Deepwater Horizon Disaster

Scientia Panel: "The BP Deepwater Horizon Catastrophe Causes, Consequences, and Cures"

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Disclaimer: This study is meant to be purely technical documentation of events and causes. It is not meant to place blame on any individual or company or industry or government.

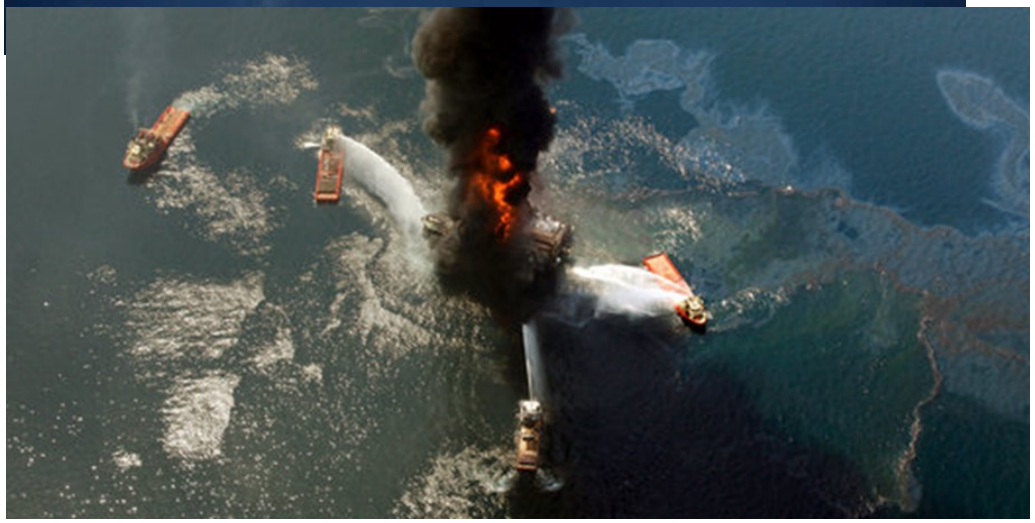
Deepwater Horizon Rig

Source: MMS and BP

April 20, 2010

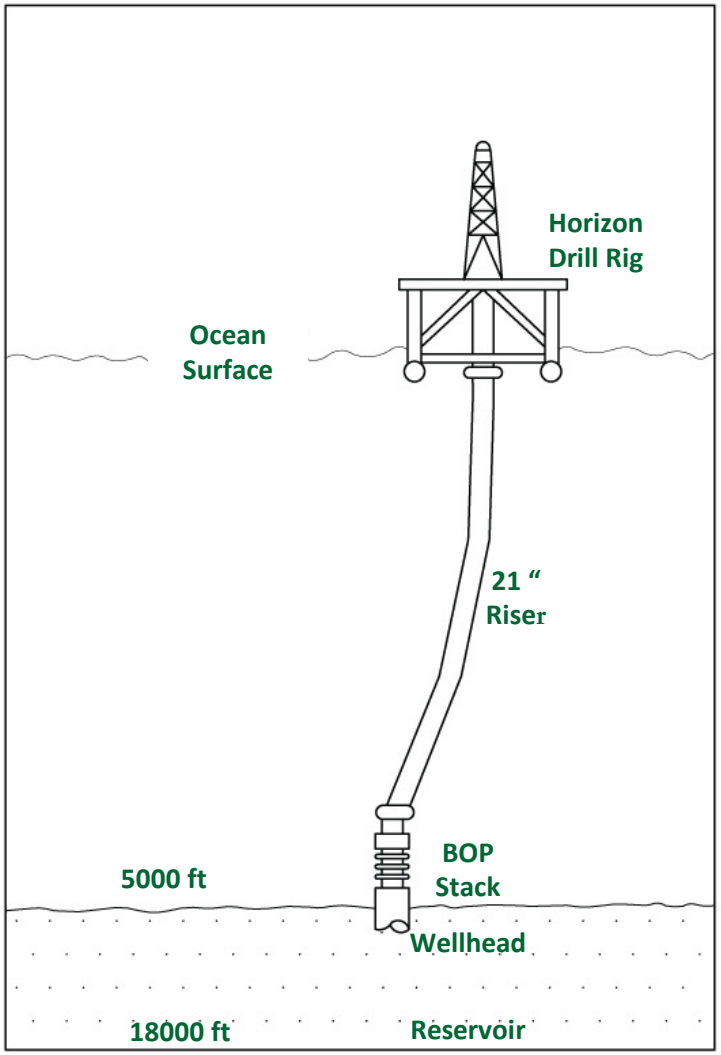
- At approximately 10 pm Horizon Rig disaster started
- BLOWOUT: Initial explosion due to Gas/Oil/Mud surge and ignition upon entry into the engine room
- Fire starts and power failure
- Violent vibrations that shook the entire rig reported
- Second explosion
- Rig evacuated and fire/containment response and rescue begins by nearby vessels

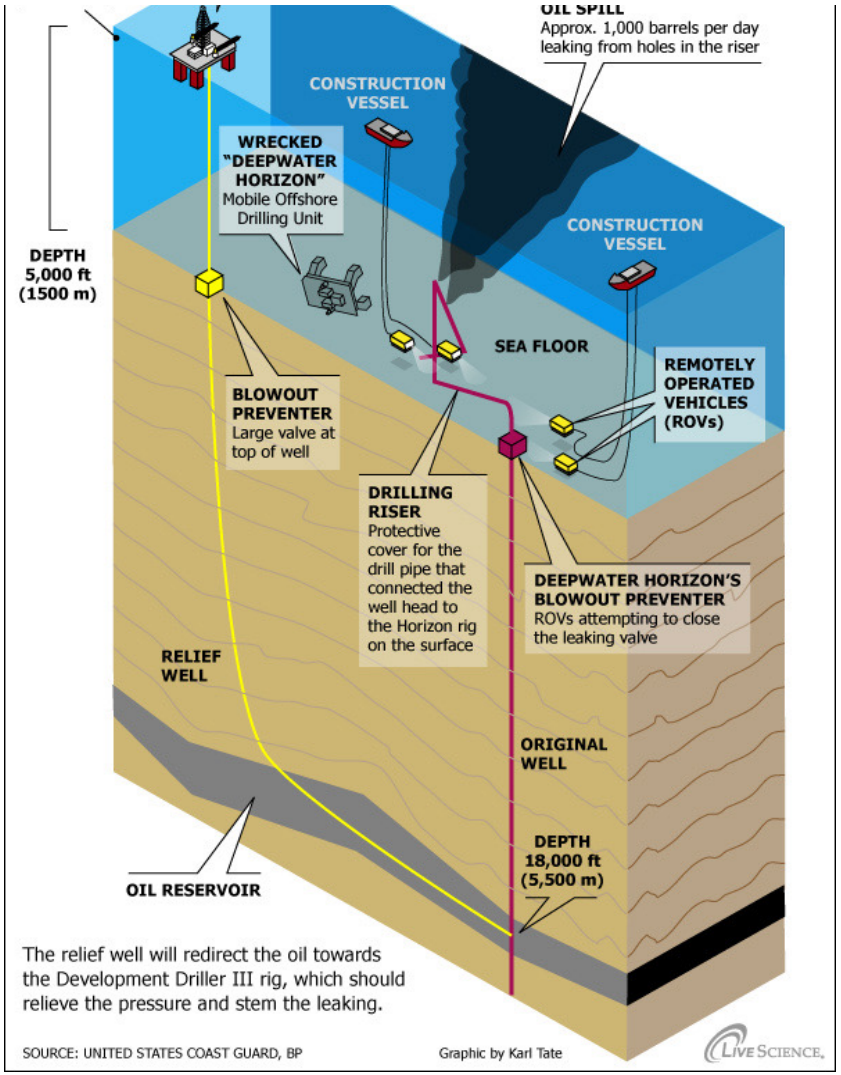
Horizon Rig April 20/21/22, 2010



Source: MMS/AP/flickr

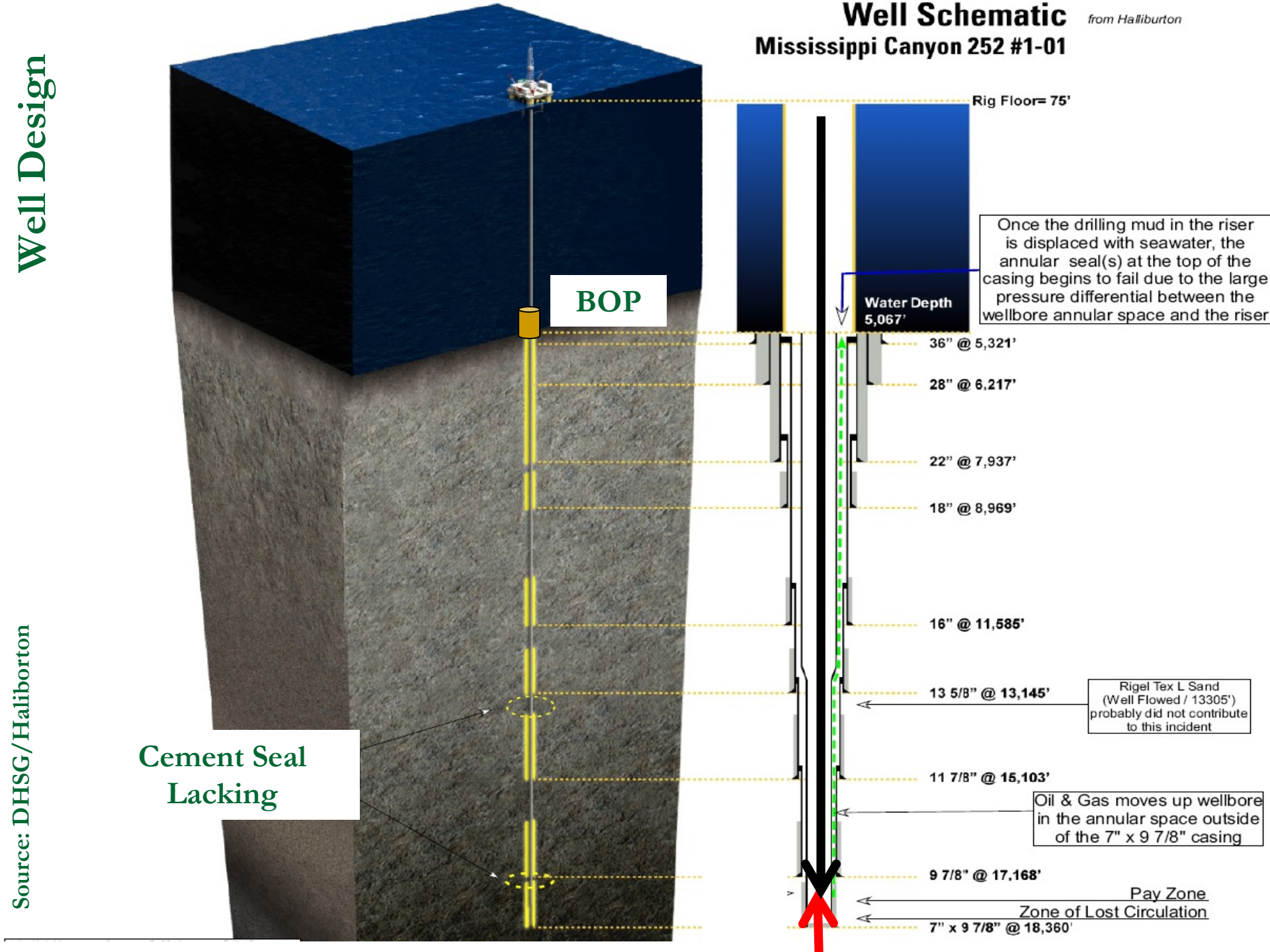
Horizon Before/After Collapse





Source: Live Science

Well Design



Source: DHSG/Haliborton

Cementing Procedure

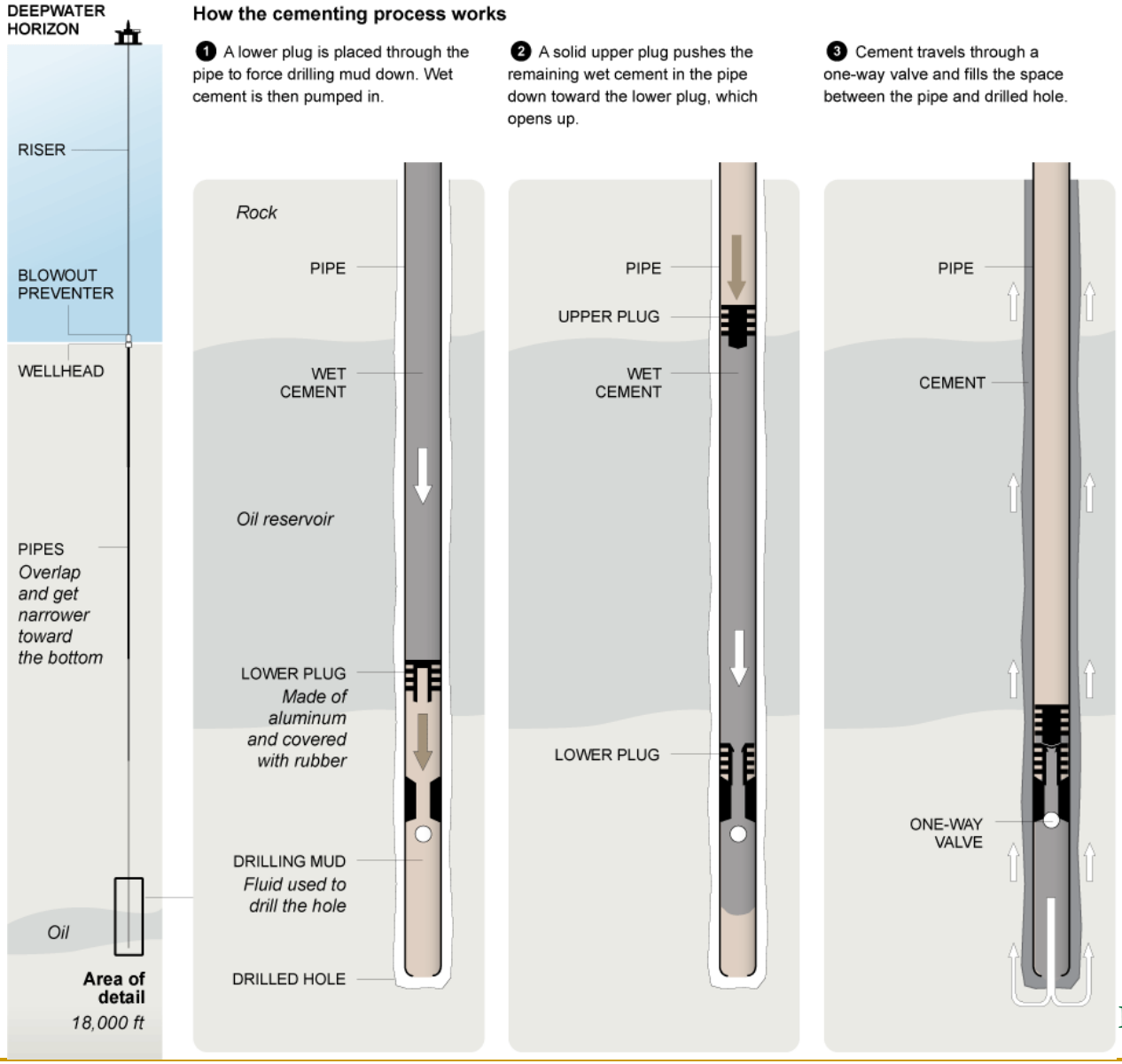
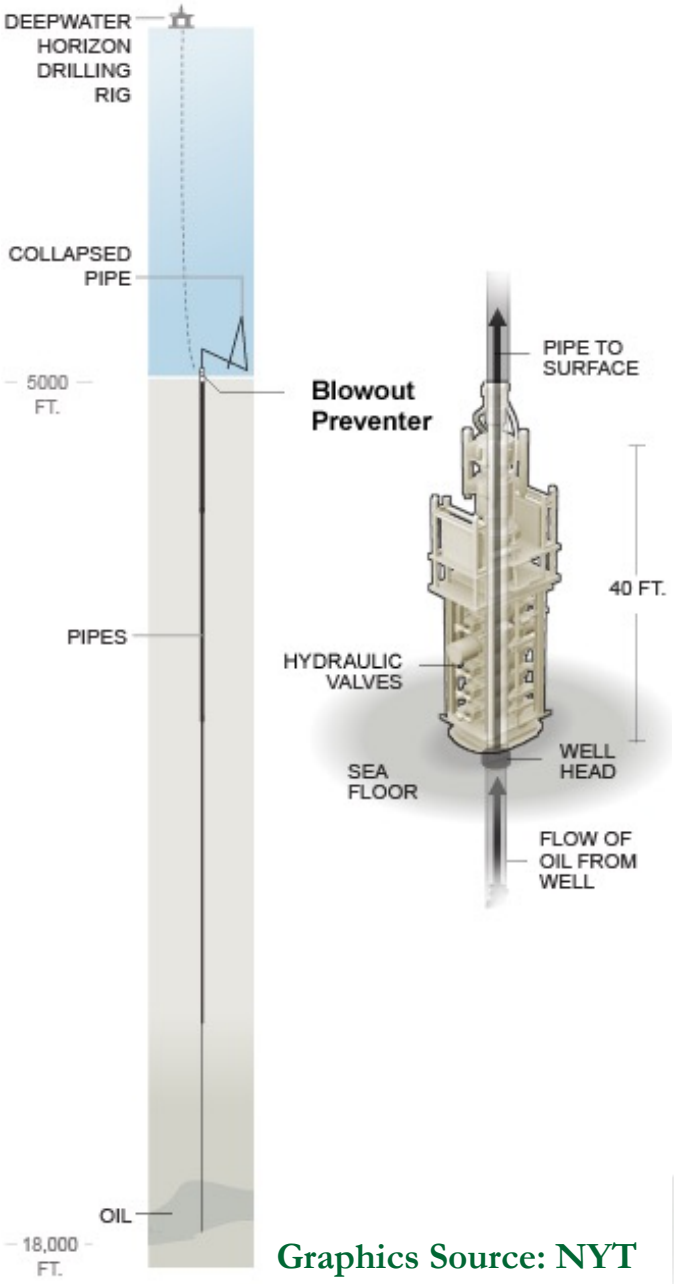


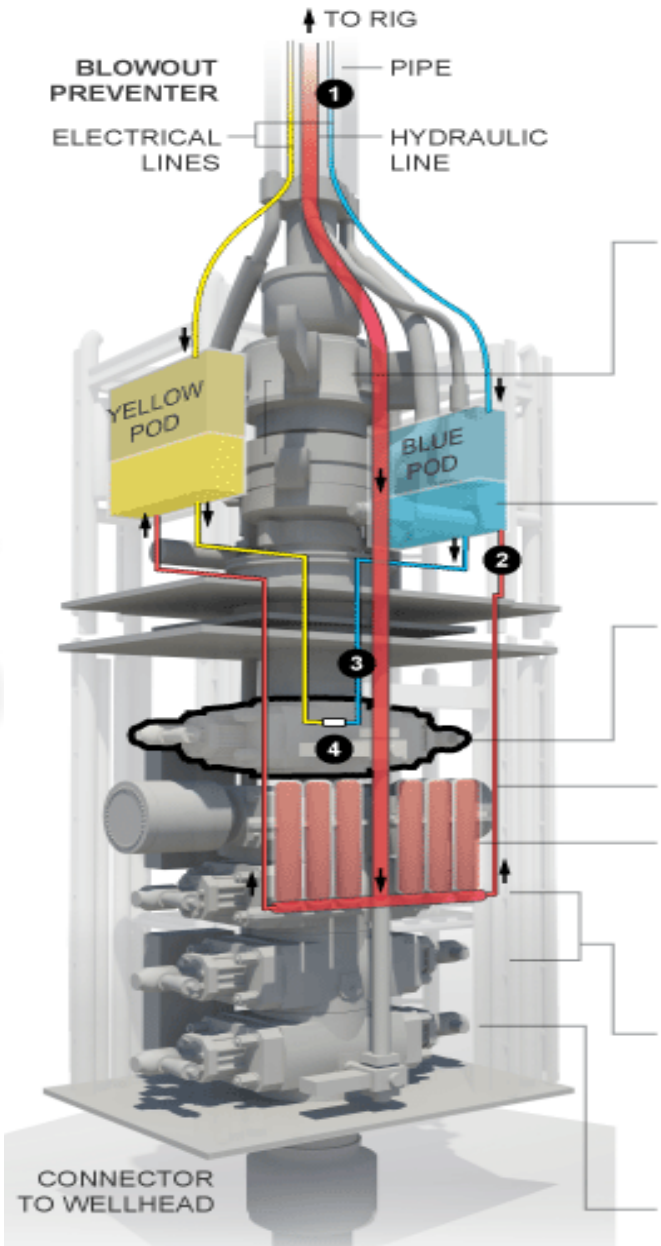
Figure Source: NYT

Well Control - Barriers

- Primary Barriers for Well Control
  - Static Equilibrium - Downward Weight of the Drill Mud in the Drill Pipe is Equal to the Upward Oil/Gas or Formation Pressure
  - Well Design - Wellhead Seal and Multiple Casing Barriers
- Secondary Barrier for Well Control
  - Blowout Preventer (BOP) Rams Activation
  - Last resort Blind Shear Ram Activation

Blow Out Preventer (BOP) 5 Story Tall





The blowout preventer is 54 feet tall.

ANNULAR PREVENTERS
Can create a seal around the drill pipe or seal off an open wellbore when there is no pipe.

CONTROL PODS
Receive electrical signals from the rig and direct the movement of hydraulic fluid. Upper portion has electrical parts; the lower portion has hydraulic valves. Only one pod is activated at a time.

BLIND SHEAR RAM
Cuts the drill pipe and completely seals the well.

CASING SHEAR RAM
Cuts drill pipe or casing in an emergency when the rig needs to disconnect from the well quickly.

ACCUMULATORS
Store fluid sent from the rig. During an emergency, pressurized fluid from these canisters can provide force to power the blind shear ram.

PIPE RAMS
Seal off the space between the outside of the drill pipe and the well bore and keep the pipe centered.

TEST RAM
Used to test the rams above it.

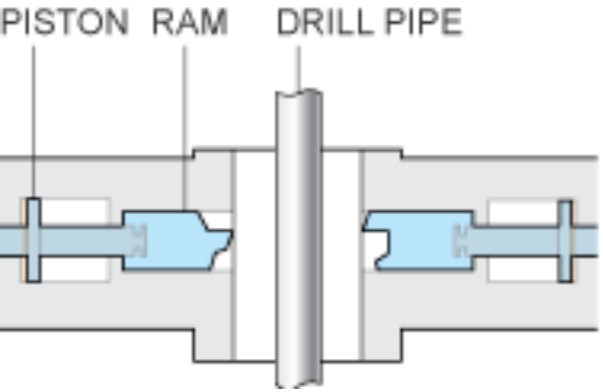
Graphics Source: NYT

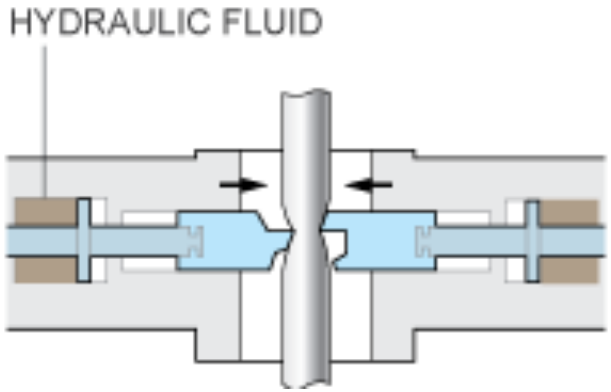
Blow Out Preventer (BOP)

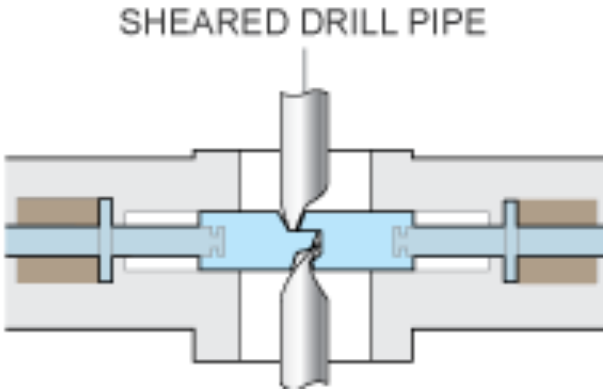
- A Series of Rams (Valves)

Stacked one top of another

- Forms Secondary Barrier
- Last Resort Blind Shear Ram

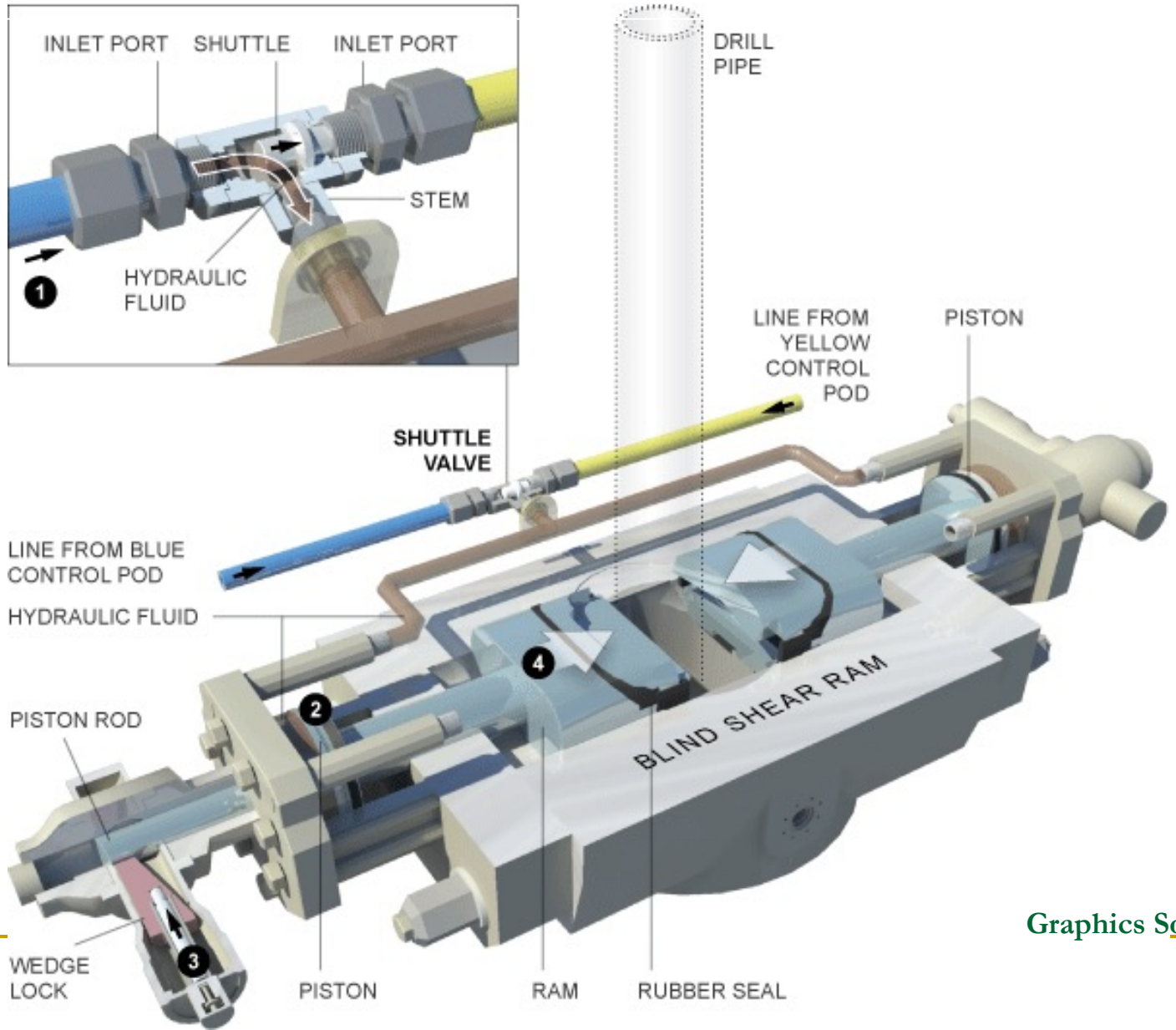




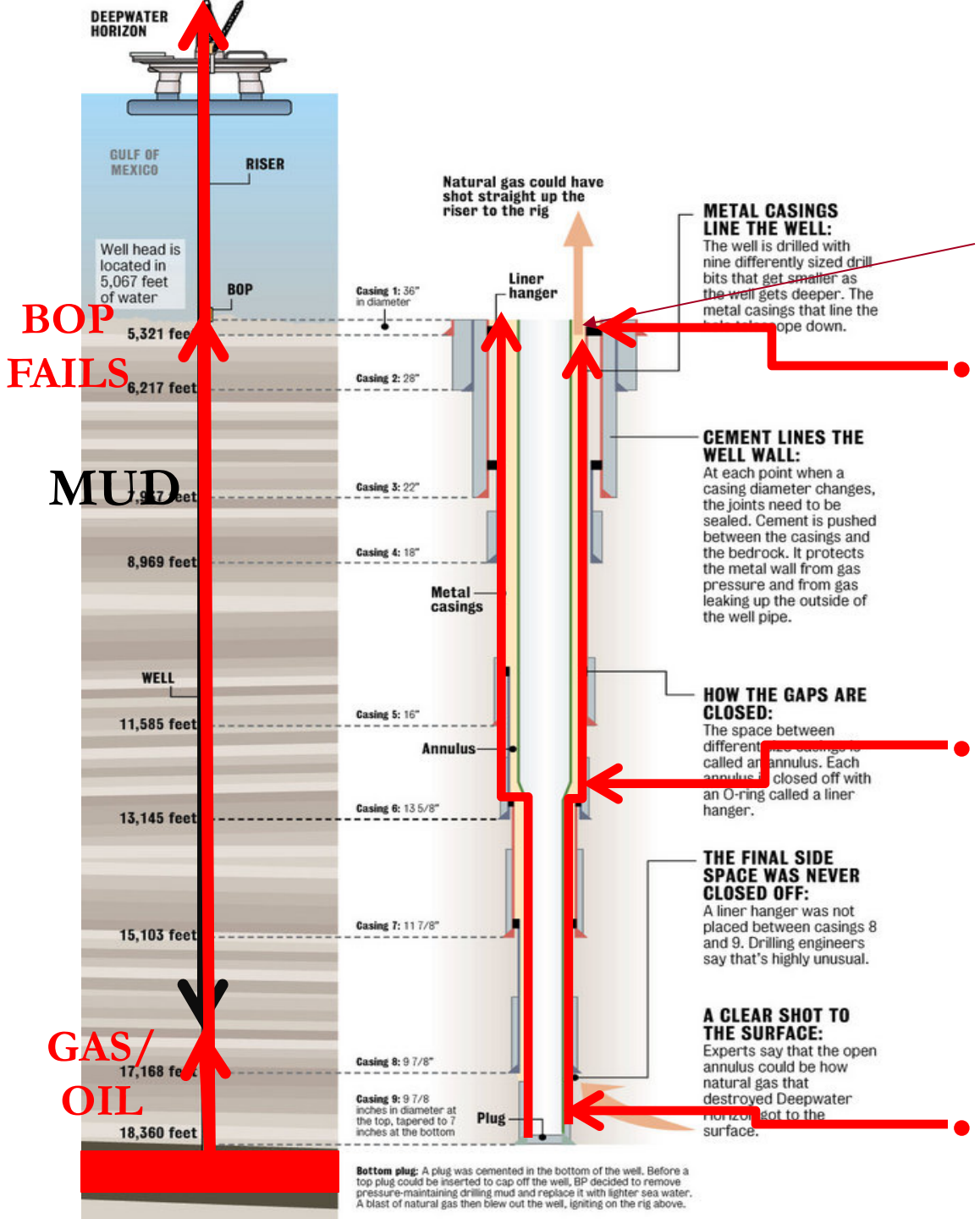


Graphics Source: NYT

Blow Out Preventer – Blind Shear Ram



Graphics Source: NYT



BOP FAILS

MUD

GAS/ OIL

Missing lockdown sleeve allows annular seal to fail

- Missing lockdown sleeve allows annular seal to fail, gas/oil rushes to the rig floor
- Methane Gas Bubble/oil rushes up the annular space from 18000 ft to 5000 ft
- Casing/Cementing Fails

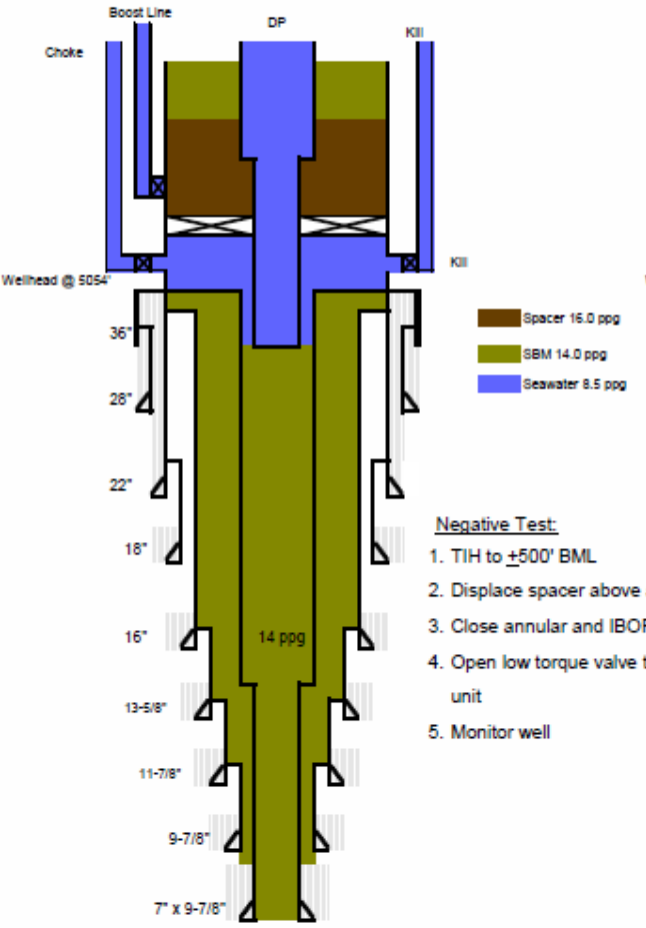
Sequence of Events

- Well System Failure
  - Cement plug failure
  - Wellhead Seal Assembly Failure
- Well Control Failure
  - Mud Removed – Resulting in Upward Gas/Oil Pressure Greater than Downward Weight of the Drill Mud in the Drill Pipe – PRIMARY BARRIER LOST
- Blowout Preventer Failure
  - SECONDARY BARRIER LOST
- Blowout with Methane Gas Bubble Rising to Rig Floor
- Ignition and Ensuing Explosion and Fire

Loss of Primary Well Control

Procedures – Negative Test Setups

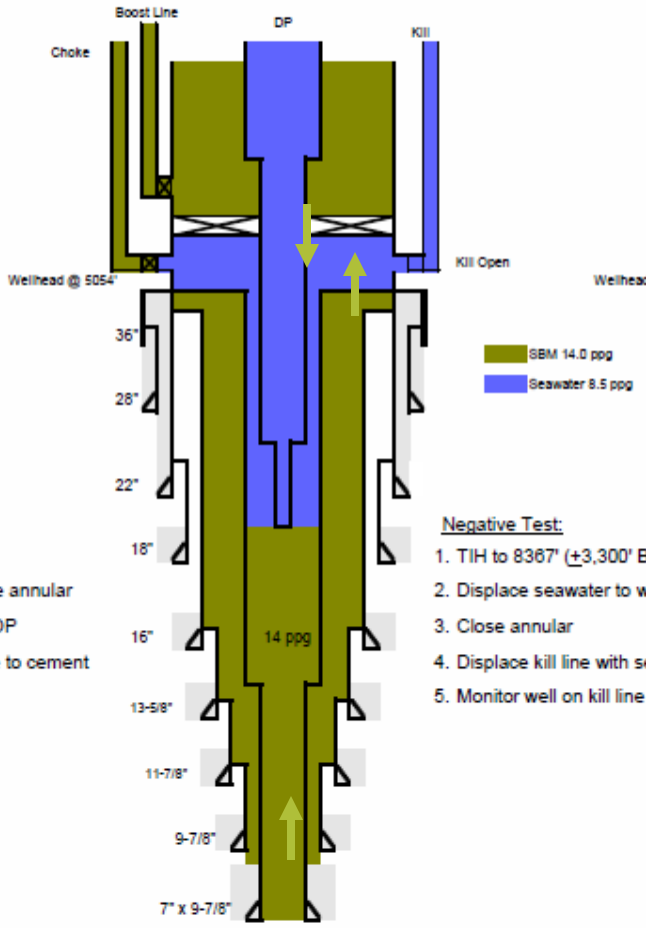
Negative Test Standard Procedure



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

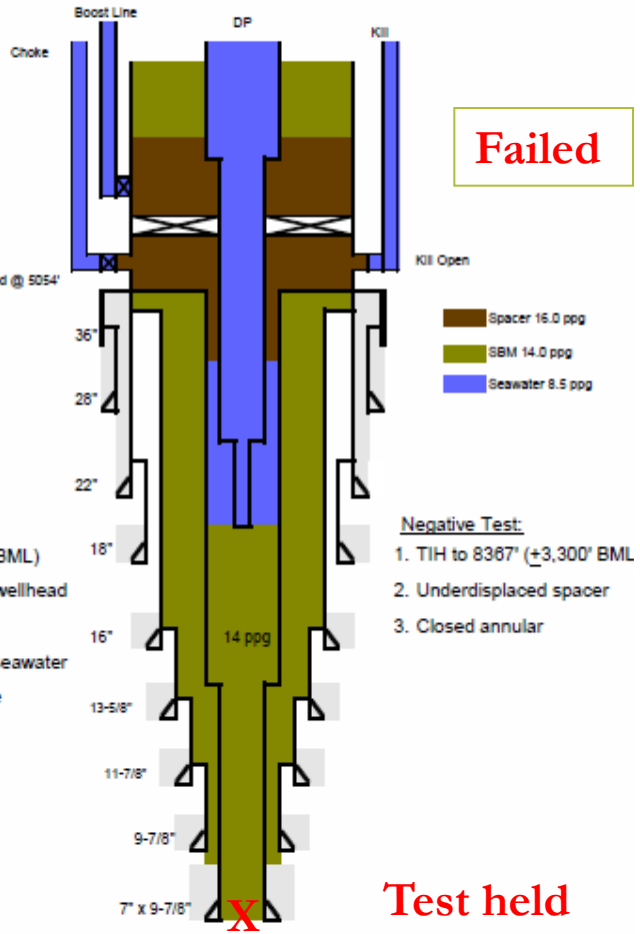
Negative Test Approved on MMS Permit



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



Failed

Negative Test:

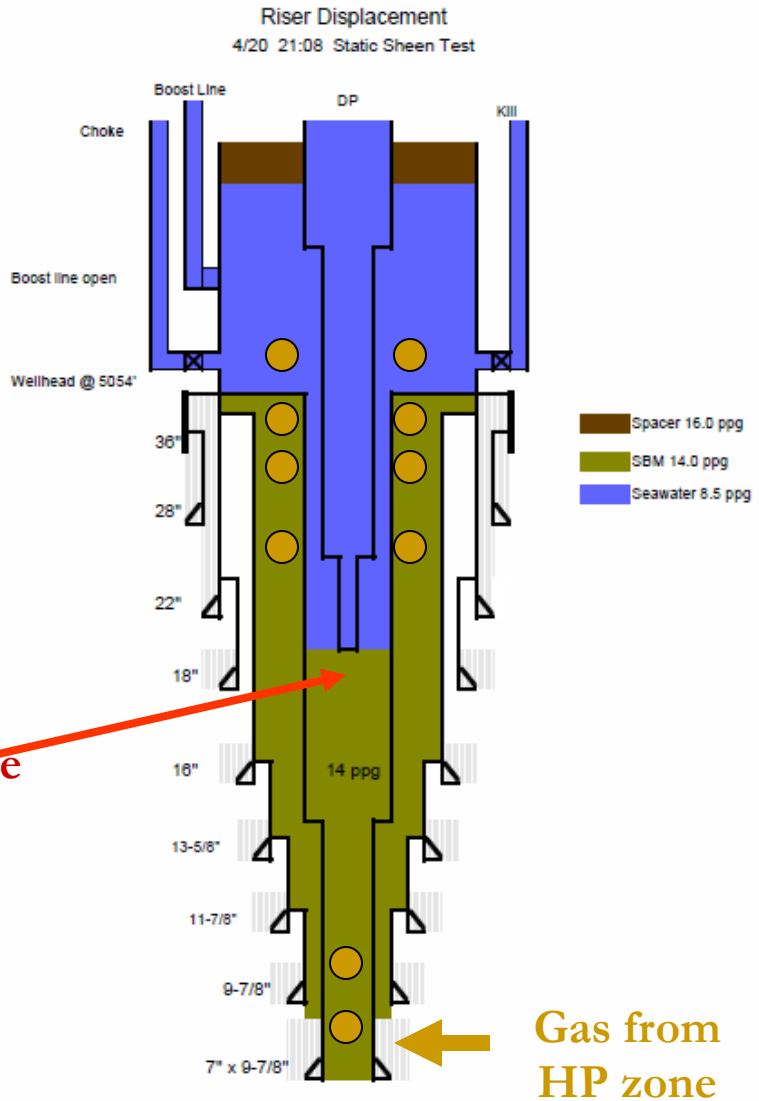
1. TIH to 8367' (±3,300' BML
2. Underdisplaced spacer
3. Closed annular

Test held 1400 psi

Source: Transocean

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*



2000 psi reduction in back-pressure
No mechanical bridge plug
No upper cement plug
No annular seal hold-down

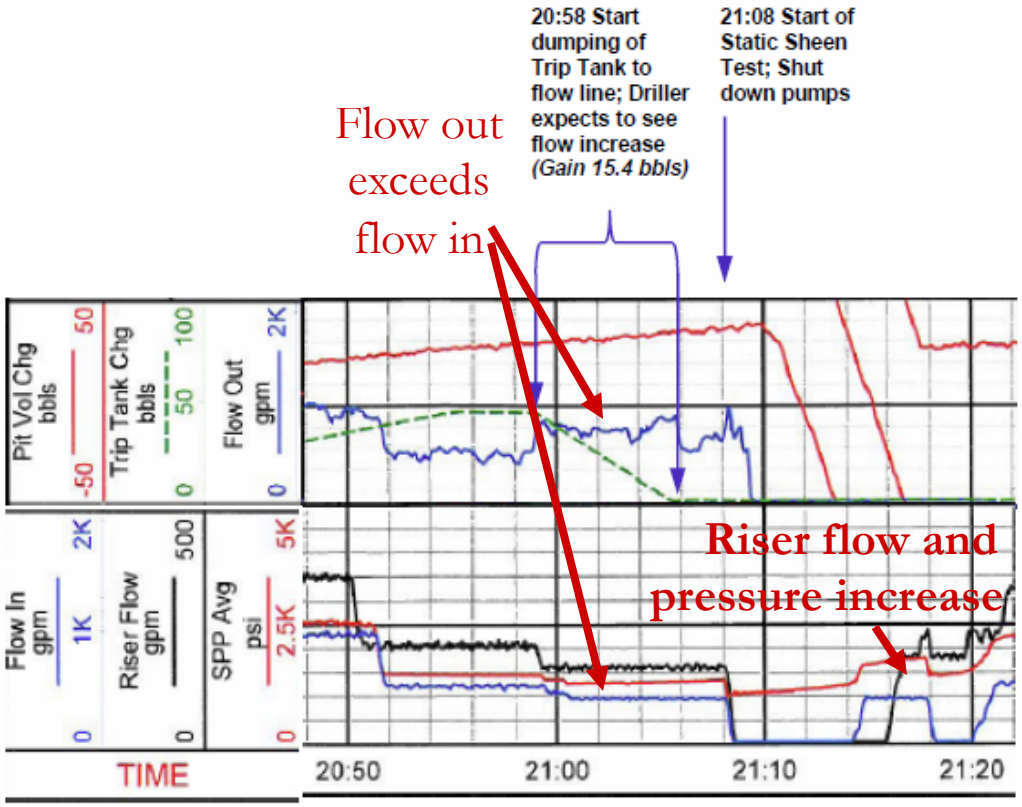
Gas from HP zone

Not all Information has been verified or corroborated. Subject to review based on additional information or analysis.

Source: Transocean

Loss of Primary Well Control
Review of Procedures (continued)

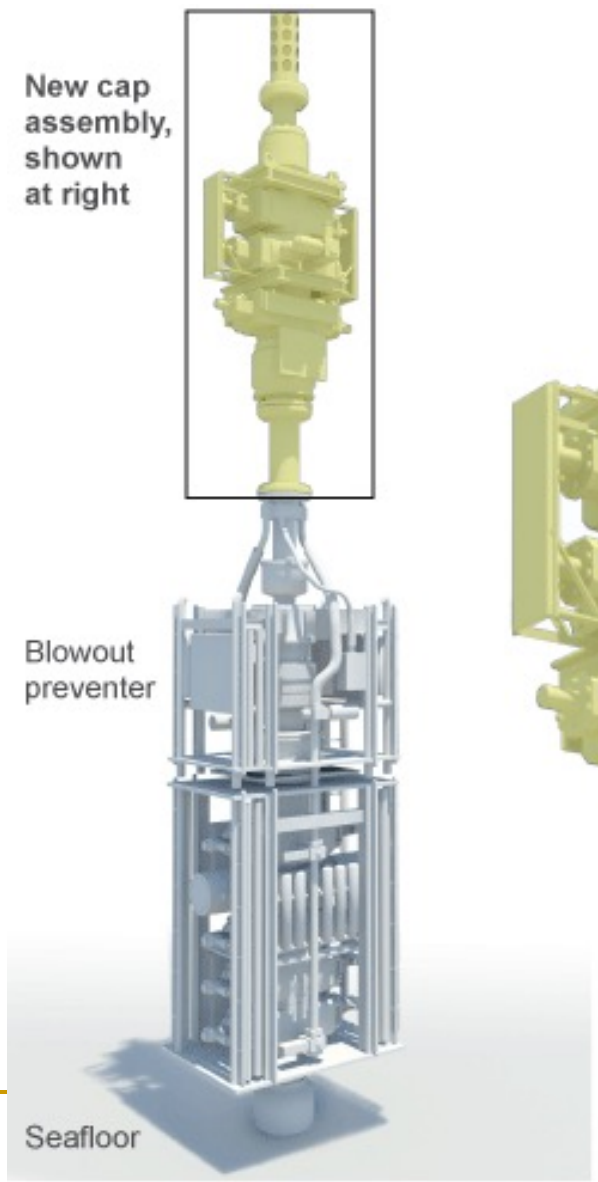
- **Flow Show at 20:58**
  - Trip tank being discharged to pits through flow line (normal procedures ahead of change from oil to water mud in active system)
    - ✓ *At same point pumps ramp down for stop at static sheen test*
  - Increased flow out due to discharge of trip tank
    - ✓ *Driller expected 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

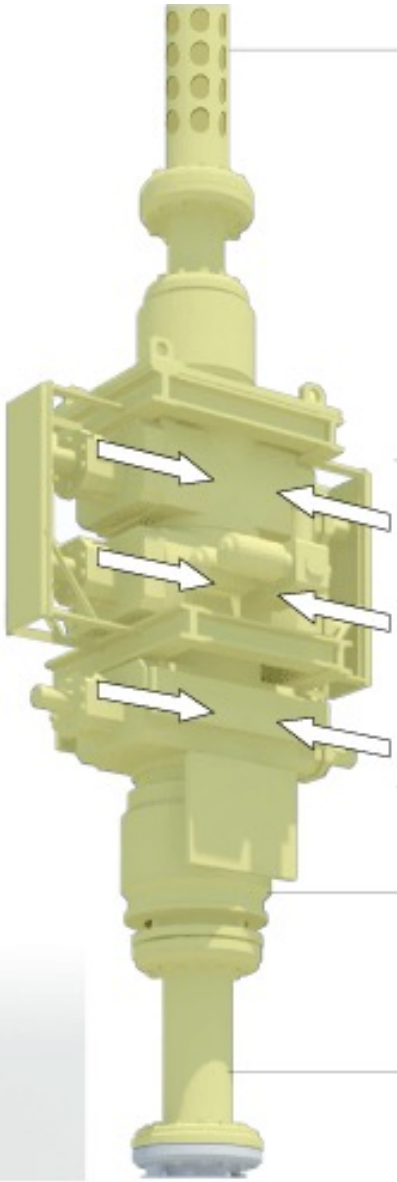


Source: BP OCS-G 32306 001 ST00BP01 Mississippi Canyon 252 Macondo, Last 2 hours before end of transmission

Source: Transocean

Containment Response (Cap Assembly)





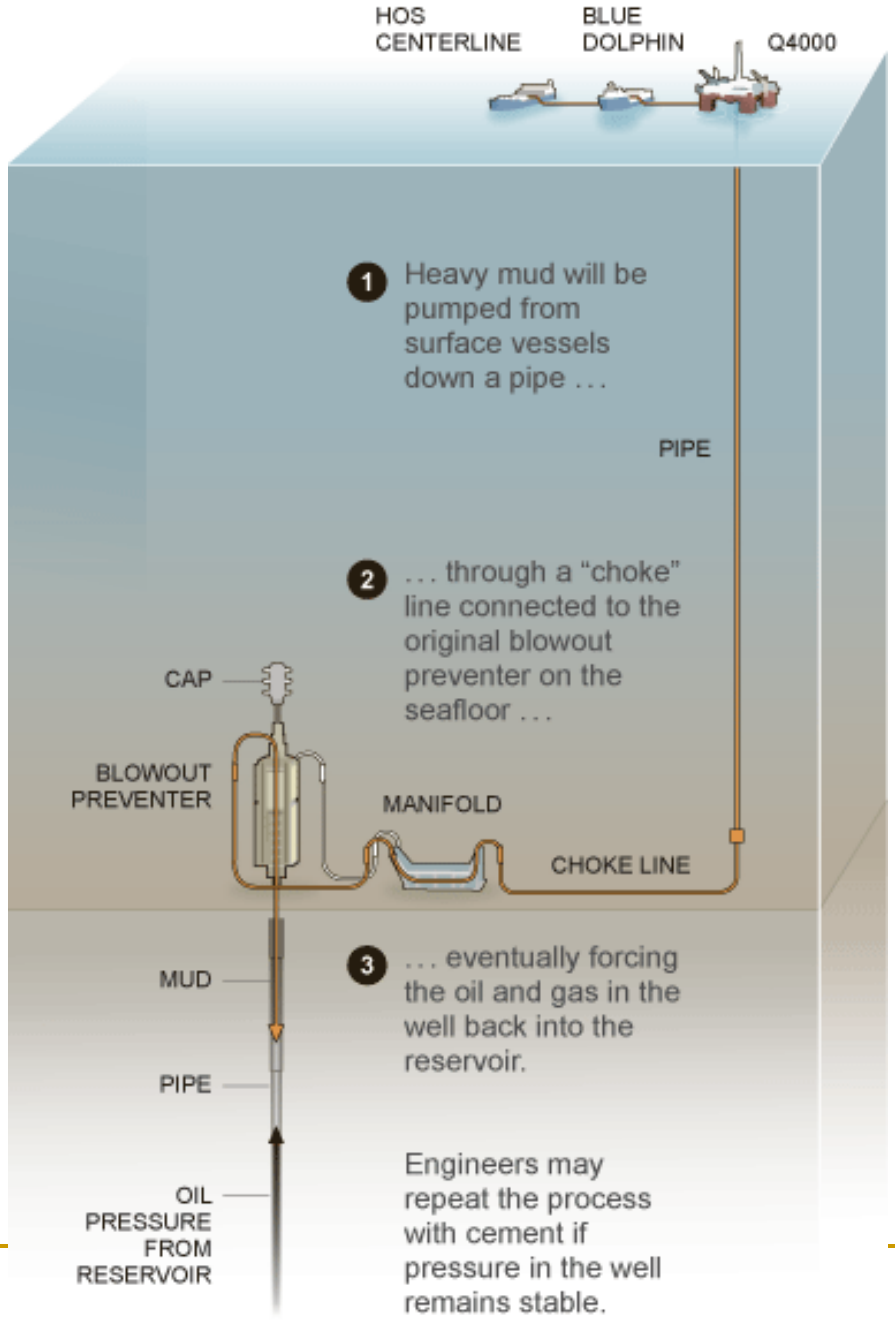
A perforated pipe was designed to allow oil and gas to escape during installation of the cap. It will be removed when the cap is closed.

SEALING CAP
The new cap has three rams, or valves, similar to ones on the well's blowout preventer. Once the cap is installed, the rams will be closed to stop the flow of oil to allow engineers to take pressure readings of the well.

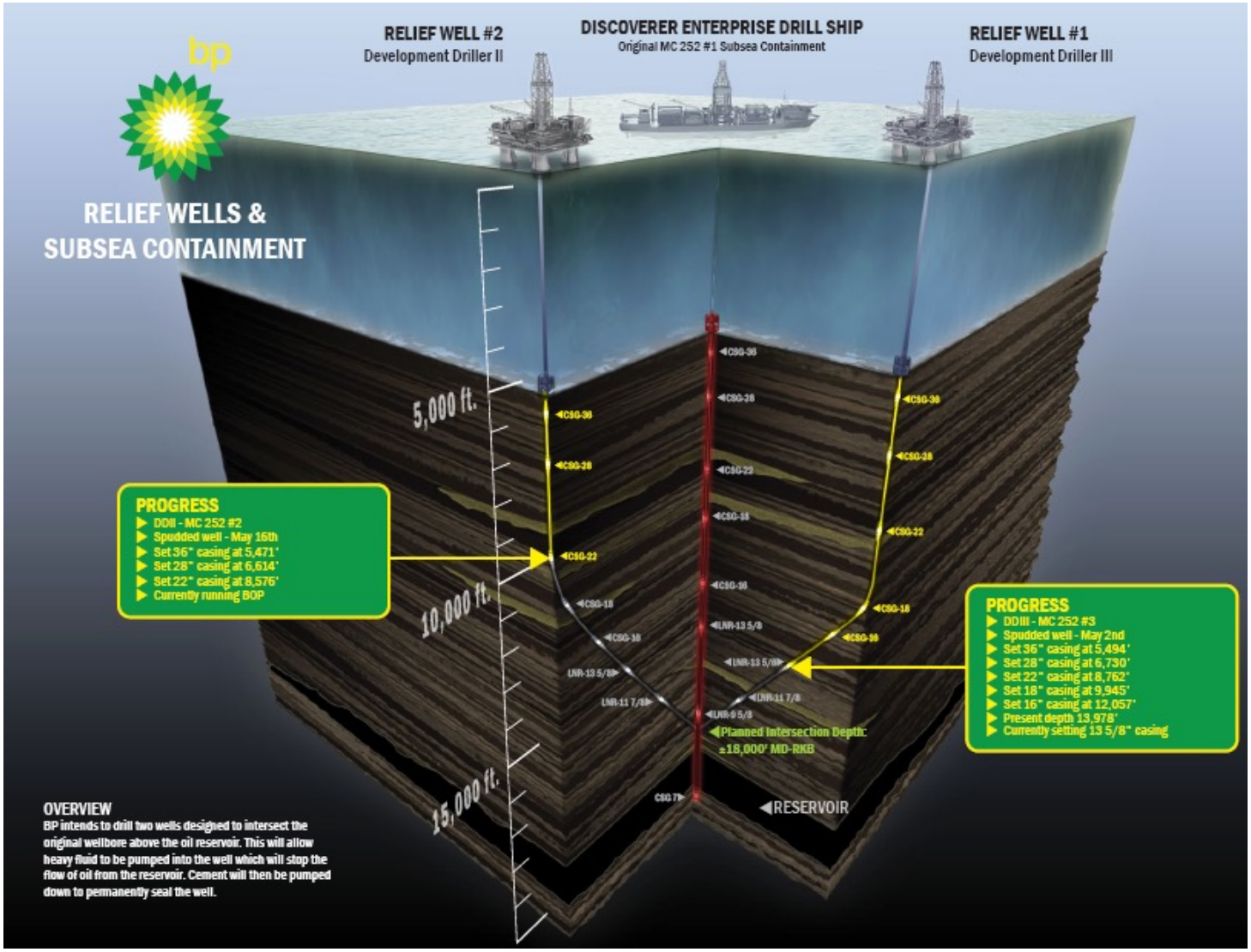
Anti-freeze is being pumped here to avoid the formation of icelike hydrates that could affect the locking mechanism.

A 12-foot tall connector pipe was bolted onto the top of the blowout preventer.

Static Kill


HOS CENTERLINE
BLUE DOLPHIN
Q4000
1 Heavy mud will be pumped from surface vessels down a pipe . . .
PIPE
2 . . . through a "choke" line connected to the original blowout preventer on the seafloor . . .
CAP
BLOWOUT PREVENTER
MANIFOLD
CHOKE LINE
MUD
PIPE
OIL PRESSURE FROM RESERVOIR
3 . . . eventually forcing the oil and gas in the well back into the reservoir.
Engineers may repeat the process with cement if pressure in the well remains stable.

Containment Response (Relief Wells)



Mid August

Source: BP

Oil Spill Magnitude