There were five minor leaks in the Deepwater Horizon BOP control system: three were identified after the BOP stack was latched to the wellhead in February 2010, and two were identified during the post-incident intervention by the remotely operated vehicle (ROV). None of these leaks caused or contributed to the April 20 incident, and they did not adversely impact the functionality or redundancy of the BOP control system to perform as designed in a well control event. The five leaks were as follows:

**Identified Pre-Incident**
- Leak on the open-side function of the test ram BOP
- Leak on accumulator surge bottle on the upper annular BOP
- Leak on the lower annular BOP close function

**Identified Post-Incident**
- Leak on a hose fitting to the lock function on the ST Lock circuit
- Leak on blind shear ram ST Lock sequence valve to ST Lock chamber

The leaks were small in volume and, in some cases, regardless of volume, they would not have adversely impacted the closure of the well-control components. Functioning of the well-control components relied on the hydraulic supply from the rig via a hydraulic conduit line, and from surface and subsea accumulator storage bottles. Low-volume leaks did not impede functionality because any fluid lost was recharged by the rigid conduit line being supplied by the Cameron Surface Control System, which included 45 40-gallon accumulators that were continuously replenished to a stored pressure of 5,000 psi. In the event the hydraulic conduit line was severed or destroyed, eight 80-gallon accumulator bottles on the BOP stack would have fed hydraulic fluid to function the BOP.

Importantly, the ST Lock circuit leak on the blind shear ram sequence valve to ST Lock lock chamber confirms that the blind shear ram functioned. The blind shear ram BOP must be approximately 90% closed for the sequence valve to open and allow fluid to pass through to the ST Lock locking chamber. Thus, the presence of a leak on the lock system of the ST Lock circuit confirmed that the blind shear ram on this bonnet was activated and closed at least 90%.

**Test Ram Open-Side Function**

The test ram was the lowermost ram and was used during function and pressure testing of the BOP stack. It was not used during well control and would not have had any impact on the incident.

The Transocean subsea team reported the small volume test ram leak to BP as reflected in the Feb. 23, 2010, BP operations report. This report identified a leak on the yellow pod, and the rig crew switched to the blue pod to allow further investigation. The leak was confirmed to be on the open circuit to the test ram, and the leak was isolated by placing the test ram open circuit in the neutral, or “vent,” position. See Figure 1.

**Upper Annular Close Circuit**

On Feb. 19, 2010, a Transocean senior subsea supervisor identified a leak in the upper annular close circuit. During the post-incident intervention, the upper annular close circuit leak was identified on the hose fitting that connects the 10-gallon accumulator surge bottle to the close function of the upper annular BOP. The leak was detectable but very small. At 1,500 psi, the leak rate was determined to be approximately 0.1 gallons per minute (gpm).

This leak would not have adversely affected the response time and sealing capability of the upper annular due to the large hydraulic supply that was continuously provided by the hydraulic conduit line being supplied by the Cameron Surface Control System that includes 45 40-gallon accumulators which were continuously replenished to a stored pressure of 5,000 psi.

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**Notes**

A. The BP investigation report identified a sixth possible leak but concluded that it would not have impacted performance. The Transocean investigation team does not agree that the evidence supports such a leak, but agrees that such a leak would not have impacted functionality.
Appendix K BOP Leaks

Leak on Lower Annular

The Deepwater Horizon BOP stack had two annular BOPs: an upper annular and a lower annular. Each annular serves as a back-up for the other. The upper annular was rated to 10,000 psi. In 2006, at the request of BP, the lower annular was outfitted with a stripping annular sealing element rated at 5,000 psi. This stripping annular sealing element allowed the stripping of large 6-5/8-in. tool joints while pressure was contained by the closed annular.

The Deepwater Horizon senior subsea engineer noted a lower annular close function leak, confirming, however, that it was very small and that the annular BOP would still close when needed. The flow rate of the leak was confirmed to be similar to the leak on the upper annular at 0.1 gpm. The leak appeared as a “tick,” or a brief flickering indication, on the hydraulic fluid flow gauge located on the BOP control panel. The flow indication appeared only when the lower annular preventer was in the closed position, and the Deepwater Horizon subsea team did not identify any fluid leaking externally from the system. This leak would not have adversely affected the response time and sealing capability of the lower annular due to the large hydraulic supply that was continuously provided by the hydraulic conduit line being supplied by the Deepwater Horizon Cameron Surface Control System, including 45 40-gallon accumulators that were continuously replenished to a stored pressure of 5,000 psi.

Lock Function on ST Lock Circuit

The ST Lock was hydraulically actuated and closed behind the tail rod of the ram operating piston to prevent the ram from opening even if close/lock pressure was lost. There were eight ST Locks on the Deepwater Horizon BOP stack, one lock on each side of the pressure containing rams. See Figure 1. A shuttle valve connected the eight ST Locks to their respective ram bonnets (one lock per bonnet). Each ram bonnet contained the operating piston and connecting rod used to activate the rams.

Figure 1 Leak in Sequence Valve Tubing on Shear Ram ST-Lock
Some of the specific firing and locking functions were plumbed (connected) together as a single function. In other words, whenever the remotely operated vehicle (ROV), automatic mode function (AMF) or auto-shear functions were fired on the pipe ram or shear ram circuits, the ST Lock locking function also was activated or pressurized.

During the post-incident response efforts, when the ROV functioned the pipe ram on the ROV intervention panel, a leak was noted on the lock function of the ST Lock circuit for the BOPs. The intervention team used an ROV to re-tighten the hose fitting to correct this leak.

Based on the ROV video, this leak was small and would not have prevented actuation of the pipe or shear rams. This leak in the ST Lock circuit would not have reduced the available hydraulic power provided by the BOP stack accumulators enough to prevent the blind shear rams from shearing the drill pipe and sealing the wellbore. Actuation of the AMF or auto-shear emergency modes would have properly operated the blind shear rams.

**Blind Shear Ram ST Lock Sequence Valve to ST Lock Chamber**

A leak in the tubing connection that runs from the blind shear ram ST Lock sequence valve to the ST Lock chamber was identified on April 26, 2010, at 7:15 a.m. The BOP ram must be approximately 90% closed for the ST Lock sequence valve to open, allowing fluid to pass through to the ST Lock locking function, creating the conditions for a leak in this location. The existence of this leak confirms that the shear ram on this bonnet was closed. Further, based on the ROV video, this leak was small and would not have prevented the ST Lock function from operating.

2. WEST Engineering Services, Accumulator Sizing Calculations, *Deepwater Horizon*, Feb. 11, 2011, Figure 2.


6. Owen McWhorter e-mail to James Kent, June 25, 2010.


19. Boa Sub C Log, April 25, 2010 at 8:16 p.m.

20. Boa Sub C Log, April 26, 2010 between 12:02 a.m. and 3:48 a.m.


22. Boa Sub C Log, April 26, 2010 at 7:15 a.m.