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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*

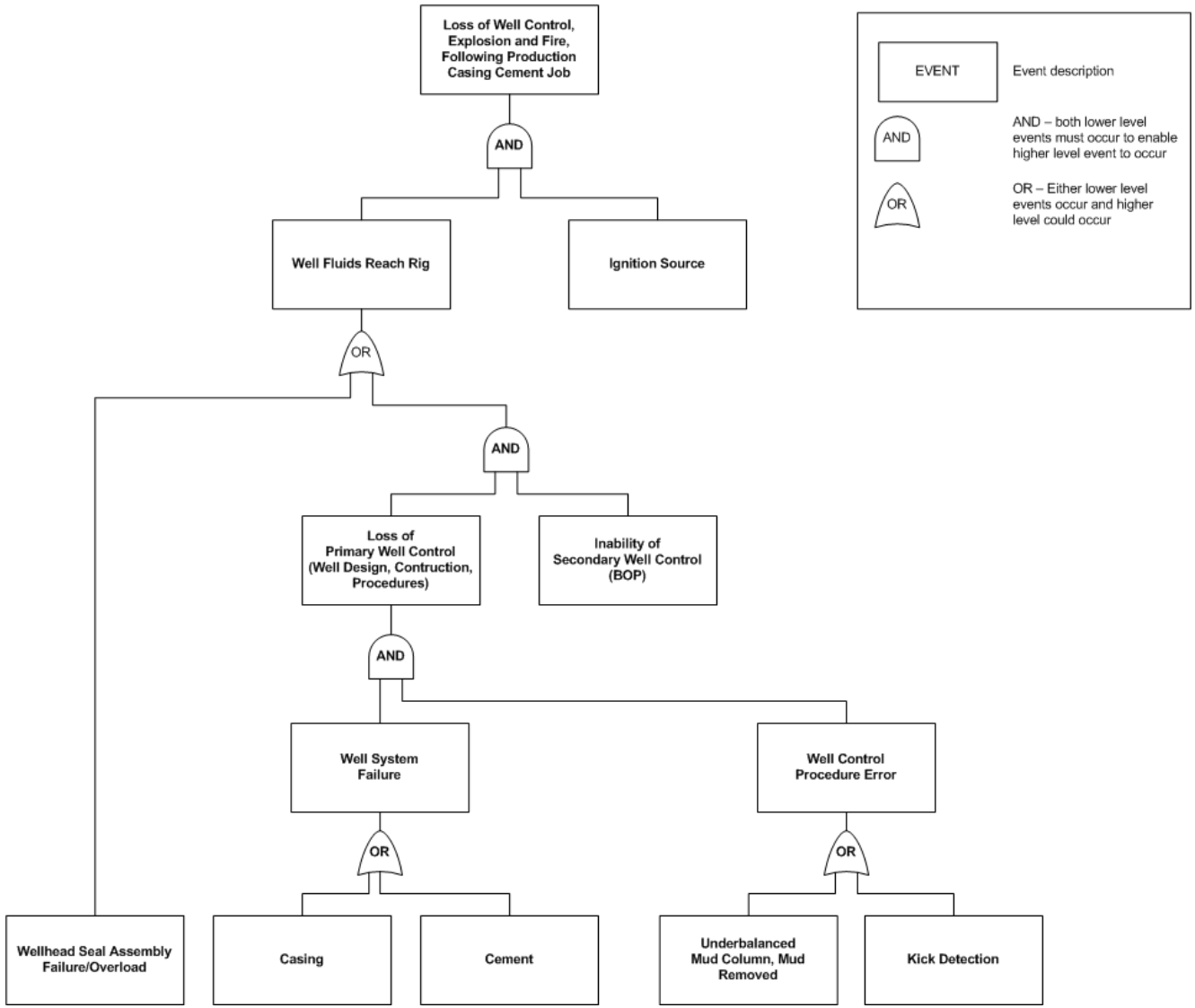
Investigation Overview

- **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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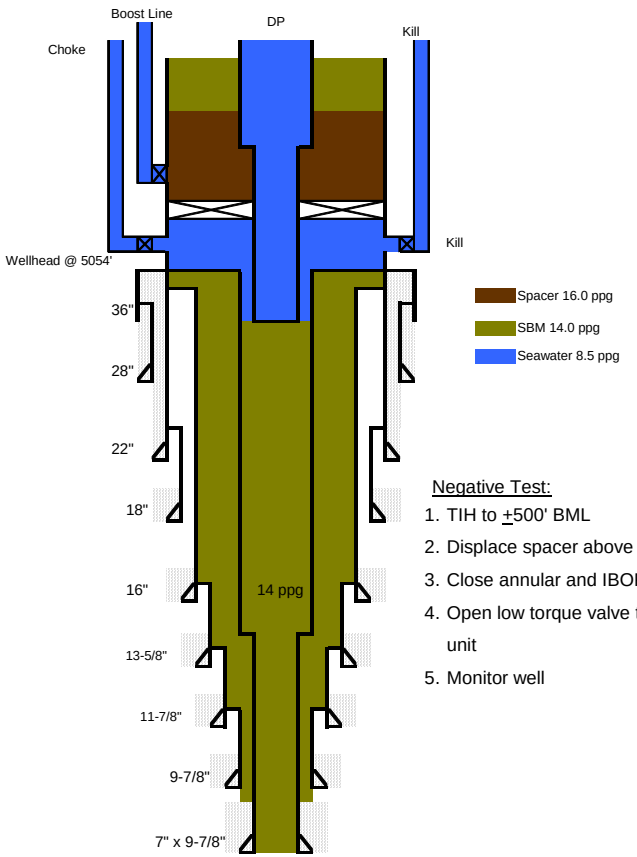
Loss of Primary Well Control

Procedures – Negative Test Setups

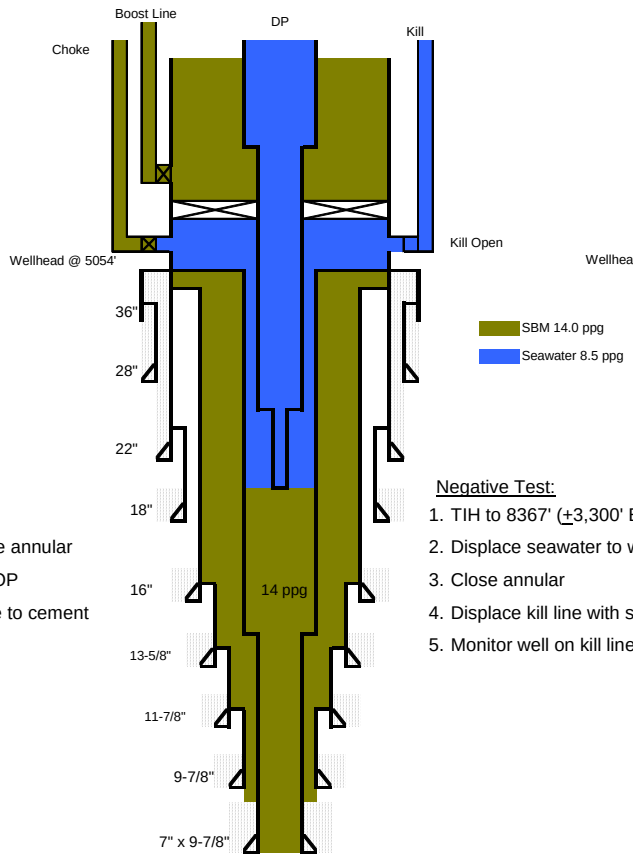
Negative Test Standard Procedure



Negative Test:

1. TIH to ±500' BML
2. Displace spacer above annular
3. Close annular and IBOP
4. Open low torque valve to cement unit
5. Monitor well

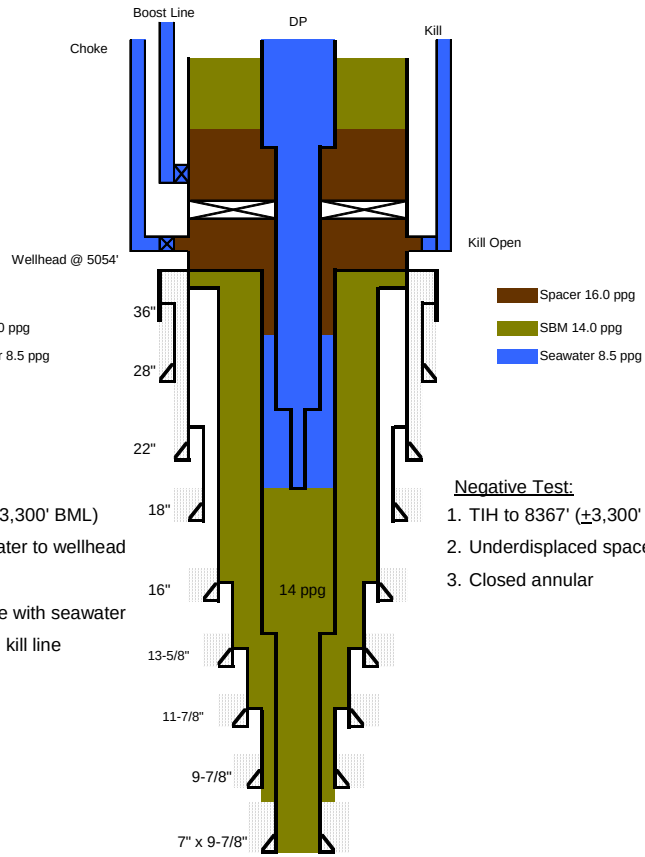
Negative Test Approved on MMS Permit



Negative Test:

1. TIH to 8367' (±3,300' BML)
2. Displace seawater to wellhead
3. Close annular
4. Displace kill line with seawater
5. Monitor well on kill line

Negative Test Setup at 4/20 17:45



Negative Test:

1. TIH to 8367' (±3,300' BML)
2. Underdisplaced spacer
3. Closed annular

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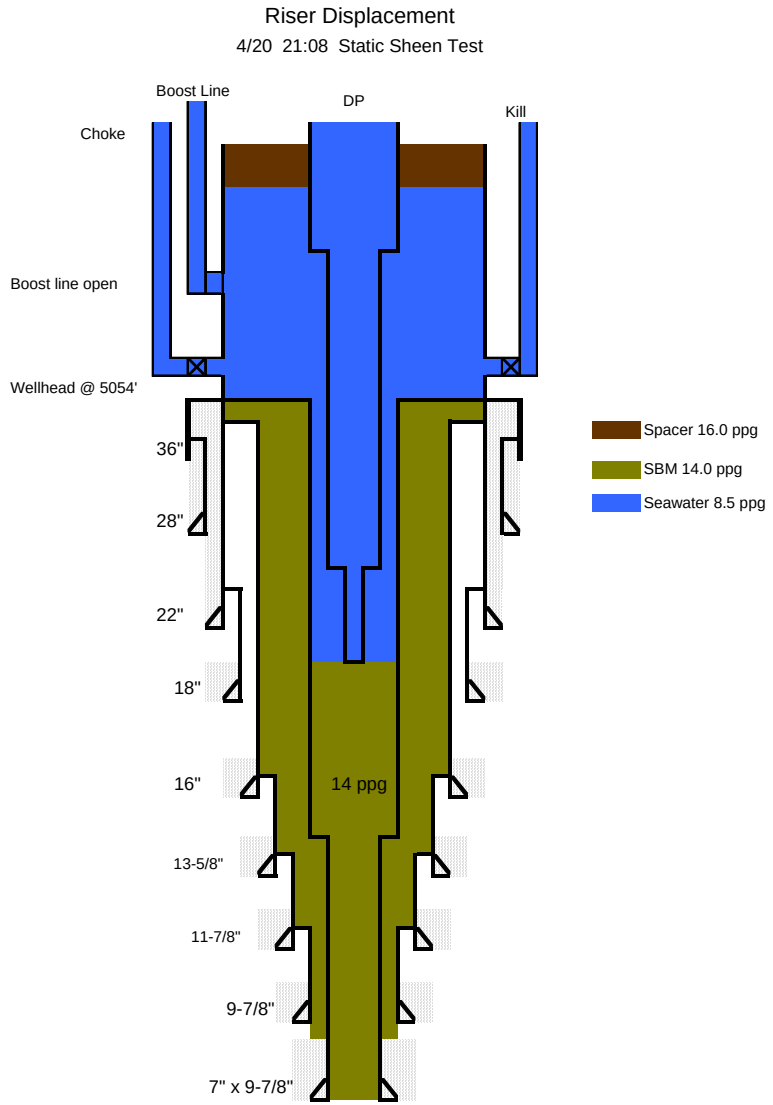
Loss of Primary Well Control
Review of Procedures

- **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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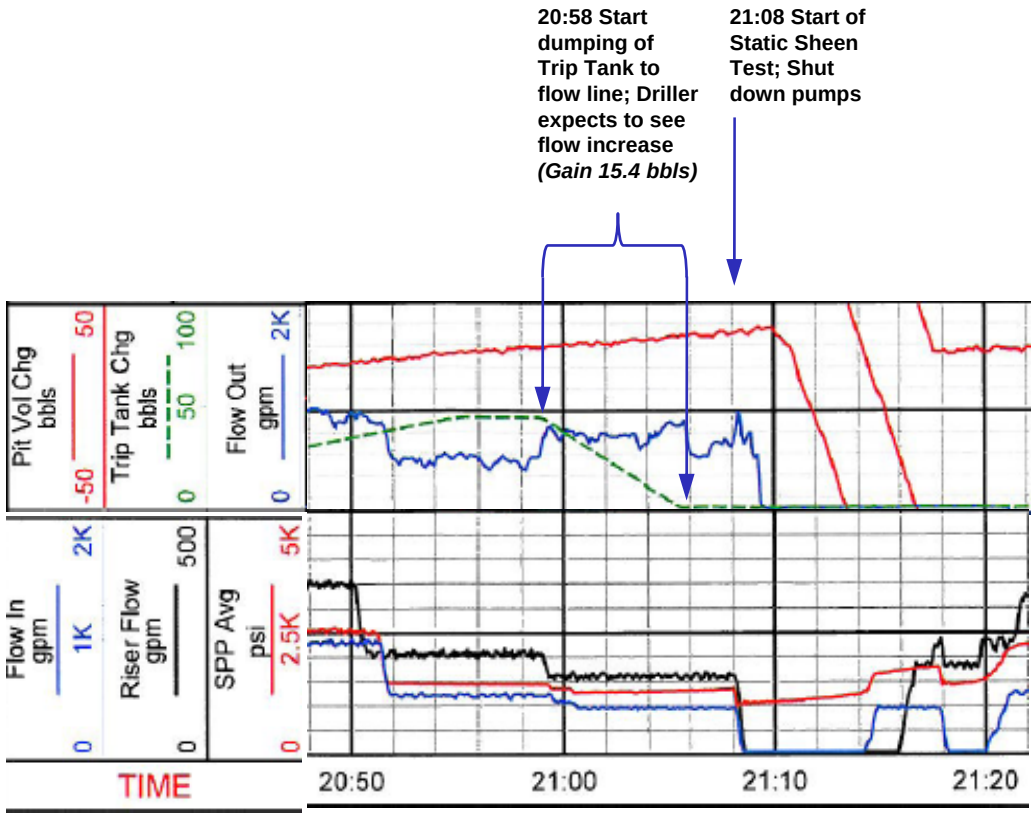
Loss of Primary Well Control
Review of Procedures (continued)

- **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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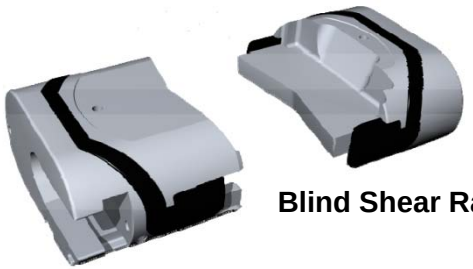
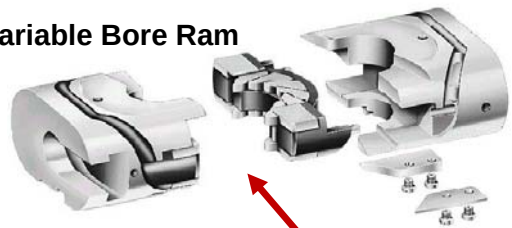
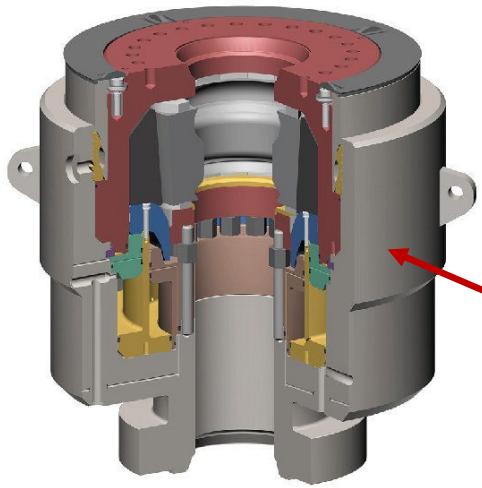
Blowout Preventer

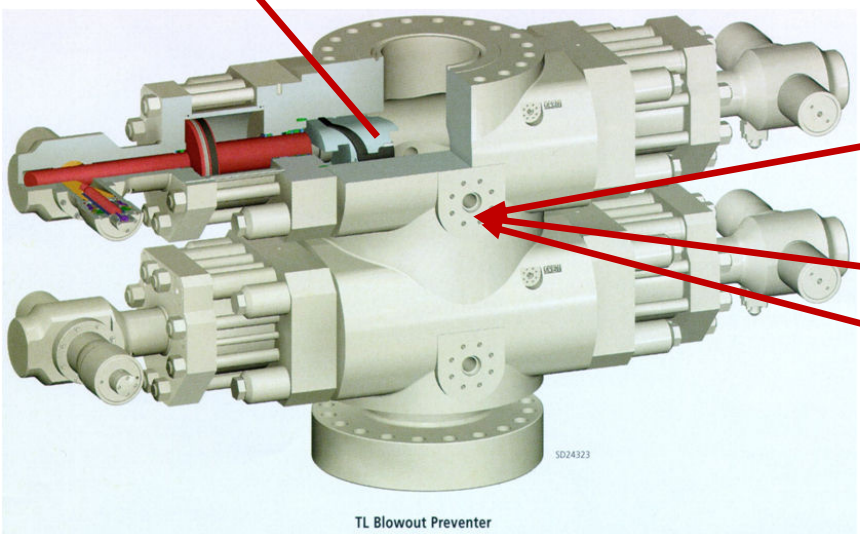


Blind Shear Ram

Variable Bore Ram







TL Blowout Preventer

RISER ADAPTER

UPPER ANNULAR

LOWER ANNULAR

LMRP CONNECTOR

BLIND SHEAR RAM

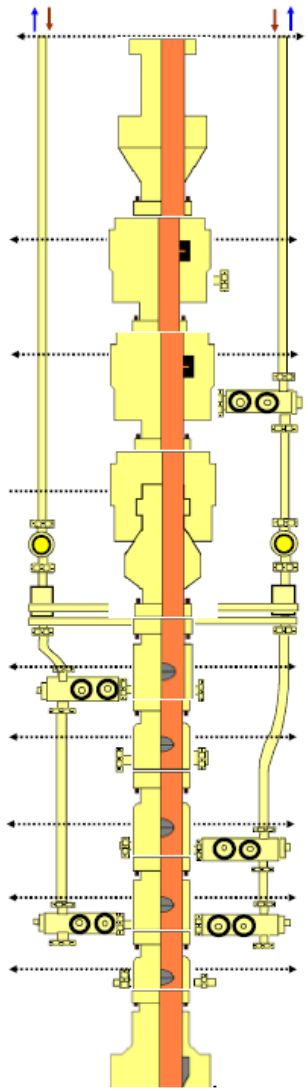
CASING SHEAR

3 1/2 TO 6 5/8 VBR

3 1/2 TO 6 5/8 VBR

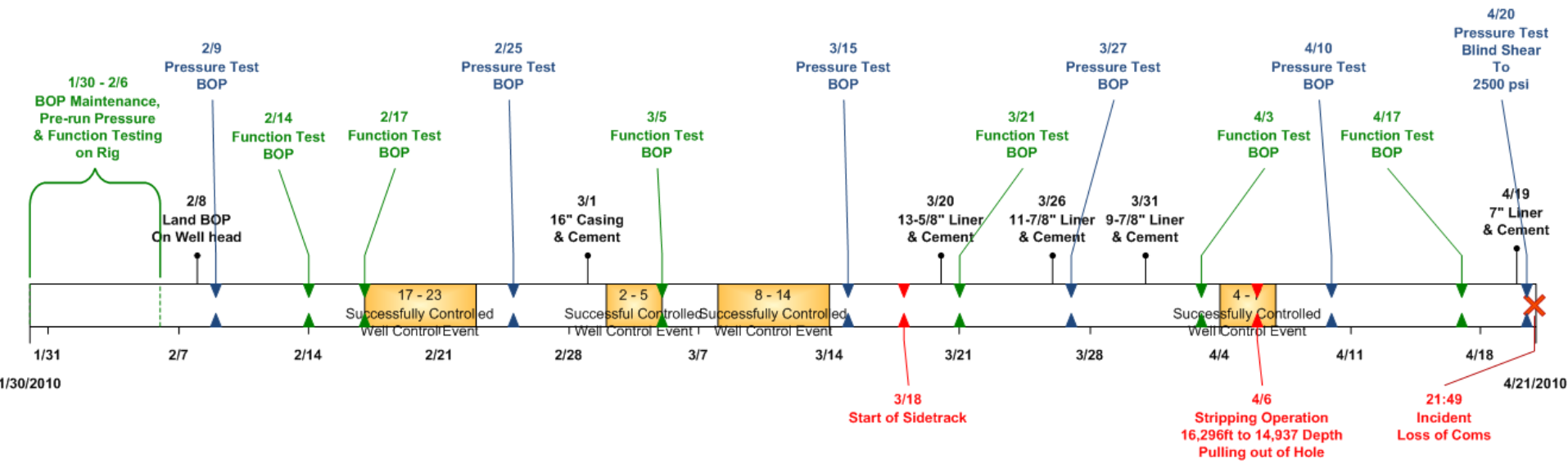
3 1/2 TO 6 5/8 VBR Test Ram

TOP OF WELLHEAD



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)***

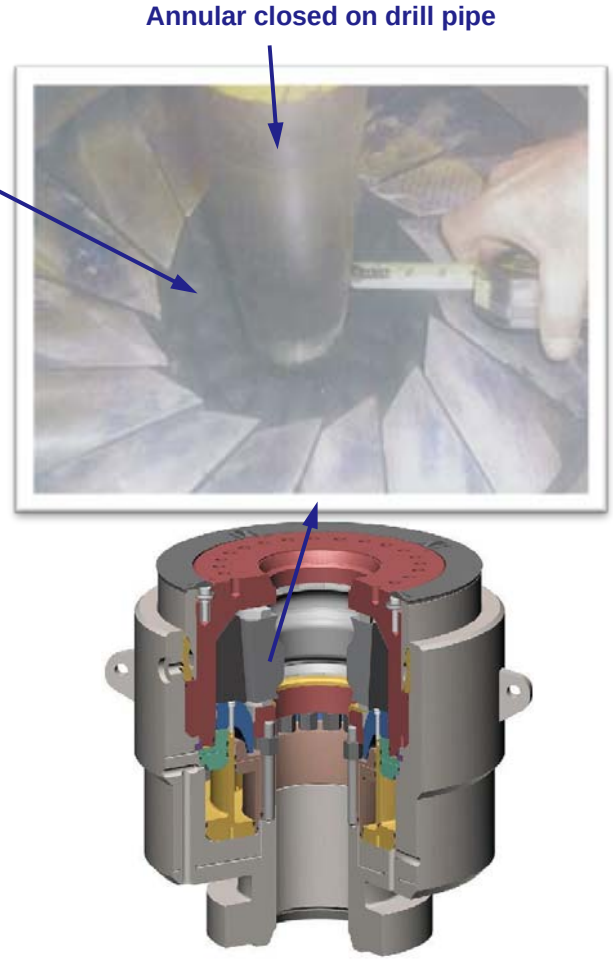


Blowout Preventer
Events & History

- **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



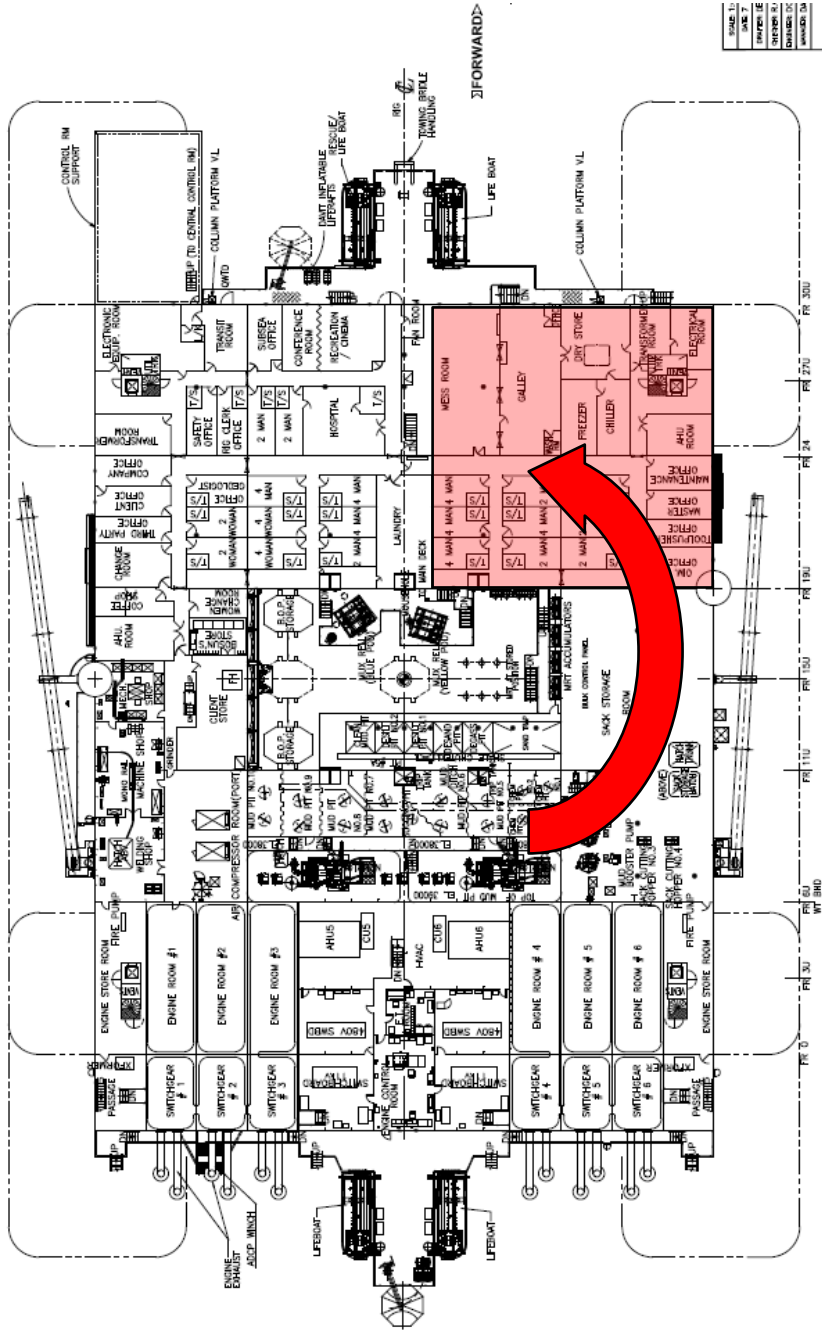
Source: Cameron web site

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

Evacuation & Response

- **From witness statements**
  - Most damage on 2nd deck, starboard side *(light red area)*
  - Believed blast moved forward from pit/pump rooms through sack room and then into accommodations
  - Main deck significantly damaged on starboard side, fire aft of derrick
- **Areas to evaluate**
  - Muster and orders to evacuate
  - Launching of boats
  - Recovery of personnel in water
  - Supply boat impact
  - Shore-based response



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