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Why "Do Not Disturb" is a Safety Message

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Key safety Q&A for waiting-on-cement (WOC) time

- What causes influxes of formation fluids into cements during WOC?
  - Many are caused by underbalances induced by rig operations!

- Why influxes by old mechanisms are undetected for leaks?
  - No downhole sensors and most are too small to see!

- How do influxes go undetected with newly reported leak mechanisms:
  - Mechanical annular seals are set, isolating hydrostatic pressures!
  - Mechanical sealing blocks observation of changes in fluid levels!

- What causes influxes by new mechanisms?
  - Fluid P/T changes in “pressure vessel” formed below the mechanical seal!
    - Leak-offs into exposed formations! (not likely in many cases)
    - Or more likely, thermal changes in fluids above the top of cement!

- Take-away lessons missed or ignored by many?
  - “Do Not Disturb” WOC to help avoid triggering an underbalance!
  - Keep annulus open or consider other solutions!

- Revised training curricula for cementing and well control?
  - Update to explain old and new mechanisms!
What are the old and new mechanisms during WOC?

- Old mechanisms have been researched and confirmed for many years:
  - Flow paths through mud channels
  - Microannulus between pipe & cement or cement & formation, stress cracks, or both
  - Flow through unset cement

- New mechanisms are recently reported and research started:
  - Sealing the annulus in subsea wellheads too early in WOC time
  - Changing thermal conditions in the drilling fluid causing an underbalance in cement
  - Underbalance is transmitted thru unset cement with zero gel time (ZGT) or low gel strength
  - 420 well study: 86% had 60 or more minutes ZGT & 57% had greater than 120 minutes ZGT
  - Many retarded cement slurries may have several hours of ZGT
How does the new mechanism work during WOC?

- Casing seal assembly is set in subsea wellhead (WH) after cement job.
- Seal is tested and isolates the hydrostatic pressure in the riser.
- The mud between WH and top of cement (TOC) cools, reducing fluid density.
- Leakoff and/or lower mud density causes an underbalance above TOC.
- The underbalance pressure is transmitted down through unset cement.
- Flowable zones are then underbalanced and begin to influx into the annulus.
- Depending on conditions, influxes range from small to large in rate/volume.
- Influxes flow to lower pressure zones and into pathways inside formations.
- Low rate flows can cause channels for sustained casing pressure (SCP).
- High rates may start cross-flows or underground blowouts with casing erosion.
- Negative pressure tests (NPT) may divert flows thru float valves to the surface.
- Flows are undetected until showing in NPT, at WH sensor, or rig’s bell nipple.
- Depending on time to close BOP rams vs. flow rate, a blowout may occur.
Case study of actual well: Mud Cooling in Most of Annulus Converts Overbalance into Underbalance.
Case study: Time-line of flow event

00:40 – Top plug bumped at 1150 psi (1000 psi > circulating) with planned volume.
00:43 - Floats tested & held after 5 bbl flowback. No immediate indication of losses during cementing. Post-job in/out data had 80 bbl losses……likely into weak zones below 18,215 ft.
01:00 – The wellhead casing seal assembly (WCSA) was set and sealed which blocked hydrostatic pressure of 5,000 ft column of drilling fluid in the riser.
01:00 – Cooling of trapped mud below WCSA caused loss of hydrostatic pressure, which transmitted thru unset cement, underbalanced five flowable formations, initiated pore-fluid in-flows down the annulus, and out-flows into a weak zone.
1:00 to 03:00 – As in-flows initiated and increased from each flowing zone below 17,684 ft, accelerating flow rates developed an underground blowout, which washed cement slurry out of annulus, and into weak zones below 18,215 ft.
12:55 – Casing pressure test was successful, indicating no breach in casing pressure integrity.
17:05 – A breach in the casing or other weak point (e.g. float valves) was initiated by:
   a) Excessive ΔP, as too much mud was replaced by seawater for negative pressure tests.
   b) Thermal effects caused lower mud density and hydrostatic pressure inside the casing.
   c) Formation sands flowed into the annulus and eroded holes in the casing.
   d) Combinations of above, which allowed formation pressure and flow up inside the casing.
21:38 - Hydrocarbons pass BOP and enter riser.
21:40 – Formation fluids blowout at rig floor causing a severe LWC incident.

NOTE: On Sept. 10, 2010, the top section of cement passed a pressure test which indicated that formation flows traveled down the annulus to enter the casing. A “u-tube” test on Oct. 7, 2010 found no light fluids (hydrocarbons & nitrogen) in the annulus showing that “the nitrified cement slurry used in the annulus likely did not fail” (BSEE report 9-14-2011).
Formation Fluid Influxes Triggered by $\Delta T$

- End of Cement Job & Set Casing Seal Assembly

Change in Synthetic Oil Mud Equivalent Weight Due to Cooling in Sealed Annulus

- 14.2 ppg pore pressure @ 17684'-17693'
- 13.0 ppg pore pressure @ 17788'-17791'
- 12.6 ppg pore pressure @18051'-18233'

Cooling temperature change F

Equivalent Mud Weight

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Case study: influx flow pathways during WOC time

- Blowout to Surface
- Loss of Overbalance Above Cement
- Loss of Well Integrity
- Underground Blowout

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Conclusions

1. User-friendly computer simulators for thermally-induced loss of wellbore pressures and associated parameters should be developed for rig and office personnel.

2. Thermal modeling software may be used for many applications, such as:
   a. Predicting hydrostatic pressures when logging, tripping DP, running casing/liners, and WOC time.
   b. Cementing laboratory test temperature and pressure ramping schedules.
   c. Predicting microannuli created by thermal effects.
   d. ECD and ESD profiles to minimize or avoid kicks and lost circulation.
   e. Frac gradient and hole collapse pressure profiles.
   f. Negative pressure testing, casing pressure testing, and shoe leak-off testing.
   g. Managed pressure drilling, underbalanced drilling, and overbalanced drilling.

3. Predictions by thermal simulations may justify preventive measures to avoid SCP and LWC incidents.

4. The “Zero Static Gel Strength” time for cement slurries cannot be considered a completely safe WOC time interval for drilling and cementing engineers. An overbalanced state in a well is not always maintained during this time interval (static gel strength development from 0 to 100 lbf/100ft²), including where other sources of annular pressure decay are present.

5. Case study found that claims of cement job failure were contradicted by positive results in downhole barrier testing (pressure test, U-tube, & logging results).
Thank You for Your Attention

Questions or Comments?