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Safety In Light Workover Subsea BOP Operations

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When testing is either impossible or too expensive, prevention is twice as important. The seabed is such an environment, and going off track is potentially disastrous.

As water depth of new oilfield discoveries increased and Dynamic Positioning (DP) systems became safer and more precise, oil well drilling, completion and workover relied increasingly on DP oilrigs. Even with many advantages, well disconnection in case of an emergency became an issue, and that demanded a new solution. Both drilling and completion BOP systems were added a disconnection package, as well as means to remotely shut the well.

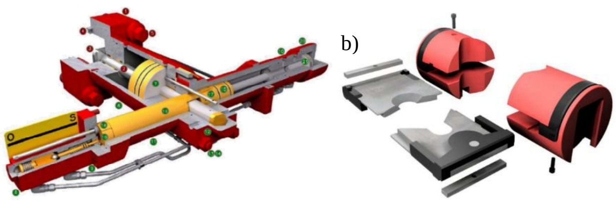
a) 

Fig. 1. (a) Shear Ram actuator; (b) Shear Ram. Courtesy of TOT.

Completion systems have faced increasing challenges as water depth has increased, as they rely on nitrogen pre-charged accumulators to provide energy for shear ram closure and disconnection, which is a very reliable system once correctly designed and primed. Despite over 30 years of a positive track record, gaps were found in accumulator sizing, often underestimated and unable to cope with an emergency.

Such finding demanded a careful investigation, once it was hindered by simpler mechanic faults, such as inoperative position indicators or punctured bladders. Accumulator bank sizing has so far been designed according to OEM method of choice, as API Spec 17G does not refer to API Spec 16D, which defines sizing method for different equipment layouts. In PETROBRAS' experience that opened up space to undersize the accumulator bank in different degrees, to the point of limiting operational envelope to half the nominal water depth and working pressure.

Currently there are 18 different Workover BOP systems (WBOP) in service at PETROBRAS, designed under different requirements over 30 years of deepwater experience. Both industry standards and in-house specifications have evolved over time, especially considering the increasing water depth, from ~300m to current ~2300m. Therefore, quite different systems had to be evaluated to verify whether operating envelope corresponded to the nominal capacity or define the actual operating envelope.

As a reliable calculation method was available, an implementation was developed and tested by comparison with field data log. A complete list of characteristics was supplied by each OEM so that different WBOP could be modeled. The operating envelope could then be defined for each system, allowing the assessment of the operation safety during planning stage, thus identifying light workover programs that would be outside of operating envelope and preventing unsafe conditions. Expected test results could also be determined with an accuracy of 3% to 5% of absolute pressure.

Table 1. Gas state calculation method.

#	Step	Constant	Variable	NIST
1	Deck setup, nitrogen only	Temperature	Pressure (given), density, entropy	Isothermal
2	Descent into seabed	Density	Temperature (given), entropy, pressure	Isochoric
3	Seabed accumulator charge	Temperature	Pressure (given), density, entropy	Isothermal
4	Quick discharge	Entropy	Density (given), temperature, pressure	(interpolation)
5	Stabilization	Density	Temperature (given), entropy, pressure	Isothermal

Defining the gas state during quick discharge is possible by evaluating S(T, rho) and S(P, T). This data is not readily available from NIST database, so two interpolated tables were elaborated to provide such information automatically.

After close examination of API Spec 16D, additional safety features were identified for evaluation of current WBOP in service. Some features like deadman, for example, were already fitted to most systems, but not all. For example, the availability of accumulator ROV charging port or ROV readable pressure gauge were not present on all systems. A comprehensive list of modifications was defined, as well as responsibility for resulting costs.

To fully address WBOP behavior and confirm proposed model, a hyperbaric chamber test was held during January 2024. The environment conditions were slightly different from those underwater: higher temperature (22°C vs 4°C) and volume constriction, which were evaluated and considered in the simulation. Detailed pressure info was collected and processed, and based on this, a model for gas reheat dynamic was proposed.

a) b)

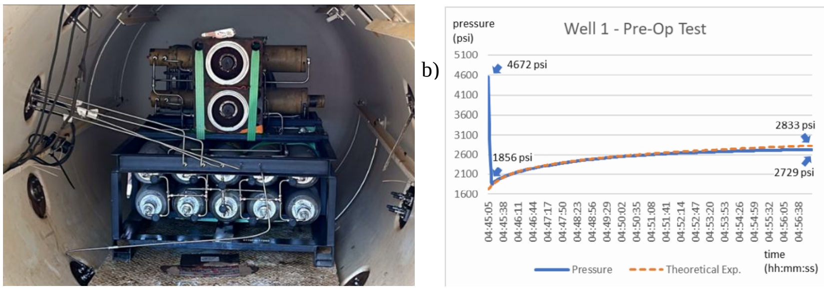


Fig. 2. (a) Test frame plumbed inside hyperbaric chamber; (b) Chart showing pressure data and proposed reheat dynamic curve.

This effort enabled PETROBRAS and suppliers to evaluate tool capabilities in detail, adjusting upgrades as required and possible for existing structures and systems. The authors hope this information can significantly contribute significantly to other oilfield operators' efforts to promote safer subsea operations, and enrich safety discussion with OEM, thus focusing effort on incident prevention.

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References

API, 2018. Control Systems for Drilling Well Control Equipment and Control Systems for Diverter Equipment (Spec 16D). API Publishing Services, Washington, DC.

API, 2019. Design and Manufacture of Subsea Well Intervention Equipment (Spec 17G). API Publishing Services, Washington, DC.

NASA, 1981. Simulation of Ideal-Gas Flow by Nitrogen and Other Selected Gases at Cryogenic Temperatures. Langley Research Center, Hampton, VA.

ORELL, 2020. Hydraulic Accumulator Dimensioning. ORELL Tec AG, Düdingen (Switzerland).