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Deepwater Horizon Incident – Internal Investigation
INVESTIGATION UPDATE – INTERIM REPORT

June 08, 2010

Areas of Discussion

- **Investigation Overview**
- **Focus Areas**
 - Primary Well Control
 - ✓ *Well integrity*
 - ✓ *Procedures*
 - Secondary Well Control
 - ✓ *Blowout preventer*
 - Ignition Source
 - Evacuation & Response
- **Forward Plan**



Investigation Overview

- **Remit**

- The purposes of this investigation are (1) to establish the root cause(s) of events that led to the incident onboard the *Deepwater Horizon* on the night of Tuesday, April 20, 2010 and (2) to review the personnel evacuation, the rig layout that allowed for an evacuation, and the emergency response.

- **Key Questions to Address During the Investigation**

- 1) Why was primary well control lost? *See slides 6-12*
 - ✓ *Well design*
 - ✓ *Casing, cement, well head hanger seal assembly*
- 2) Why was secondary well control unable to stop the flow of well fluids? *See slides 13-15*
- 3) How did the well bore fluids ignite? *See slide 16*
- 4) Should the rig structural design be improved for personnel protection? *See slide 17*
- 5) Can evacuation and emergency response protocols be improved? *See slide 17*

Investigation Overview

- **Investigation Team**

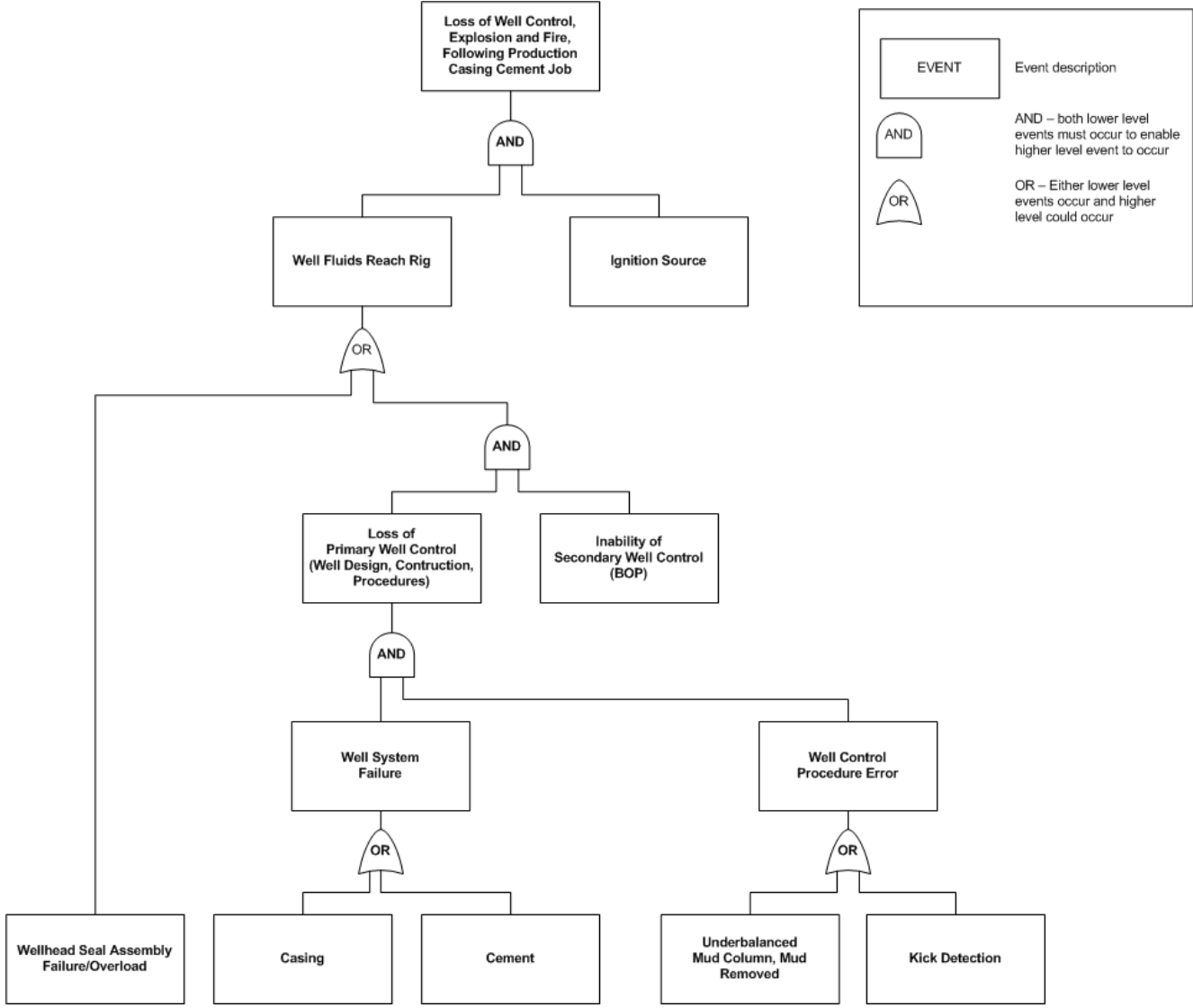
- Internal and external experts
- External third-party experts
 - ✓ *Well design*
 - ✓ *Cementing*
 - ✓ *Gas migration*
 - ✓ *Explosion analysis*
 - ✓ *Emergency response*

- **Basis**

- Interviews & witness statements (*subject to factors restricting access*)
- Reports & documentation (*need BP well design and other requested documents*)
- Equipment inspection & testing (*need access, protocols, court and U.S. Coast Guard approvals*)
- Real-time well data (*needed from BP, Sperry Sun*)
- Modeling & analysis (*through external experts for well design review*)

Investigation Overview

High Level Root Cause Tree



Loss of Primary Well Control

Cement – Areas of Investigation

- **Design**

- Was it appropriate to utilize nitrogen foamed cement at this depth?
 - ✓ *May be uncommon at this depth*
 - ✓ *Typically used for shallow conductor casing string*
- Did the operator give the cement enough time to cure? *(from Halliburton lab test reports)*
 - ✓ *Test on 3/29 of 9-7/8" liner slurry (previous casing): 15 hours needed to reach 2100 psi compressive strength*
 - ✓ *Test on 4/12 of 7" casing slurry : 0 psi compressive strength after 24 hours; needed 48 hours to reach compressive strength of 1590 psi*
 - **Negative test started ~18 hours after pumped**
 - **Do not have any sample test results from rig samples; requested**
- Was the volume for 7" production casing cement job appropriate?
 - ✓ *60 bbls pumped (requested third party caliper logs to determine if adequate)*
 - ✓ *16.7 ppg cement in shoe track over 14 ppg mud in open hole beneath the 7" shoe*
 - **could fall out into the open hole**
 - ✓ *Estimate of 2 bbls nitrogen cement in shoe track – normally would pump all into annulus*

Loss of Primary Well Control

Cement – Areas of Investigation

- **Was there contamination of the cement?**
 - Wiper plug was run through two casing internal diameters
 - ✓ *Potential for mud bypassing plug into cement*
 - Circulated bottoms up only to the wellhead rather than to the surface
 - ✓ *Potential cuttings in well bore*
 - ✓ *Potential non-homogeneous mud or gas content*
 - **Could lead to cement channeling and flow path for formation fluids**
- **Was there a problem with the float equipment?**
 - There were 9 attempts to activate (*IADC and BP daily report 4/19*)
 - Double flapper type
 - ✓ *Requires back pressure from annulus side to close*
 - ✓ *Less than 40 psi back pressure from annulus by calculation*
 - **Potential to open while cement is setting**
 - 1st positive test on casing against wiper plug at 10 hours set time – potential to slightly open flappers during cure time
- **Were the appropriate tests run following the cement job?**
 - No cement bond log was run prior to proceeding with pressure tests
 - Need to test samples of cement recovered by BP from the Damon Bankston deck

Loss of Primary Well Control

Casing Hanger Seal Assembly – Areas of Investigation

- **Were Operator procedures appropriate?**
 - Operator did not run lock down sleeve prior to negative test or displacement
 - No bottoms up circulation prior to landing of 7" casing hanger
 - ✓ *Potential to allow debris in seal area*
- **Was the hanger design adequate?**
 - Was outer lock ring run on assembly?
 - ✓ *Need to understand rating or tolerance for pressure on annulus side*
 - Annulus side pressure
 - ✓ *Could pressures measured (Sperry Sun data) unseat seal assembly?*
 - ✓ *Pressures seen at well head had potential to make 9-7/8" X 7" casing string neutral weight*
 - Need Dril-quip hanger running report showing hanger arrangement as it was run, including 9-7/8" seal assembly

Loss of Primary Well Control

Procedures – Negative Test

- **Negative pressure testing**

- Set up for negative pressure test began approximately 17:00
 - ✓ ~17:15, 60 barrels of spacer moved below annular
 - ✓ Increased annular activating pressure from 1200 to 1900 psi
 - ✓ Set up fluids through crew handover at 18:00
- Under-displaced 16 ppg spacer
 - ✓ Spacer was not in MMS permit
 - ✓ Position under annular led to confusing pressure readings
 - ✓ Float equipment under tested by 285 psi
- Discussion 18:00-19:00
 - ✓ About fluid volumes due to movement below annular and line up for monitoring – either from drill pipe (normal procedure used by rig) or kill line (MMS permit)
 - ✓ Either line up is appropriate and will correctly monitor well

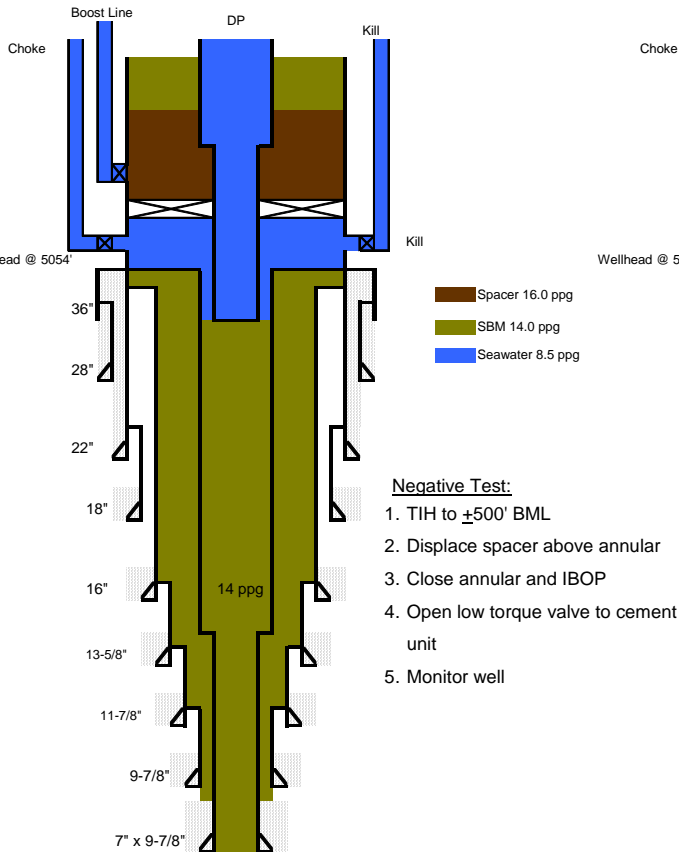
- **Area of Investigation**

- Typically negative test to ~500 ft below well head with sea water
 - ✓ ~3300 ft below – stated on MMS permit in order to prevent well head seal area contamination
 - ✓ Imposed additional 1000 psi differential on float equipment/casing/cement
- Where did ~60 bbls from riser go below annular
 - ✓ U-tube up kill line or up drill pipe?
 - ✓ Impacts final negative test pressure applied to well

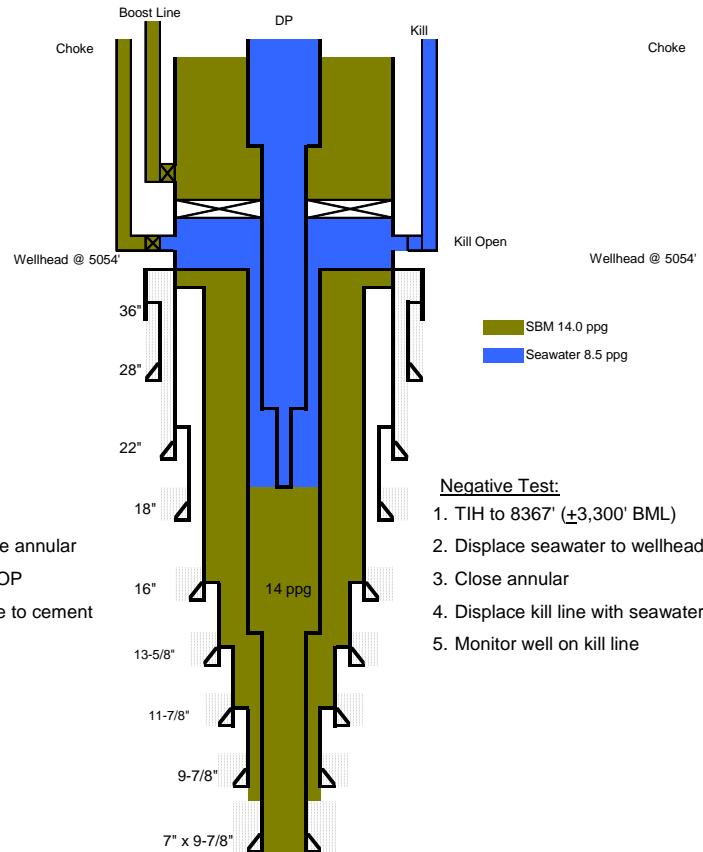
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Loss of Primary Well Control Procedures – Negative Test Setups

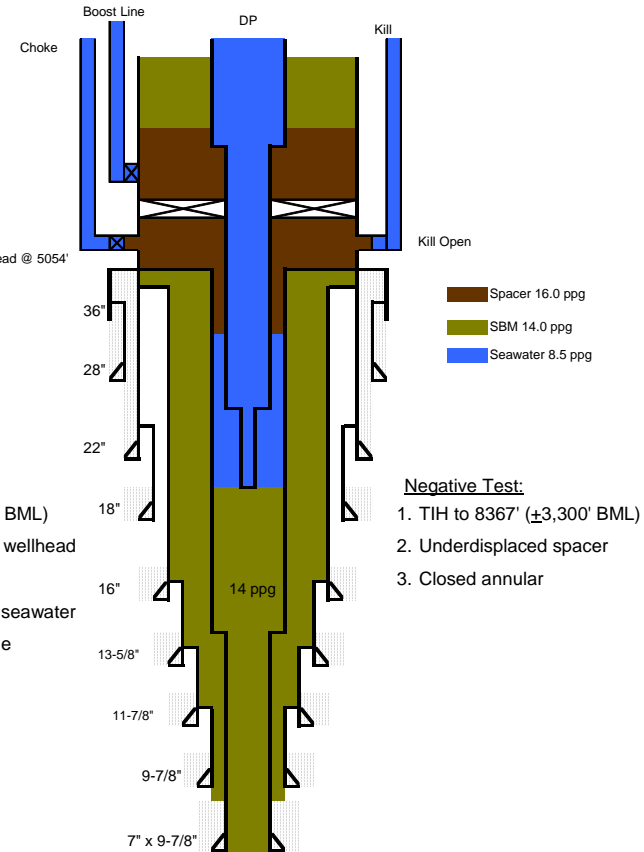
Negative Test Standard Procedure



Negative Test Approved on MMS Permit



Negative Test Setup at 4/20 17:45

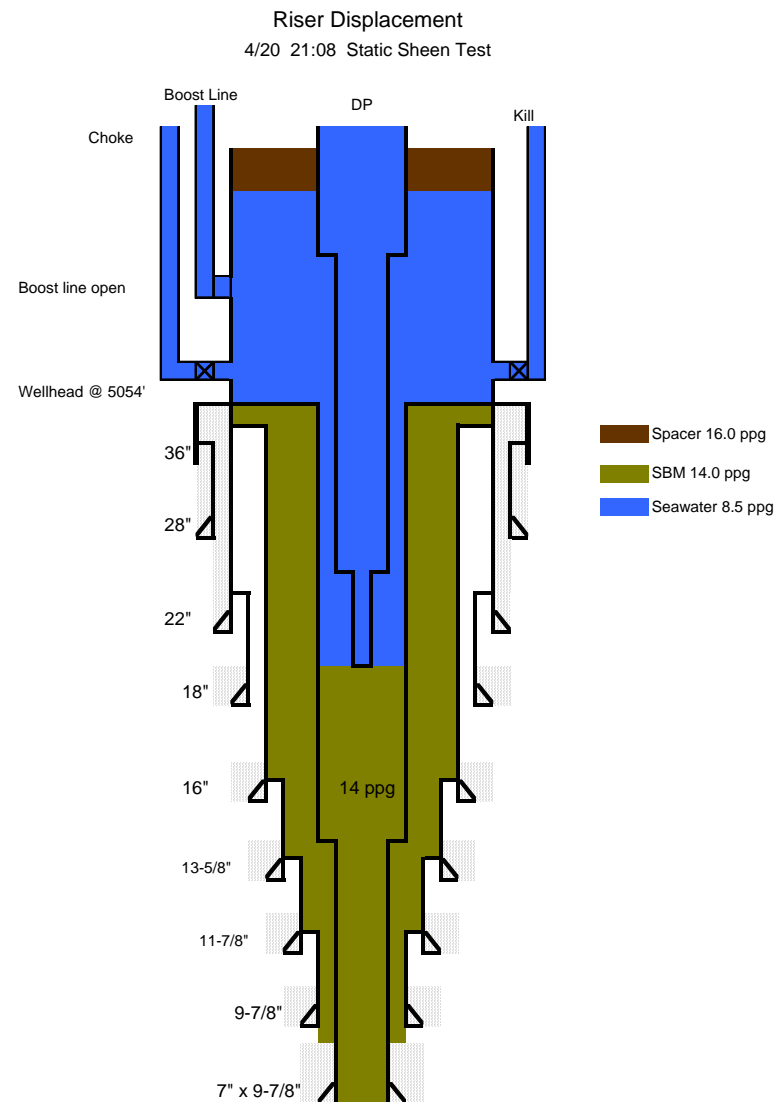


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Loss of Primary Well Control

Review of Procedures

- **Circulate out riser 20:00 to 21:08**
 - Mud circulation out prior to second plug – well reaches highest underbalanced pressure to this point
 - Shut down for static sheen test to begin going over board with water-based spacer
- **Areas of Investigation**
 - Flow changes and volumes
 - Mud transfers
 - Flow sensors accuracy
 - ✓ *Require Sperry Sun system set up details and calibration records*



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Loss of Primary Well Control

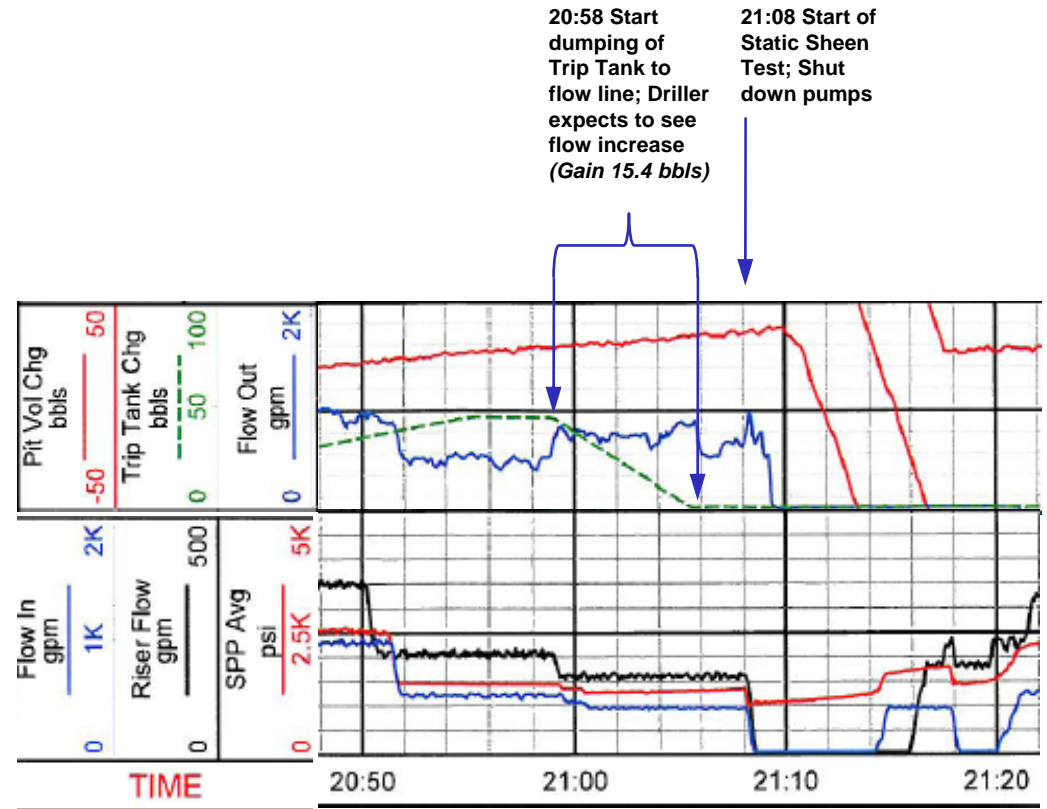
Review of Procedures (continued)

- **Flow Show at 20:58**

- Trip tank being discharged to pits through flow line (normal procedures ahead of change from oil to water mud in active system)
 - ✓ At same point pumps ramp down for stop at static sheen test
- Increased flow out due to discharge of trip tank
 - ✓ Driller expected to see flow increase
 - ✓ Flow returned near pre-tank discharge level when trip tank pump stopped, THEN increased
 - ✓ Potentially masked the gain

- **Area of Investigation**

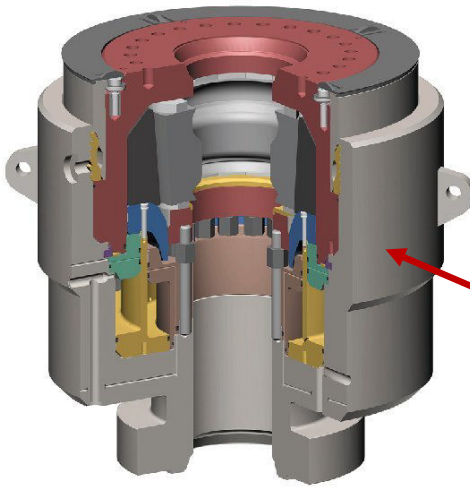
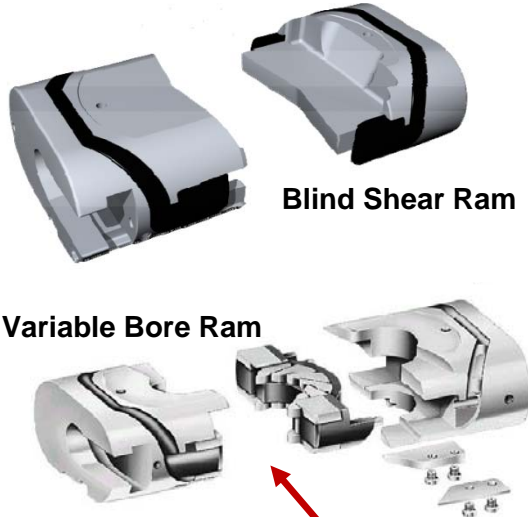
- Complete review of all volumes and real time data (received 5/24)
- Use of trip tank in operation
- Sperry Sun sensors failure to record a flow out after 21:10



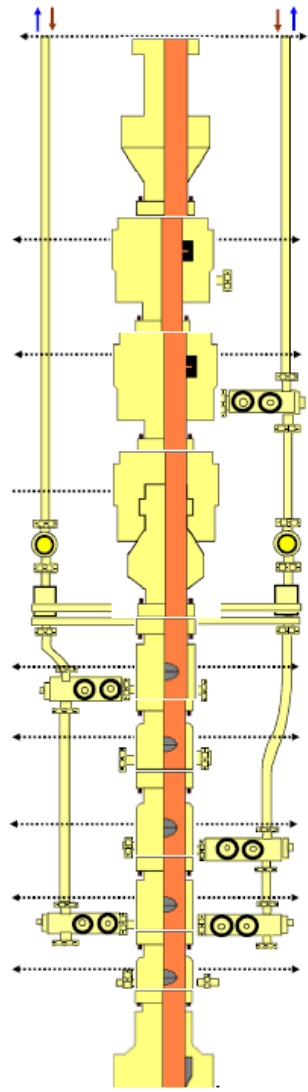
Source: BP OCS-G 32306 001 ST00BP01 Mississippi Canyon 252 Macondo, Last 2 hours before end of transmission

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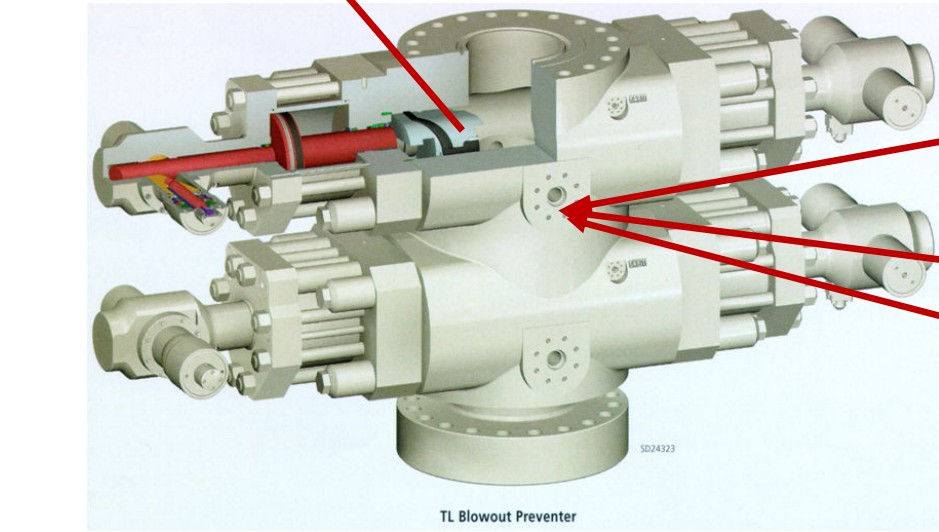
Blowout Preventer



RISER ADAPTER
 UPPER ANNULAR
 LOWER ANNULAR



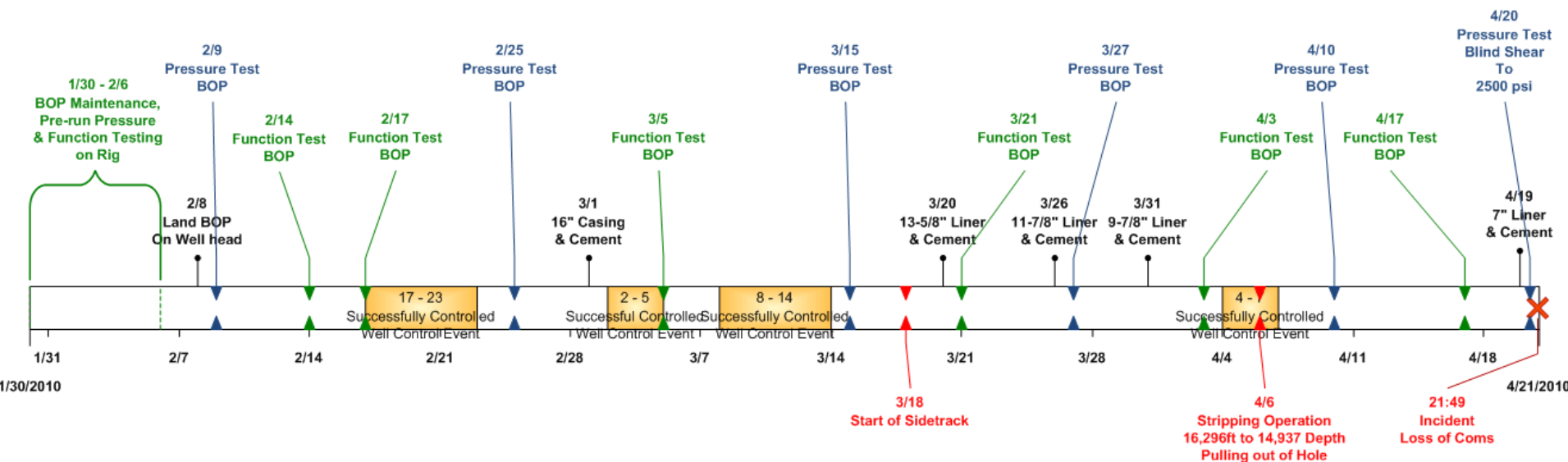
LMRP CONNECTOR
 BLIND SHEAR RAM
 CASING SHEAR
 3 1/2 TO 6 5/8 VBR
 3 1/2 TO 6 5/8 VBR
 3 1/2 TO 6 5/8 VBR Test Ram
 TOP OF WELLHEAD



TL Blowout Preventer

Blowout Preventer Testing

- **Function Test**
 - Preventers activated individually from surface to confirm commands perform subsea
 - No pressure applied
 - Required every 7 days
- **Pressure Test**
 - Preventers activated individually from surface
 - Pressure applied individually to maximum anticipated well bore pressure (*per Operator or MMS*)
 - Required every 14 days
- **Timeline of tests from start of drilling – all tests passed** (*source: IADC reports*)



Blowout Preventer

Events & History

- **Stripping Operation – 6 April**

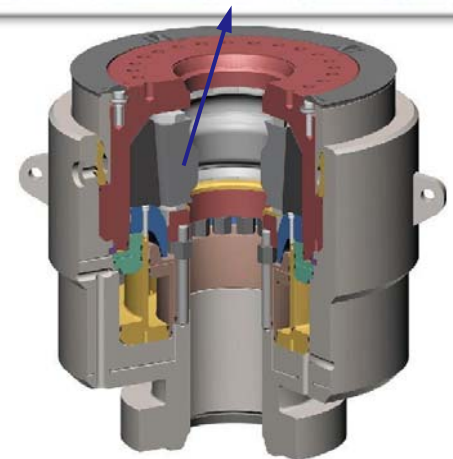
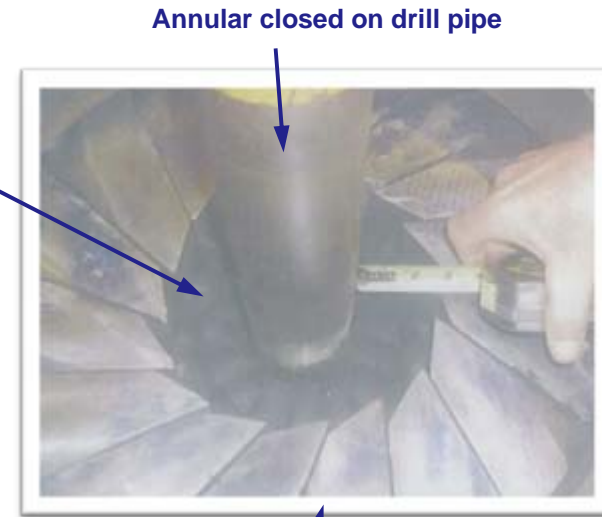
- Witness stated pieces of rubber returned in mud flow over shakers
- Estimated to be from stripping operations during well control event (~1300 ft pipe stripped)
- Expected normal wear on lower annular rubber element
- Annular passed subsequent pressure test on 10 April (250psi/3500psi)

- **Condition at the time of incident**

- Lower annular & diverter closed prior to explosion (witness statements)
 - ✓ *Visual indications on Toolpusher panel*
 - ✓ *Fluid seen coming from diverter line by rig & boat crew (diverter confirmation)*
 - ✓ *Flow subsided and then started again (annular confirmation)*
 - ✓ *Last pressure reading over 5400 psi and exceeds lower annular rating of 5000 psi*
- Evidence of upper pipe ram activation
- Potential for multiple tubulars in BOP at time of incident

- **Action items/work needed**

- Full control system software review
 - ✓ *Software code requested from manufacturer for investigation*
- Review of data from ROV intervention
- Assemble 10-yr history of BOP maintenance, modifications, & upgrades



Source: Cameron web site

Ignition of Well Fluids

- **From witness statements**

- Gas cloud like fog from water up to main deck (*observer on Bankston supply boat*)
- Fishing boat motoring from under aft lifeboat station (*roustabout*)
- Gas/well fluids exiting diverter lines, derrick, and degasser overflow line
- Gas “hiss” like bleeding off pressure (*potential release from slip joint packer to moon pool*)

- **Potential ignition sources**

- Fishing boat
- Supply boat
- Engines
- EX-equipment in derrick and moon pool

- **Area of investigation**

- Gas dispersion study in prevailing weather conditions (little or no wind)
 - ✓ *Incorporate rig ventilation system*
 - ✓ *Proximity of boats*
- Structural damage assessment with review of bulkhead strength against design

Forward Plan

Immediate Actions

- **Complete interviews and fact gathering**
- **Complete BOP maintenance and modification history review**
 - BOP control software code review against known sequence of events
- **Continue well construction review**
 - Cementing
 - Obtain well head casing hanger information
 - Casing load calculations
 - Hydraulic model and gas migration study to determine likely failure point
- **Well procedures**
 - Time line displacement to seawater and mud transfers
 - Real time data analysis – require mud loggers pump schedules
 - Negative test review