Petronas Carigali Sdn. Bhd operates 13 oil and gas fields in the South China Sea, located offshore the Malaysian state of Terengganu in water depths from 65 to 80 m. The area has more than 30 platforms, most with small deck space areas and crane lifting capacity of only 5 t.

The fields began to experience increased sand production, high water cut and larger skin factor. Well interventions and treatments such as matrix stimulation, water shut-off and sand cleanout were required to sustain production rates. CT well intervention is the most effective method to perform the required treatments; however, when platform space is limited, it is often not practical to accommodate the required facilities onboard. In addition, crane capacity may be inadequate to safely handle the CT equipment. A solution is to deploy a minimal amount of equipment on the platform deck and use a suitable vessel to perform heavy lifting and other support for the CT operations.

Mohd Hairi Abd Razak and Fuad Mohd Noordin, Petronas, Malaysia, and Mohd Nur Afendy and Rahmat Wibisono, Schlumberger, Yemen and Malaysia, present an example of the planning and execution of coil tubing (CT) operations on platforms too small to accommodate all the required equipment.
Pilot project

Petronas selected two small platforms for a pilot CT intervention project. Platforms in its Penara field are of a lightweight design featuring a cable-guyed caisson monotower (Tarpon) and a topside deck with minimum facilities. First oil from the field was in May 2004, and peak production reached 12 000 bpd. The selected platform had just 180 m² of main deck and its jib crane had a maximum capacity of 5 t.

The Malong field was completed in March 2000. The selected unmanned minimum-facilities platform was a lightweight optimised jacket structure that supports conductor slots for production and water injection wells and is suitable only for a jack-up drilling rig. The platform houses all the necessary production, well testing, water injection, pig launcher and gas lifting facilities, and is provided with a life support system. It has 650 m² of main deck, but taking into account all the fixed surface facilities, the operations area is insufficient for conventional CT operations. In addition, the jib crane has a 5 t capacity, sufficient only for lightweight wireline equipment.

CT support vessel evaluation

Petronas performed a detailed analysis to determine the type of vessel that would meet the technical requirements and be most cost-effective in supporting CT operations at the selected platforms. Three options were considered: lift boat, work boat, and work barge. The evaluation was based on completing the CT pilot project within three months, chartering the vessel on a spot basis rather than a long term contract.

A lift boat is a self-propelled, self-elevating vessel with a relatively large open deck. Like a jackup rig, it is capable of raising its hull clear of the water on its own legs. This feature means that it does not require an anchor pattern for stability and to maintain a safe distance from the platform. This saves the cost of an anchor tug handling supply (ATHS) vessel and avoids the risk of anchors damaging seabed equipment if dragged by tides or currents. A disadvantage of the jackup system is the necessity to conduct a soil investigation prior to installation.

Work boats are commonly deployed to assist CT operations in East Malaysia, and Petronas often uses them for workover operations. This option would require installation of an anchor pattern.

Work barges with the same specifications as work boats were available at lower daily charter rate (DCR) and shorter waiting times. Costs for the planned three month project were evaluated for each of the three technical options. These included ATHS vessel costs for the work boats and barges, crane costs if quoted separately from the DCR, fuel, manning and bunkering. The lift boat was the most expensive option. Due to lower DCR and faster availability, the work barge was the most cost-effective option for the project that met the essential technical and timing requirements.

Work barge assessment

Throughout the operations, only the coil tubing injector head, jacking frame and CT control cabin would be erected on the platform while the remaining equipment would stay on the barge. It was determined that the barge must have a minimum 500 m² deck space without a crane, or 350 m² with a crawler crane installed. The heaviest equipment that required lifting to the platform was the 12 t injector head and CT blowout preventer (BOP) assembly, which required a crane capable of lifting 15 t at 60˚ boom angle for safe operations. A 150 t capacity crawler
crane with 150 ft (45.72 m) boom was considered adequate to meet the requirements while minimising the required deck space. The barge needed an eight point mooring system to provide improved stability and facilitate faster disconnect in the event of emergency. Accommodations required sufficient workspace for at least 80 personnel.

**Flowback handling system assessment**

The Penara work programme required a system to separate sand from the return fluid. A sand filter system and a cyclone sand separator were considered. Sands produced in Penara have fine (10 - 40 micron) grain size. Filter systems cannot separate such fine sand and were not a viable option; however, a centrifugal cyclone system would be able to handle them effectively. The sand separator was hooked directly into the well, so the platform shutdown system and surface safety valve (SSV) had to be bypassed. To enable the flowback handling system to override the existing emergency shutdown device (ESD) and SSV, a dedicated SSV in the return line and separate ESD control panel were required.

To improve cleanup efficiency, water-based gelling fluid was used to raise the viscosity of the injected fluid. However, sand separation is more efficient with low viscosity fluids, requiring a breaker solution to be injected before the separator, which is capable of destroying the polymer structure of the gel. Facilities were also required to store sand and liquid effluent.

**Health, safety, and environment (HSE) assessment**

The monsoon season in the South China Sea area is between October and March when there are often strong winds and swells in excess of 6 m. It is usual to avoid operating during this season; however, due to other commitments, the work barge was only available in February. The HSE assessment determined that operations should only start in less than 3 m swell and 20 knot winds. Weather forecasts were updated hourly to maximise the time available for crews to stop operations and perform the necessary steps to move away from the platform. A special device in the CT reel was deployed during the project to allow emergency disconnect and immediate pull-away from the platform if forecasts indicated dangerous conditions within 3 hours.

**Results: Penara Well 1**

Previous bullheading operations unsuccessfully removed wax from this wellbore, and another treatment to bullhead solvent also proved to be ineffective. A high pressure jetting tool was used to pump different solvent fluids, and was able to reach plug back total depth (PBTD). A final slickline gauge ring run indicated that the wax had been successfully removed, and the well had returned to oil production with encouraging results.

**Results: Penara Well 2**

Bailer runs in October 2007 became hung at 2073 m and upon retrieval to surface, the bailer recovered traces of sands. The CT intervention programme of this well required sand cleanout from hung-up depth to PBTD—an interval of approximately 935 m. Bipolymer gel was conveyed by a special nozzle. In the event of hard sediment that was not removed by this nozzle, acid could be conveyed by a high pressure jetting tool. The programme was executed as planned, with a CT rate of penetration between 1 - 3 ft/min. The separator worked effectively to capture produced sands from the wellbore. A small pill of acid had to be pumped to enable the CT to reach final cleanout depth. Rough weather led to one emergency disconnect, in which planned procedures were successfully implemented.

**Results: Malong Well**

The production and intervention history of this well indicated that it required water shutoff treatment to block water production from the lower reservoir; however, leaks in the completion tubing complicated these operations. The only way to effectively squeeze water shutoff chemical was by conveying it with a CT multi-set mechanical packer. After setting the packer, the leak could be isolated, enabling the chemical to be squeezed into the lower operation.
CT operations in this well proved unsuccessful. Prior to reaching target depth, a sequence packer activation procedure was performed to test its functionality and integrity. The setting sequence showed that pressure was holding during injection; however, the unsetting sequence showed that the packer could not be released from its position. High pulling force and multiple packer manipulation were attempted, but after two days of trying, it was decided to release from the packer by activating an emergency disconnecting tool. The upper portion of the disconnecting tool was retrieved to surface. Subsequent attempts to fish the packer were unsuccessful, and it remains in the hole.

**Conclusions**

This case study confirms that CT operations can be cost-effectively performed with the support of a work barge on platforms that cannot accommodate all of the necessary equipment. Thorough planning is required to ensure that the technical requirements of multiple types of CT intervention can be effectively delivered and that operations can proceed safely in potentially adverse conditions.