Press Association

Last month's report by BP into the causes of its Gulf rig explosion and fire, and the lessons to be learned, points to a chilling sequence of failures. Brian Tinham reports

Deepwater

Halliburton, Transocean and others should shoulder responsibility, alongside BP, for the Deepwater Horizon explosion and fire that killed 11, injured 17 and caused the US's biggest ever oil spill earlier this year. That's one of the key, and perhaps unsurprising, findings of BP's report into the disaster – immediately, and just as unsurprisingly, described by rig owner Transocean as self-serving. Its other key conclusion is that no single factor caused the Macondo well tragedy: instead, a sequence of failures involving several parties and their engineering and training was to blame.

The report is thorough – based on a four-month investigation led by Mark Bly, BP's head of safety and operations, and conducted by a team of 50 technical and other specialists drawn from inside BP and elsewhere, independent of BP's emergency response effort. BP cites disciplines including safety, operations, subsea, drilling, well control, cementing, fluid flow modelling, blow-out preventer (BOP) systems and hazard analysis.

That team states that the accident arose from "a complex and interlinked series of mechanical failures, human judgments, engineering design, operational implementation and team interfaces". Amplifying that, it starts by observing the obvious – that the accident involved a well integrity failure, followed by loss of hydrostatic control of the well. "This was followed by a failure to control the flow from the well with the BOP equipment, which allowed the release and subsequent ignition of hydrocarbons. Ultimately, the BOP emergency functions failed to seal the well after the initial explosions."

BP cites critical failures as starting with the cement and shoe track barriers at the bottom of the well – and in particular the cement slurry used by Halliburton. These, says the firm, failed to contain explosive gases within the reservoir, and so allowed gas and liquids to flow up the production casing.

The report states that the day before the accident, "cement had been pumped down the production casing and up into the wellbore annulus to prevent hydrocarbons from entering the wellbore from the reservoir". BP concludes that the light, nitrified foam cement used "probably experienced nitrogen breakout and migration", allowing the unthinkable to happen. The company suggests that there were weaknesses in the cement design and testing, QA and risk assessment.

But it also believes that, having entered the wellbore annulus, gases passed down the wellbore before entering the production casing through the shoe track, installed at the bottom of the casing, rather than the casing annulus. For that to happen, both the cement in the shoe track and the float collar at the top of the shoe track must have failed.

BP insists that failure mode analysis indicates this as much more likely than a rupture of the production casing itself or flow up the wellbore annulus and in through the casing hanger seal assembly. It also draws upon data concerning "shut-in pressures, wellhead pressures, pump pressures, rates, volumes and possible flow paths in the wellbore", taken during the recent successful 'static kill' sequence, which, it says, indicate that the heavy drilling mud went down the inside of the production casing and not its annulus.

BP next draws attention to the negative pressure test, aimed at verifying integrity of the mechanical barriers (shoe track, production casing and casing hanger seal assembly). In retrospect, it says, pressure readings and volume bled data "were indications of flow path communication with the reservoir", signifying that they were not gas-tight. BP suggests that both its own and Transocean's engineers "reached the incorrect view" that this test had been successful.

The report then concludes that when (as part of normal operations) the well was 'underbalanced' by replacing heavy drilling mud with seawater, gas would have flowed past the failed barriers and up through the production casing and the BOP, and into the riser. The investigation team cites real-time data over a 40-minute period before the crew took action, showing an increase in drill pipe pressure.

With gas rapidly flowing up to the surface, BP asserts that the crew's first actions were to close the BOP and diverter, routing the hydrocarbons to the rig's mud-gas separator, rather than the overboard diverter line – thus sealing its fate. As the separator was overwhelmed, gas would have been vented directly onto the rig via a 12 inch gooseneck vent and other flow lines (BP notes that the separator design allowed this flowpath, even though "the well

Incoming BP chief executive Bob Dudley: shared responsibility

Horizon

was in a high flow condition"). It would have migrated well beyond the electrically classified areas of the rig, with the HVAC system probably transferring a gas-rich mix into the engine room, causing at least one engine to overspeed and creating a potential for ignition – which the rig's fire and gas system failed to prevent.

Finally, BP observes that, after the explosion and fire had disabled its controls, the rig's blow-out preventer on the sea-bed should have sealed the well automatically. However, it, too, failed "probably because critical components were not working".

Potential weaknesses

The report states: "An examination of the BOP control pods, following the accident, revealed that there was a fault in a critical solenoid valve in [one] and that … batteries [in another] had insufficient charge." It also says that when, 33 hours after the explosion, a ROV (remote operated vehicle) initiated the BOP's autoshear function, closing its blind shear ram, that, too, failed to seal the well. BP states that a review of the rig's BOP audits and maintenance record show "potential weaknesses in the testing regime and maintenance management system".

Since publication of its report, BP has been the buck of searing criticism from environmental groups, US politicians and its named parties. They accuse BP variously of attempting to spread responsibility to get the company off the hook and also jumping the gun by failing to wait for the results of investigations into the now recovered BOP and the results of Halliburton's tests on samples of its cement.

Nevertheless, commenting on the report, BP's incoming chief executive Bob Dudley said: "We have said from the beginning that the explosion on the Deepwater Horizon was a shared responsibility. This report makes that conclusion even clearer... We have accepted all the recommendations and are examining how best to implement them across our drilling operations."

And he continued: "We are determined to learn the lessons for the future and we will be undertaking a broad-scale review to further improve the safety of our operations. We will invest whatever it takes to achieve that. It will be incumbent on everyone at BP to embrace and implement the changes to ensure that a tragedy like this can never happen again."

BP's report offers 25 recommendations, mostly directed at strengthening assurance on BOPs, well control, pressure-testing for well integrity, emergency systems, cement testing and rig audits. However, the firm also cites personnel competence and process safety as needing attention – particularly raising the matter of HAZOP reviews.

Others throughout the high risk plant sectors should be studying this report in detail for important and life-saving lessons. PE

The immediate aftermath of the Macondo well tragedy, as seen by the US coastguard

The investigation report is available online at www.bp.com, together with an accompanying video.