a typical star pattern. Each pass the torque value was incrementally increased until the final torque value was achieved. One pass with the hydraulic wrench took approximately an hour to complete, for a total of three hours. To summarize, the complete installation of one flanged pressure cap took less than five hours. The following figures present the hub cleaning and initial tightening of one of the pressure cap bolts. Note the rogue bolt that required the hydraulic stud extractor to remove.

Figure 17: Cleaning the hub to prepare for pressure cap installation. The hubs were all surprisingly clean despite having been in service for almost two decades.

Figure 18: ROV winding down bolts on pressure cap with a manipulator-held socket wrench. This improved overall installation time.

There were certainly lessons learned from the decommissioning of Jumpers A&B. While a site survey had been conducted prior to the engineering phase of the project, perhaps it would have been wise to have taken some measurements to confirm the validity of existing information. A comparative study of different hub photos taken via ROV manipulator camera may have revealed the discrepancy in nut retaining collar configuration, something that would have been useful to know in advance of pressure cap fabrication. Fortunately, a qualified welder was part of the offshore crew. Otherwise, the modifications made to the pressure cap in the field would not have been possible. This is something worth considering in projects involving equipment that has been fabricated based on incomplete or uncertain information.
More Problem Solving

Typically, decommissioning of a field will involve the plug and abandonment (P&A) of one or more wells in the field. In order to satisfy BSEE requirements that trees be monitored as long as possible, our decommissioning efforts were timed to meet the schedule of the drill rig performing the P&A work. Thus, the decommissioning of Jumper C took place several months after the decommissioning of Jumpers A&B.

To ensure the safest offshore operations, it was decided that Jumper C would be cut subsea such that the middle portion could be removed independently of the two DVC connector pieces. This also eliminated the need for a spreader bar, jumper stands, and made the entire recovery operation far less weather dependant. An additional benefit to this strategy was that it would require the rental of just a single running tool. The offshore execution of the work went according to plan with no accidents or incidents, but it is what took place following the decommissioning of Jumper C that will be of particular interest to the reader.

As mentioned earlier in this paper, a short project timeline meant that standard pressure caps could not be fabricated in advance of the offshore campaign, and there were not any existing pressure caps available in company inventory. The workaround for this dilemma was to modify two test clamps (typically used to test the integrity of the hubs). These clamps are designed to be installed and handled by technicians in a workshop, not by an ROV subsea. In order to make the clamp ROV-installable, several sets of ROV grab bars were incorporated into the clamp half-shells such that they could easily be pushed together by two ROVs. A manipulator-held socket wrench would then be used to wind down the bolts such that they could be fully torqued with a calibrated hytorc wrench, also modified to be used by the ROV. The following figure shows the test clamp prior to modification.

![Figure 19: Test clamp prior to being refurbished and modified for ROV installation.](image1)

![Figure 20: Test clamp after modifications, including the addition of lifting points, ROV grab bars, and a back seal test port.](image2)
Conclusion

Reflecting on the success of these decommissioning campaigns has raised some ideas worth contemplation. Given the improvements to ROV functionality and tooling, is there a cost-savings benefit to the use of flanges instead of more expensive alternatives? Does a few hours of vessel time spent torquing bolts make more sense than the price of a more sophisticated option? These questions can only be answered through a detailed FEED study, as every project is different. Moreover, when a project team is faced with old, outdated technology, it is still possible to provide a modern approach to project engineering and planning. This requires a “start again” strategy that applies to the design of new equipment and especially to the writing of new procedures. A realistic, physical SIT is ultimately the best way to refine procedural methodology and to identify potential issues with newly designed equipment. Subsea field decommissioning projects will be laden with unknowns, but fortunately you don’t have to be an astronaut to get to the bottom of it.

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