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Subsea Tree Installation, Lessons Learned on a West Africa Development

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Abstract

A Subsea Production Development Project was undertaken in West Africa. The Development is a subsea production project in 1200 ft of water. Twenty-eight subsea Horizontal Trees (HT) were installed from 1999 through 2002 in four drill centers over several campaigns. A remaining five trees are scheduled for future installation.

A project was undertaken to review and analyze the field service reports for each of these installations. The scope of this review included the subsea tree, tubing hanger, crown plug, internal tree cap, and debris cap. Ancillary operations such as wear bushing retrieval, bop test tool, straddle sleeve, and bore protector were also included. Other subsea equipment and interfaces were not subject to this analysis in order to maintain focus on the tree itself.

The review of this data had several purposes:

- To compare the equipment and activity performances against related variables such as rig, personnel, well condition, and environmental conditions.

- For benchmarking, to establish mean and standard deviations of installation times and other key variable data such as landing loads, pull-out forces, etc.

- A critical review of the installation procedures against the actual field reports to look for "hidden factories" and other undocumented activities. Based on this review, the procedures were revised to both optimize the process, and ensure the required performance data is recorded.

- To establish a standard electronic format for the future collection of field tree installation data. This on-line database will be used to maintain baseline performance statistics, identify equipment performance trends, and formally address field failures for complete resolution. The field data will be back-loaded into this existing WELS (Well Electronic Log System) database, and all future tree installations will use this format.

This paper will document the results of the West Africa installation data analysis, including:

- Presenting the installation data in chart and graph format.
- Drawing conclusions about the equipment performance and effectiveness of the procedures.
- Making recommendations as to the requirements for a tree installation data collection system.

Introduction

Project and Field Description

The field, discovered May 1997, is located in West Africa in about 1200 ft of water. The operator for and on behalf of joint venture partners decided to develop the first of three phases as a fast-track early production system. First oil was in December 1999, 30 months after discovery and 15 months after contract awards.

Refer to Figure 1 for an illustration of the full field development.
The field is a full subsea development with a local FPSO host. The nature of the field dictated multiple drill centers and pressure maintenance on the natural drive reservoirs. The subsea architecture is a traditional cluster system with discrete wells surrounding central manifolds at each of the three major drill centers. Another key aspect of this development was the desire to maintain a Zero-flare environment for the produced gas. Surplus gas is used for both Gas-lift service into the production wells and then for re-injection into the reservoir at a dedicated Gas Injection well. Phase B, brought on the water injection wells for reservoir pressure maintenance, and Phase C completed the coverage of the reservoir complex.

A moored MODU provided the drilling, tree, and completion installation services prior to the construction activities by CSO. Both this rig and sister MODU provided subsequent drilling and tree operations, and finally by the sister MODU alone. The base case and preferred process was to perform batch operations for drilling open hole, drilling with BOP, running trees, and installing completions. The batch operations allowed for very efficient operations due to the reductions in equipment set-up's and increase in repeat cycles. In addition to the above activities, the drilling rigs also performed limited construction activities, primarily flexible jumper and control flying leads installations.

The field well-count and status (as of this publication) is as follows:

Phase A		
Production Wells	12	
Gas Injection Well	1	(discrete from Manifold)
Phase B		
Water Injection Wells	8	
Phase C		
Production Wells	8	(5 yet to be installed)
Water Injection Wells	1	(spare)
Production Wells (infill)	3	(yet to be installed)
Total	33	

There has been 1 major workover and 1 minor workover to date on these wells. There is one planned future workover.

Subsea Horizontal Tree Description

The demands placed on the functionality requirements of the subsea tree were not technically challenging, compared to current state of the art designs. The field and environmental conditions, being relatively benign, allowed the specification of an existing and proven design.

The tree can be defined as follows:

Pressure Rating	5,000 psi
Production Bore	4" – Production Trees 5" – Water Injection Trees
Wellhead	18-3/4" SG-5 – A Field 18-3/4" MS700 – B & C Fields
API PSL Level	PSL 2 on tree and PSL 3 on Tubing Hanger and Valves
API Material Class	FF on tree and HH on Production path through choke
API Temperature Class	35º F to 250º F
Guidance	GLL Funnel down by Guidepost up
Controls	Retrievable SCM on tree
Choke	Retrievable Choke on tree
Penetrations	3 x Hydraulic and 1 x electrical for DHPT

The HT in this configuration had a shipping envelope of 12 ft. x 18 ft. x 14 ft., a net shipping weigh of 80,400 lbs., and a full running weight of 84,800 lbs. Refer to Figure 2 for a cross section of the HT assembly.

The primary challenges for the design team was to maintain a short delivery schedule and supply reliable equipment with respect to the frontier location of the field.

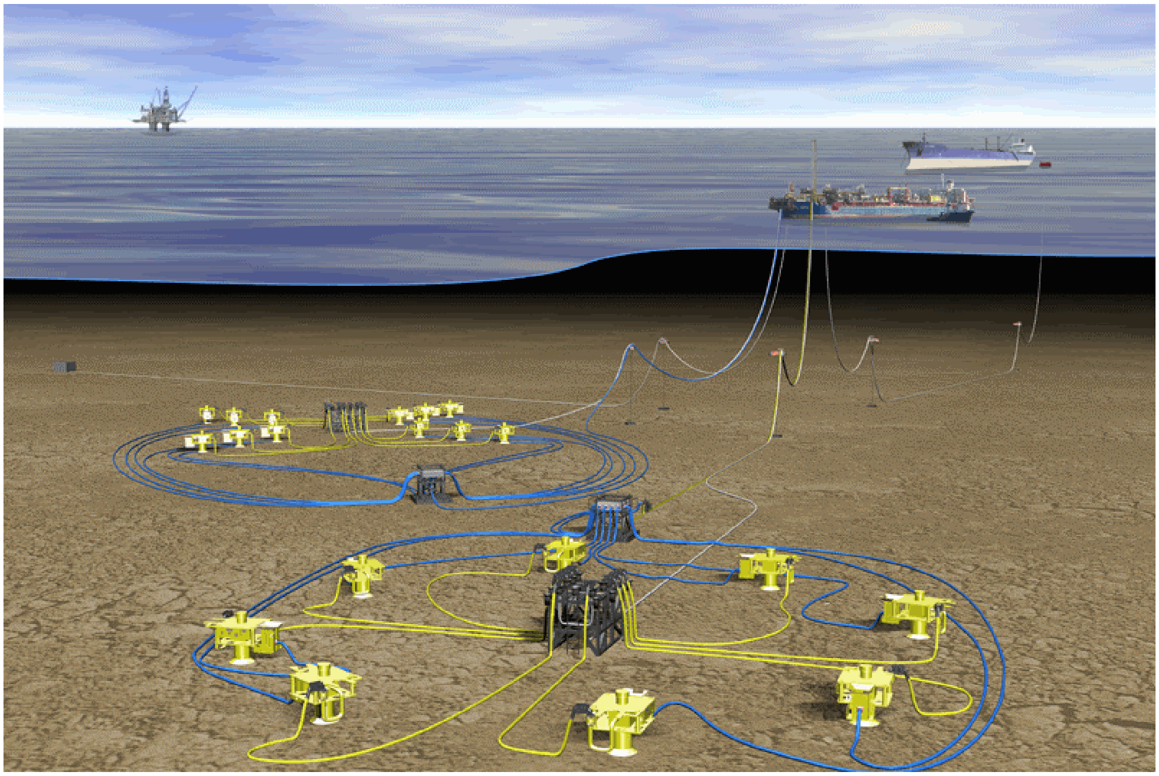

Figure 1 – Field Layout

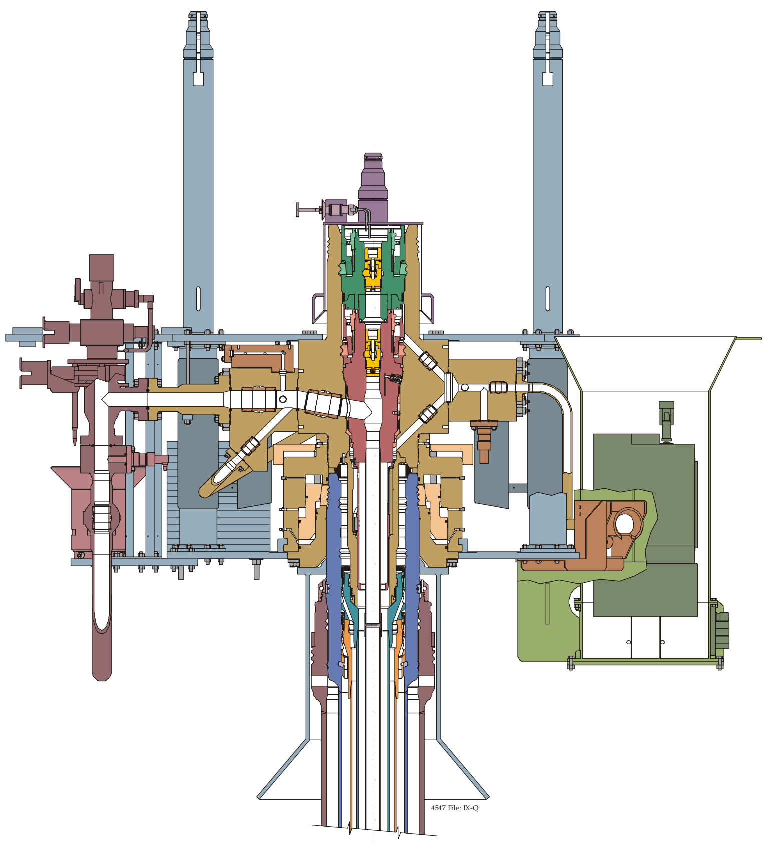

Figure 2 – Tree Cross Section

Installation Logistics

The supply of a complete subsea production system in 15 months (contract to first oil) required utilizing the supply chain from multiple facilities and in several regions. While the tree was unitized in Houston, key subcomponents came from Europe. A comprehensive System Integration Test (SIT) was performed on Tree Assembly #1 and #2, and due to the use of proven subcomponents, the SIT was very successful.

One aspect of the SIT that generated several lessons-learned was the ROV Interface. The tree ROV interface was based on a GOM regional standardized practice of direct docking into the desired function with a hard-mounted ROV tool. The ROV contractor, which was selected after the tree design phase, was North Sea based. In the North Sea, the more common tree ROV interface was the use of tools mounted on an adjustable coordinate table. This tooling system required docking profiles on the tree. Both interfaces are accommodated for in API, and both have their merits. An extended session of practice and training, along with adjustment of the procedures, overcame the initial interface difficulties with the ROV tooling.

Based on this success, and driven by the need to minimize cycle time, subsequent trees underwent Extended Factory Acceptance Testing (EFAT) only. In fact, the Subsea Control Modules (SCM) were shipped direct from England to West Africa, where they were first integrated with the HT on the rig.

The Customer had a mature and established sea freight program for supplying drilling equipment and consumables from the USA and European Union to West Africa. The project team, taking advantage of this asset, delivered the trees via these container ships. The tree EFAT's were back-scheduled to meet the regular ship sailing schedules. The first three trees were fully crated for export shipping, however based on feedback from the receiving personnel, this practice was eliminated as a cost savings measure. Metal shipping skids were used for all trees.

Upon arrival in West Africa the trees were offloaded directly onto a supply boat and then onto the Rig (Figure 3). Initially, this was necessary due to the absence of a suitable deepwater port in the vicinity. As the trees arrived directly to the Rig, it was of utmost importance that they were in a suitable condition to be run immediately with little set-up from the Service personnel.

Another logistical issue was related to the batch running of the trees, as discussed in more detail below. Since several trees were run sequentially, and this was accomplished in a simple and quick drillpipe trip, the timing of tree arrival to the rig was critical. Given the limited deck space and deck load (VDL) on the rig for tree storage and the lack of a nearby dock facility, the project team had to carefully back schedule the tree output from the factory in Houston. Despite this dependence, the tree delivery logistics went extremely well, which was accounted to a detailed management of the sub-suppliers down to the forging level.

Figure 3

Once the tree arrived on the Rig deck it was transferred from the shipping skid to the Tree Test Stump, and the tree was fully fitted for subsea installation including adding the SCM and counter-balance weight kit. Fitting these items on the rig kept the tree on-loading weight to a manageable level for the rig cranes. The tree Wear Bushing is normally factory installed, however to optimize the quantities of this non-consumable item, after the initial tree deliveries, the retrieved Wear Bushings were rig reinstalled on subsequent trees. After final tree assembly, the tree underwent an abbreviated deck test prior to deployment to the moon pool.

Besides the above-mentioned Wear Bushing, there were several other reusable items, which required rationalizations as to the optimum quantity needed to support a multi- tree installation program in West Africa. Some of these items were required back in Houston for support to future trees. For the 33 well programs, smaller quantities of support equipment was deemed adequate, as follows:

Tree Wear Bushing	5	
Tbg Hgr Bore Protector	4	
Tbg Hgr Straddle Sleeve	5	
Tree Shipping Skid	13	
Tree Guideposts	28	(7 sets)

Two complete sets of tree running tools were maintained in West Africa. Separate tools sets resident in Houston supported the tree assembly, FAT and EFATR operations. Figure 4 illustrates the total equipment scope.

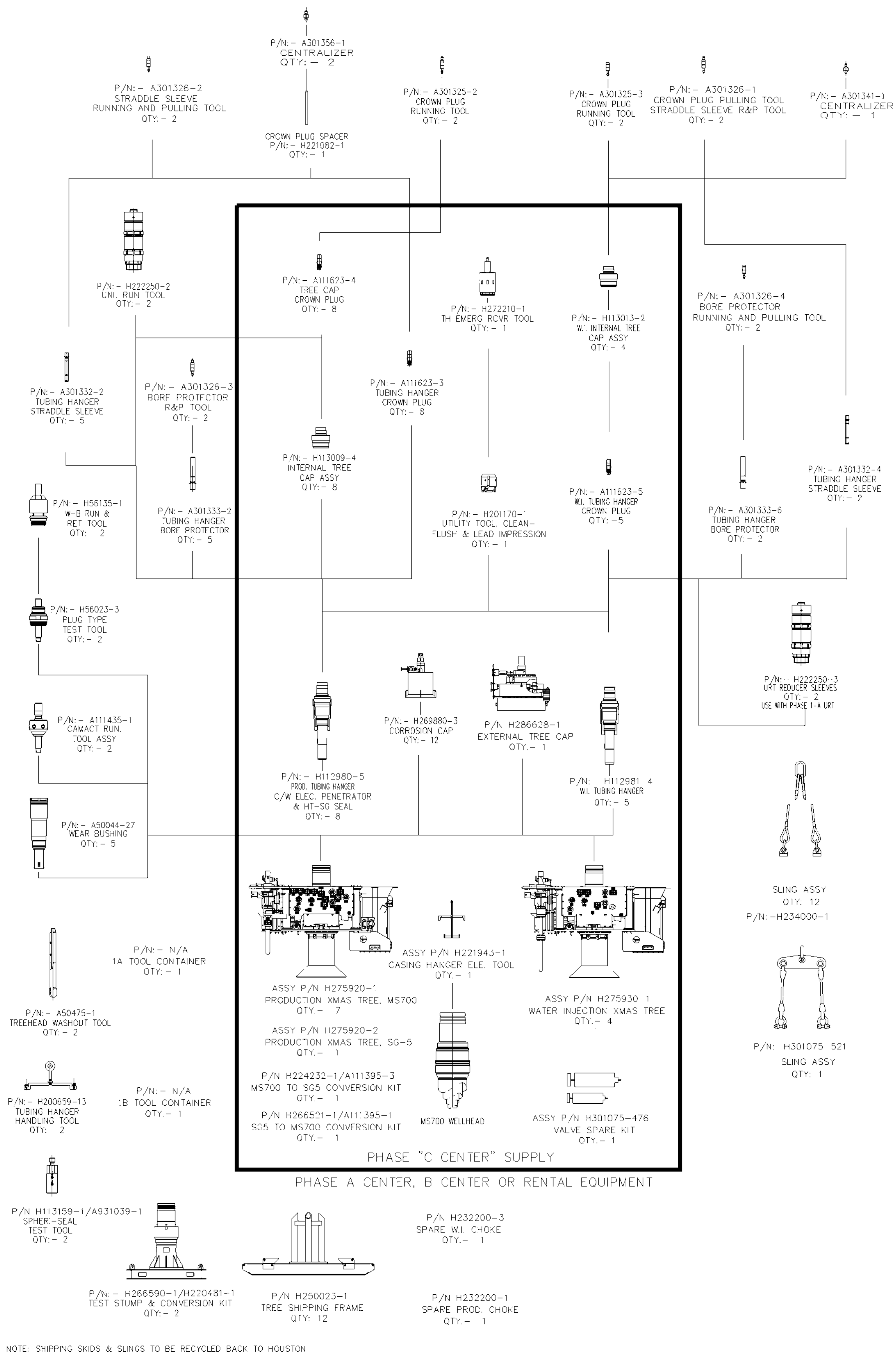

Figure 4 – Scope of Equipment

Installation Process – System and Procedures

At a macro level, the installation process was based on performing batch operations whenever possible. The high well counts at few drill centers made this efficient mode of installation possible. In general terms, the wells in each drill center were drilled and frac-packed prior to arrival of the trees. As trees arrived in sets, they were batch installed, and completion operations followed under BOP control. The rig could not be on the drill center during construction activities (flowline, umbilicals, and manifold installations), and the Rig accommodated this construction window at each phase of the program by moving to other drill centers.

At the component level, detailed installation and operating procedures were published by the manufactures. These procedures gave instructions as to the basic operation of the component and provided key technical data such as pressures, volumes, torques, turns, and over-pulls. This information, while useful to the service technicians, was relatively generic in nature and did not cover the project specific issues and interfaces. The projects team, led by the Customer, prepared a systems level installation and operating procedure, whereby the detailed component procedures were references as appropriate. In addition, it was important that the System Procedure was integrated along with the various multi-supplier component procedures into a single Field Service Manual (FSM). While sounding reasonable and logical, the actual coordinating of the documentation proved challenging, especially with Revision Control. Also, while not imperative, a consistent format and look-and-feel was desired but elusive. A noticeable improvement in the final issue of the FSM for Phase C was obtained, and the distribution on CD-ROM helped manage the flood of paper and updates. However, conflicting format and arrangement standards between European and American FSM's are impeding the progress toward more standardized and user-friendly documentation.

Integrating the Equipment and Procedures required detailed planning, and several planning meetings were held at the subsystem level. However, the Customer recognized a need for a high-level systems review. In March 1999, about 3 months prior to the first tree installations, such a meeting was held in Houston. Representatives from the Customers various operating groups and disciplines were in attendance, as well as project personnel from every subcontractor. Over three days, the complete installation program was reviewed, resulting in the identification of several issues and actions. This activity was crucial in any such complex tree installation program.

Installation Process – Components

An outline of the tree equipment installation process is as follows:

A) Tree Pre-Installation Operations

Wells are drilled and Rig is moored over the drill center with skid access to each well location. The wellheads are bare (no guide frame), with a corrosion cap and wear bushing installed. Standard practice is to raise and lower open water components off-center from the well for protection. The Tree Installation/Workover Control (IWOCS) umbilical is deployed through the moon pool on a dedicated downline. The IWOCS umbilical is terminated in an umbilical termination assembly (UTA), consisting of a Mudmat and Hydraulic flying lead. A separate umbilical and UTA for the tree SCM electrical supply is also deployed. This arrangement, via the flying leads, allows for the IWOCS connection to multiple trees during one deployment. The trees run much faster on drill pipe without having to attach and detach the umbilicals for each tree trip. The trees were run funnel down with no guideline support. Guideposts were installed on the first tree only.

B) Run Tree (Figure 5)

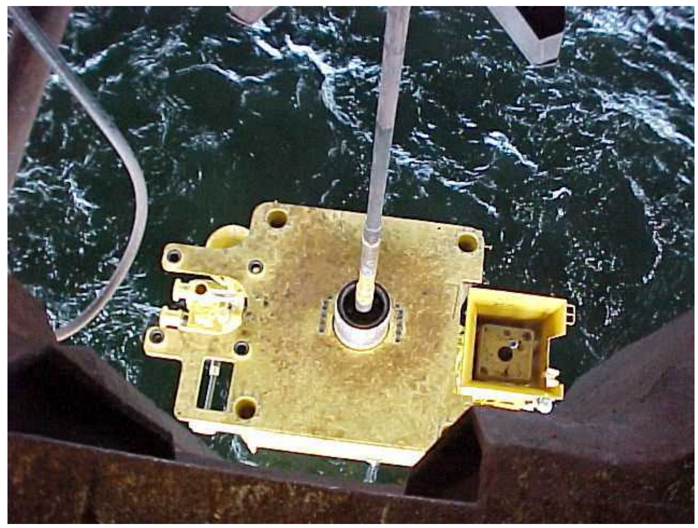

Figure 5

- Skid Tree to Spider Beams (tree sat on top of beams and no special hang-off provisions were required).
- Perform final tree configuration check.
- Lower Tree Running Tool (TRT) through the rotary on drill pipe and make-up to the tree with 5 LH turns. (DATAPOINT: <u>number of turns</u>)
- Pick up tree, retract spider beams and lower to seabed. (DATPOINT: <u>hook weight</u>)
- Position tree over wellhead, establish correct orientation (ROV visual), land and confirm full down. (DATAPOINT: <u>set down weight, tree heading</u>)
- ROV Attach IWOCS control leads.
- Lock tree connector, over-pull, and pressure test VX gasket. (DATAPOINT: <u>hook load</u>)
- Unlatch TRT with 5 RH turns, retrieve TRT and drill pipe. (DATAPOINT: <u>number of turns</u>)
- Run debris cap on down line and install on tree mandrel with ROV assist (off-line operation).
- Disconnect IWOCS leads (off-line operation).
- Skid Rig to adjacent well (parallel operation with next tree set-up operation).
- Repeat batch operation for next tree.

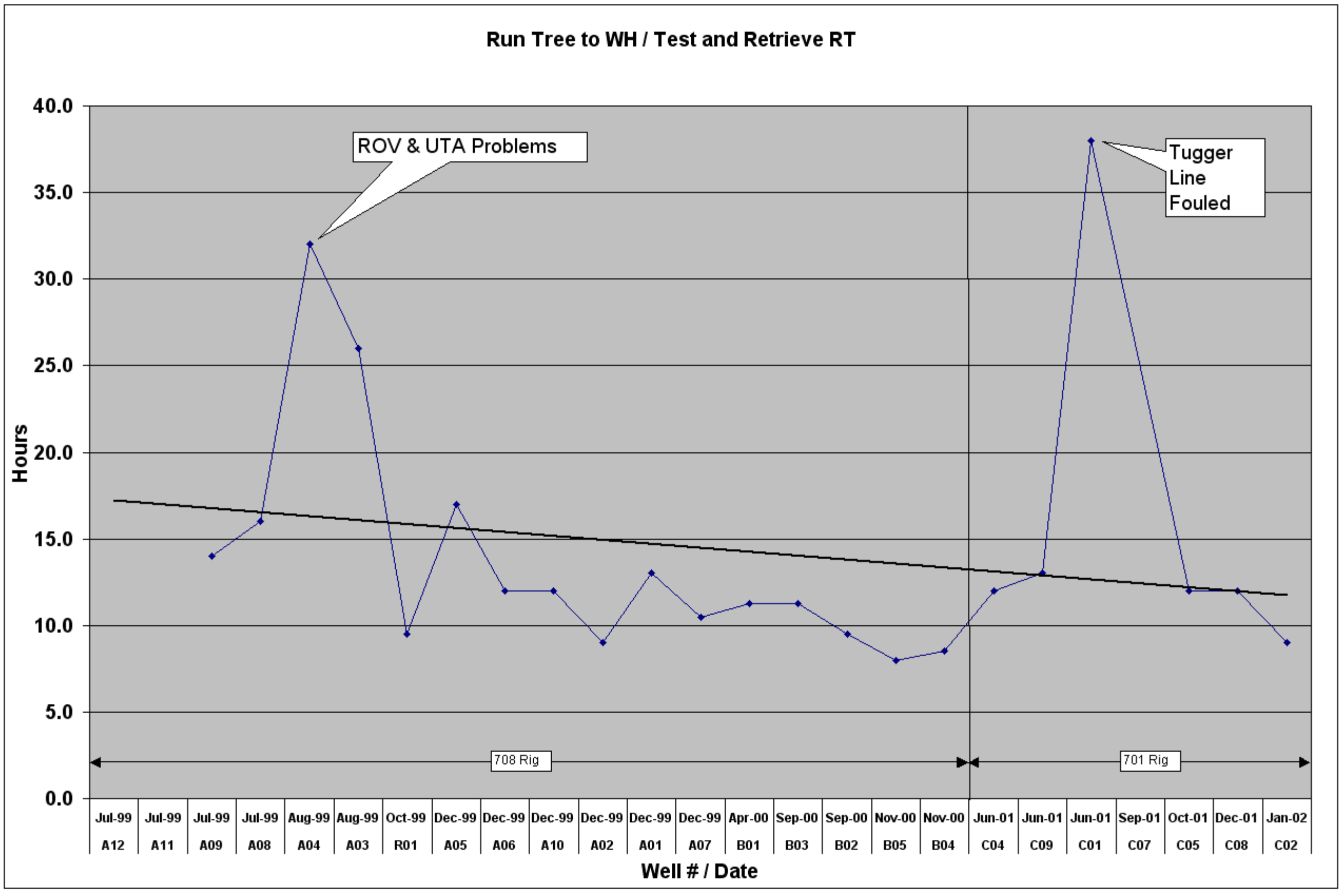

Figure 6

The tree installation process was extremely efficient, averaging 14.5 hours for 22 data points and, trending from 17.5 hours to 12 hours over the scope of the project. Complications occurred on two trees, the major problem being fouling and loss of the tugger cable. See figure 6 for a graph of the tree installation times.

The main lesson-learned on this operation was in the development of a comprehensive tree "pre-splash" checklist. Despite experienced service technicians, the complexity of the tree functionality mandated a formal check-off to ensure the required tree status.

A second lesson was in the dependence of the ROV for the tree installation process. A full back-up ROV system was deployed for the program, and this proved to be of great value. Besides avoiding rig down time due to ROV problems, the second ROV reduced cycle time by allowing multiple tool set-ups and alternating the ROV's on sequential operations. Another value of the second ROV was in using two lines of sight to more quickly position the rig and subsea package over the intended landing point. Finally, the ROV cages were fitted with 300 meter tethers, which allowed access to the entire drill center, with the rig at any coordinate position.

C) Completion Pre-Installation Operations

Guidelines were established with remote connectors onto the tree guideposts of the first tree. The BOP and Marine Riser were then deployed for batch completion operations. While the BOP was being lowered, the tree debris cap was removed with a down line by ROV assist, and a new VX gasket was placed on the wellhead. After completion operations on a given well, the BOP was unlatched and pulled off the tree. The ROV then unlatched the guideposts from this tree, and the posts are retracted into their respective BOP funnels. Upon positioning the BOP over the next tree, the guideposts are extended, and the ROV guides them into the tree frame receptacles and activates the latches to hold them down. After the guidelines are tensioned, the BOP is landed and locked onto the tree.

D) Completion Operations – BOP test and Wear Bushing retrieval.

- Run BOP Plug Type Test Tool on drill pipe; land out on tree Wear Bushing.
- Test BOP. Retrieve BOP Test Tool.
- Run Wear Bushing Retrieval Tool on drill pipe. Land in Wear Bushing and turn ¼ LH
- Equalize pressure across Wear Bushing and over-pull to free the Wear Bushing (DATAPOINT: hook load).
- Retrieve Wear Bushing.

Since the day reports did not break out these operations individually, separate running times were not easily ascertained. Recommendations have been made to gather this data for future operations.

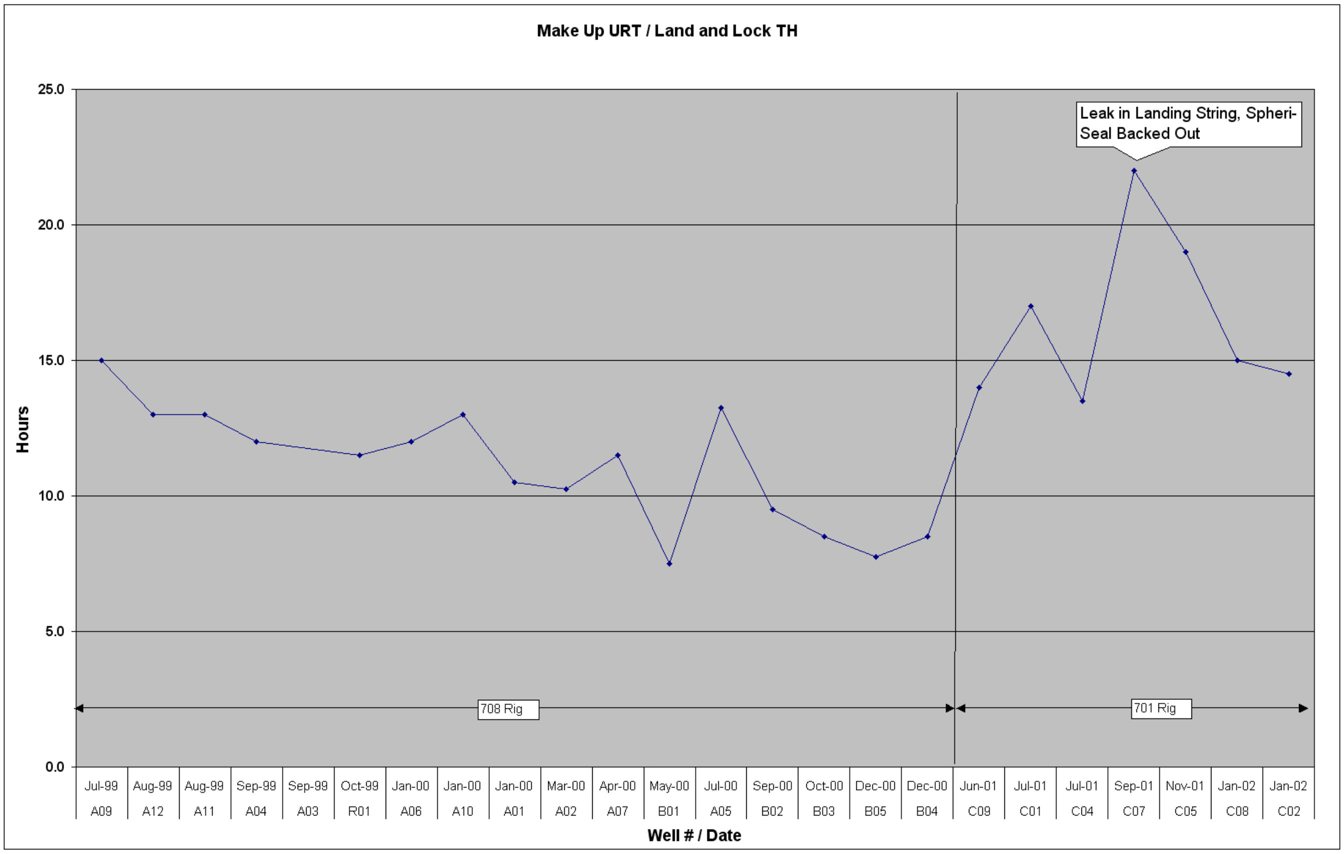

Figure 7

The main lesson-learned on this operation was that the wear bushing over-pull loads were higher than expected, as compared to field historical and factory test values. Another wear bushing problem was that the Elastomeric detent ring was shearing, leaving debris in the hole. A design change has been proposed to address both of these issues, and is currently being evaluated for incorporation into the existing wear bushing and wear bushing running tool inventory.

E) Tubing Hanger Installation

Note: The tubing hanger installation starts when the tubing hanger is attached to the tubing string and downhole control lines, and suspended in the rotary table. The straddle sleeve is pre-installed in the tubing hanger. The tubing hanger running tool (URT) and subsea test tree (SSTT) are stood back in the derrick with the umbilical connected and ready to attach to the tubing hanger. The landing string is 7" T&C liner casing, and an umbilical is also deployed strapped to the landing string for URT and SSTT control. The tree IWOCS umbilical is also attached to the tree prior to this operation.

- Pick up URT and SSTT and land on tubing hanger.
- Apply latch pressure and perform separation test.
- Pick up string weight, remove slips/split bushing and lower in hole.
- Just prior to land-out, confirm ball joint angle, flush tree SCSSV line, and note surface tree heading.
- Slowly land out and confirm tubing hanger rotation to correct orientation via the surface tree, observe pressure spike on SCSSV line.
- Lock tubing hanger, over-pull, perform seal test, and pressure test control seal gallery. (DATAPOINT: <u>hook load, pressure charts</u>)
- Test primary tubing hanger annulus seals. (DATAPOINT: <u>pressure charts</u>)
- Test downhole hydraulic control penetrations. (DATAPOINT: <u>pressure charts</u>)
- ROV actuate the DHPT downhole electrical connector and test. (DATAPOINT: <u>torque and turns, Pod reading</u>)

This operation averaged 13.4 hours of rig time. See Figure 7 for a detailed graph of the times.
Problems encountered during this operation were few but significant. On two hangers, the DHPT failed to make electrical contact. One Tubing Hanger lost a gallery seal at installation, causing subsequent problems landing the ITC. The root cause of both of these problems is still unknown.

F) Retrieve Straddle Sleeve, Install Lower Crown Plug, and Retrieve URT

Note: for typical operations, an internal bore protector is run after the straddle sleeve is retrieved, to protect the crown plug seal area during downhole wireline and coiled tubing operations. As the field did not require these operations, a bore protector was not run.

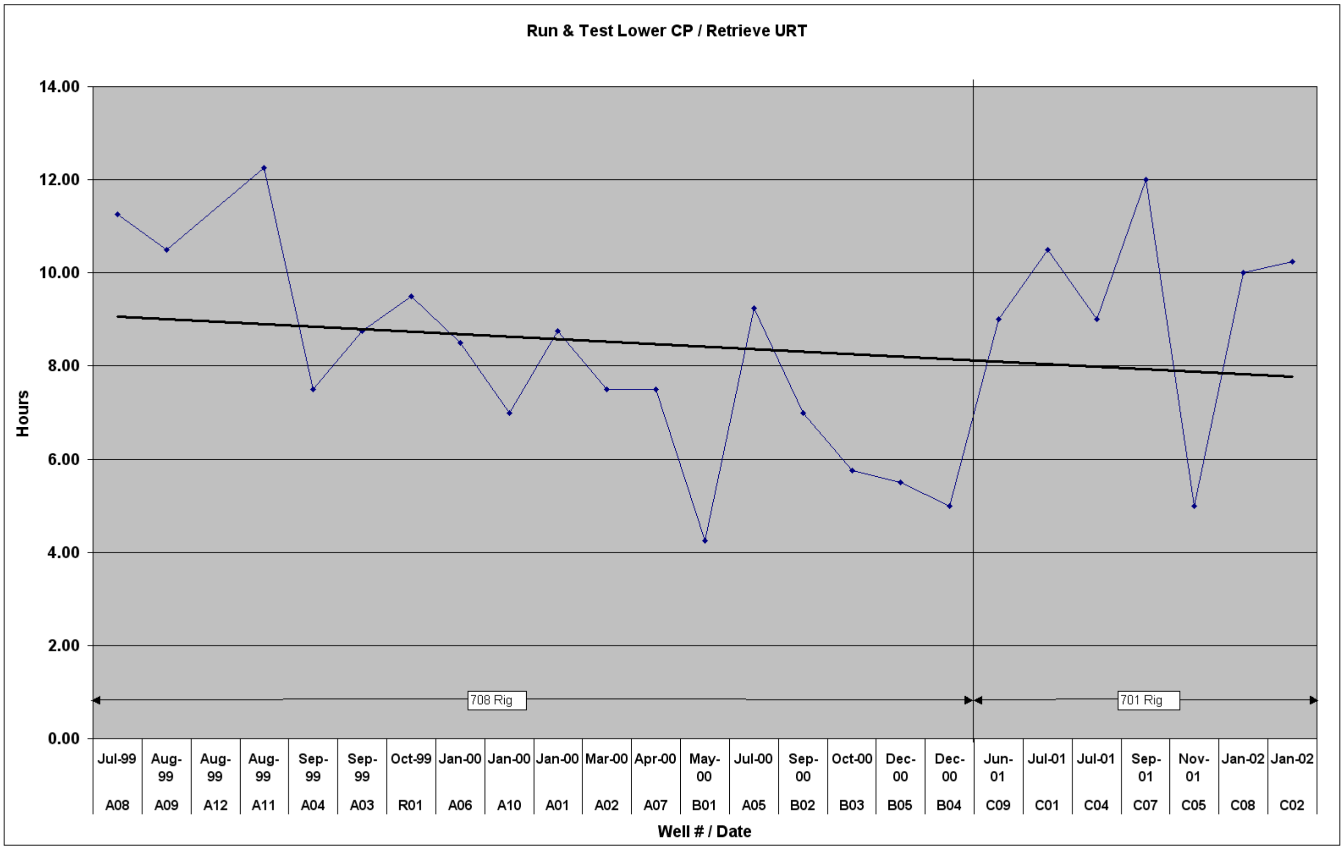

Figure 8

- Run Straddle sleeve retrieval tool on wireline. Jar to lock to straddle sleeve. Pull to retrieve.
- Run Lower Crown Plug on wireline with crown plug running tool (CPRT).
- After land-out, apply 2000 psi on top of plug to set metal seal.
- Jar to lock and release from Crown Plug.
- Pressure test to maximum working pressure on top of the crown plug.
- Retrieve CPRT on wireline.
- Ensure riser bore and URT gallery is vented.
- Confirm acceptable ball joint angle.
- Unlatch URT from tubing hanger.
- Slowly disconnect URT and retrieve landing string.

This operation averaged 8.43 hours of rig time. See Figure 8 for a detailed graph of the times.

Problems encountered during this operation were again very few but significant. On one Crown Plug, the unit became disengaged from the tubing hanger at some point prior to ITC installation, thus causing significant problems when attempting to install the ITC. These problems resulted in damage to the tree bore, and thus required a tree retrieval and repair. Fortunately, there were new trees coming behind with which to fill the gap. The root cause of this failure was not determined.

G) Install Internal Tree Cap (ITC)

Note: The ITC was set up with a factory installed upper Crown Plug on the Production wells. The Injection wells had a solid ITC. A separate URT was made up to a drill pipe slick joint and this assembly was installed on drill pipe and umbilical, just after the URT and SSTT were retrieved from the previous operation.

- Pick up ITC/URT/Slick Joint and set in slips in rotary table, perform separation test.
- Run in hole with drill pipe.
- Land, lock and perform over-pull test (DATAPOINT: hook load)
- Test below ITC to maximum working pressure. (DATAPOINT: pressure chart)
- Unlatch URT and pull drill pipe out of hole.

This operation averaged 8.88 hours of rig time. See Figure 9 for a detailed graph of the times. As noted in step F), one tree cap trip took a considerable amount of time due to the crown plug displacement. The use of a down hole bore camera assisted in the diagnostics of this problem, although it was sensitive to the cleanliness of the bore fluid. Another ITC was not successfully installed due to damage to the locking dogs during installation.

A successful ITC trip required a clean marine riser and BOP bore to prevent debris build-up on top of the tubing hanger. Because of these batch completion operations, it was relatively easy to maintain a clean bore because the drilling operations were conducted in a prior batch operation.

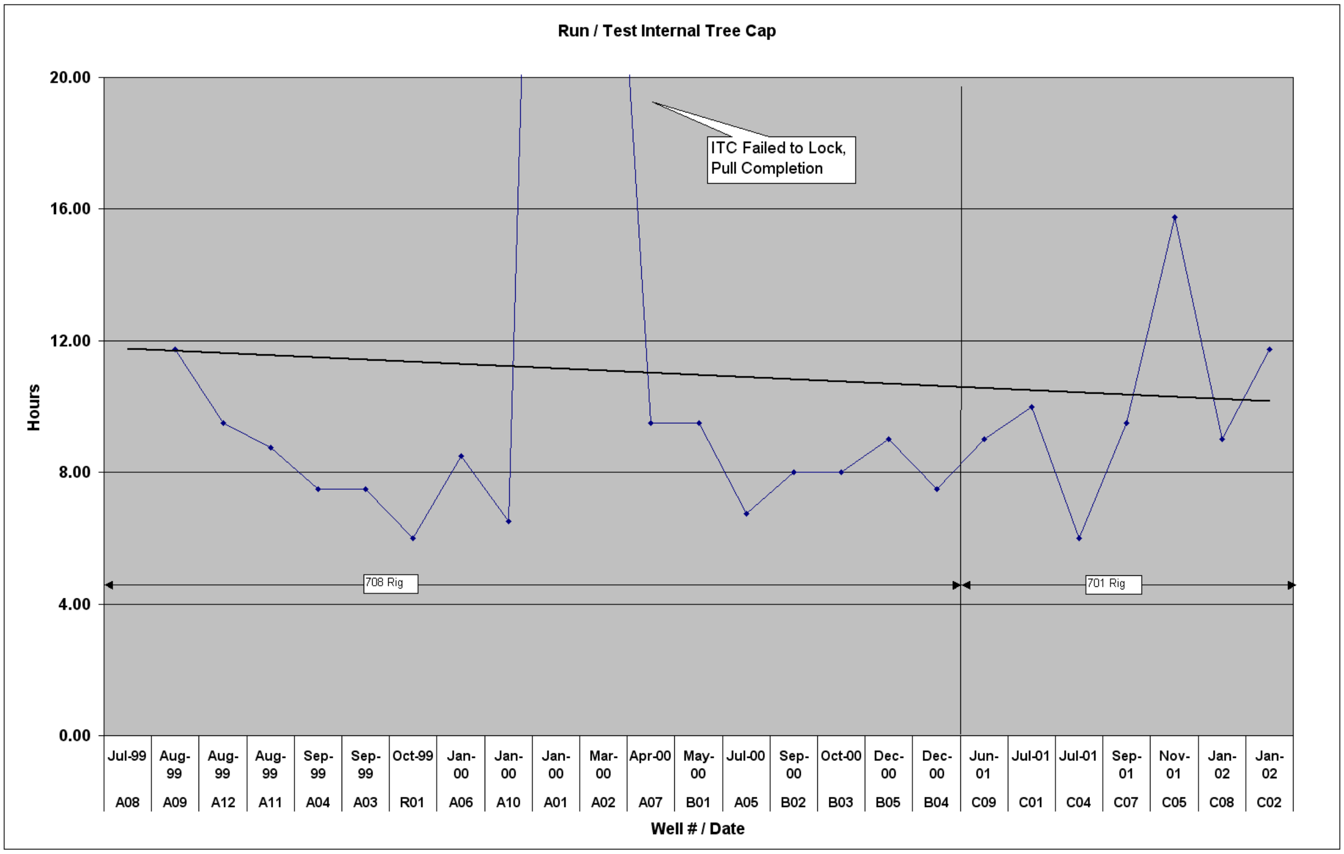

Figure 9

After ITC installation and testing, the BOP can be disconnected and moved to an adjacent well to repeat the completion batch process. A debris cap is installed on downline with ROV assist as an off-line operation. The ROV also applies corrosion inhibition fluid under the debris cap to protect the tree bore and ITC.

Installation Results

The combined times for all of the above operations was 1340 hours or 55.83 days. Averaged across the 28 trees, yielded a per tree installation time of 48 hours (2 days).

As can be seen from the installation graphs and as expected, there was a general improvement in cycle time over the installation sequence. One consistent change in the installation times was identified as related to the change of Drilling Rigs. Although being sister rigs helped, there was a general relearning process for the new crew. Other complications were a different BOP (required slight frame modifications), and a different C center tree heading relative to the drilling rig required heading. Aside from the specific problems noted above, there was no apparent affect on the cycle times related to:

- The personnel rotation
- The weather
- The time of the year
- The Project Phase

However, while the information taken from the formal day reports was concise and correct, there was not enough detail to perform formal statistical tests.

Lessons Learned

A well-known oil-field phrase is “the devil is in the details”. In remote locations, logistical issues become as important as the equipment and technology. Precise procedures, contingency plans, and the use of proven components will enhance successful logistics.

While hard to support through the data, the operational efficiency is obviously a function of the effectiveness of the field personnel. Again, given the remote location and expansiveness of the equipment, it is hard not to underestimate the personnel requirements. Good thorough procedures and other reference documentation will considerably reduce this burden, but not fully eliminate it.

Having computers with e-mail on the rig for the Service Supervisors was a tremendous communication tool. In some cases both Houston and Aberdeen were able to tag-team problems and provide around-the-clock support.

The formal day reports were adequate, but lacking in some key information. As is customary, field service personnel keep more detailed records in their tally books, from which the formal reports are created. Each technician keeps his or her tally books, but the data within is difficult to access across an entire project.

Design interchangeability between Production and Water Injection Tree types proved a cost-effective method to maximize back-up equipment coverage. An injection tree was converted in Country to a production tree, which was damaged during installation. The production tree was factory repaired and converted back to an injection tree. This process avoided costly rig delays. The field conversion of the tree also was made possible by the simple and robust design of the tree components.

A suite of contingency tools is necessary insurance to facilitate unexpected problems encountered during the installation process. These tools include, mill tools, wash tools, gauge tools, and emergency recovery tools.

Spare parts are needed with the base equipment delivery. While there was good focus and performance on the tree deliveries, the spare parts came behind, causing some anxiety.

The procedures were revised as changes became evident, and this reflected positively on the decreasing installation times. Major revisions included:

- Adding more information for contingency operations.
- Adding more technical data.
- New Tree Pre-Submergence Check list
- New Tree datasheet for FPSO hand over purposes

The under abundance of installation data points is not important, until a problem arises and results in root cause analysis to be difficult. Root causes to several of the noted problems were never fully identified. The lack of installation data also prevents the collection and analysis of reliability data.

A careful trade-off is required when evaluating design changes during the course of equipment supply. A balance is required to ensure problems are corrected and necessary enhancements are made while ensuring the supply chain is efficiently making their delivery commitments. While the basic tree component design was satisfactory, several minor design enhancements were incorporated, primarily at the ROV and other interface areas. Design changes of note include:

- Hot Stab lanyard – increase length and strength for improved ROV handling.
- Guidepost Release – change from removable pin to ¼-turn handle to increase ROV efficiency.
- Small bore Valve Visual Indicators – improve ROV visibility.
- ROV Handles – reposition and increase quantity.
- Cut-and-Crimp lines – reposition to avoid mistaking for ROV grab handles.
- Tree handling Slings – shorten for use in cellar deck
- Debris Cap bale – increase size to accommodate ROV hook access.
- Debris Cap Hot Stab – extend handle to prevent manipulator fouling.
- Tree reentry Funnel – increase angle to accommodate interface with VX gasket on wellhead.
- Shipping Skid – change pedestal from welded to bolted, to facilitate return shipping.
- Choke – add shipping protective cover.
- Choke – down stop added to prevent over travel due to trim damage.

Conclusions and Recommendations

General

By any standard, the project as a whole can be deemed a resounding success, both technically and commercially. All of this was accomplished despite the cycle time constraints and remote location. Of more importance, an outstanding Project HSE record was achieved, with only one LTA (Lost Time Accident) recorded on the operations described in this paper.

The primary cause of this success was in the quality and commitment of the operations personnel involved in the deployment of the HT equipment. These people represented several different companies and interests, however acted as an integrated team with common goals and objectives. Perfection in the Equipment and Procedures will not alleviate the need for this level of commitment.

Equipment

The HT and associated equipment proved fit for purpose for the Project application. The use of proven and standardized equipment both facilitated the quick delivery requirement, and provided the overall reliability required for this remote region.

While fit for purpose, several small enhancements and upgrades were identified, but not incorporated due to the delivery cycle requirements. On future deployments, especially in large quantities, it is recommended that incorporating these upgrades will more than pay for themselves.

Procedures and Reports

Standard procedures were available and were utilized for this project. While proven and generally error-free, they were lacking in contingency information and ancillary data. Installation reporting was accurate, however the formal documentation was brief. The incorporation of a Web-based service reporting system is recommended for these complex project tree installation programs. A description of one such system follows.

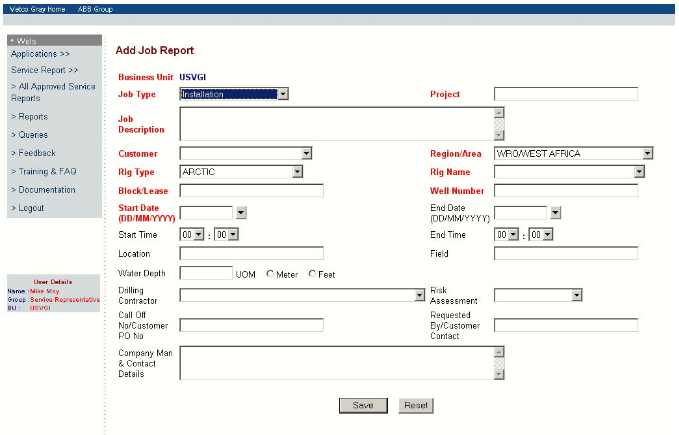

Figure 10 – WELS Screen Shot

WELS (Well Electronic Log System)

During the middle of the Project tree installation program, the WELS program was introduced to the Field Service Organization. See Figure 10 for a screen shot. As of this date, several Horizontal tree installations have been recorded into WELS, and the complete Project Installation database is being back-loaded into WELS. As part of this analysis, the original WELS program was compared against the Project field data for compatibility, and revisions were made to facilitate this particular Product Line.

WELS is basically a Web-based electronic Service Ticket, which can be generated directly on the rig using a laptop computer and modem. Besides generating the basic data required for invoicing purposes, it includes fields for job summaries, problem reports, and field conditions. Because it needs Service Technician names, Rig names, and Customer information, the data can be sorted by these attributes to identify trends and issues.

A powerful addition to WELS is the incorporation of a procedure database, engineering bulletins, rental tool inventory, and other technical utility data. This gives the Service Technician access to his companies' entire service database, all at the latest revision.

One of the most important aspects of the WELS report is in the standardized method of reporting data. The report fields are arranged by Trips in the hole, where a time stamp records the trip durations and the running string type and tool part numbers are recorded. Serial numbers are also recorded to facilitate maintenance programs. Besides efficient reporting of the obvious problems, this format also enables collection of reliability statistical data such as defects per million opportunities (DPMO).

The primary WELS revision identified by this exercise was including the ability to address complex installation programs typical to a multi-well subsea tree project. This included the ability to identify multiple technicians, technician change-outs mid-trip, recording of off-trip activities (tree testing, ROV operations, etc.), and the attachment of special project files such as checklists. Finally and most importantly, the ability to record Lessons-Learned, including near miss and other HSE related issues is paramount to such a Field Service Reporting System.

Acknowledgements

The Authors would like to thank the field support personnel who were responsible for the installation of this equipment and the reporting of the field data.

Metric Conversion Factors

Meters	= Feet x 0.3048
Kilograms	= Pounds / 2.204
Bar	= PSI / 14.696