SPE GCS Annual Drilling Symposium

# *Well Integrity: What Completions and Production Engineers Need from Drillers to Make the Well Successful*

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# What is Required for Completions & Production Ops?

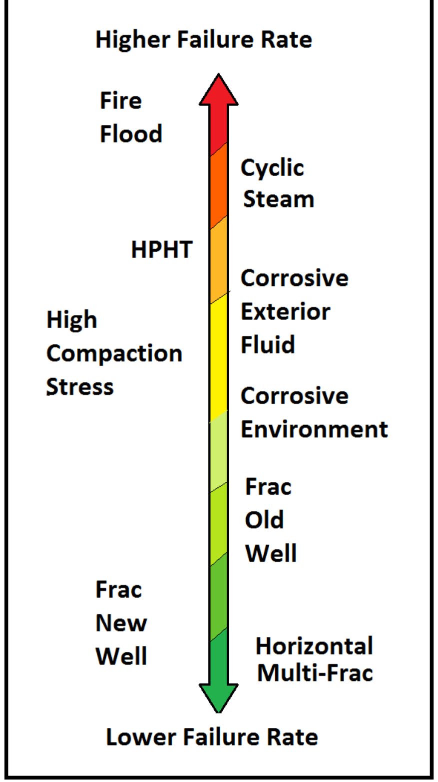
- A smooth transition from vertical to horizontal and the straightest wellbore possible in the zone of interest (minimum undulations).
- A cement job that will seal off leak and inflow paths and protect the casing from outside corrosion.
- Tubular joints that are made up to the best standards.
- A wellbore large enough to run required equipment to depth.

# Risk Factors Recognized:

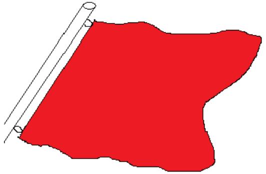
- **Type of Well**
- **Maintenance Culture**
- **Era of Construction**
- **Geographical Location**
- **Age of Well**
- **Design & Construction**
- **Usage Change**

**Full Details in SPE 166142**

Figure 6
Range of Failures
by Well Type

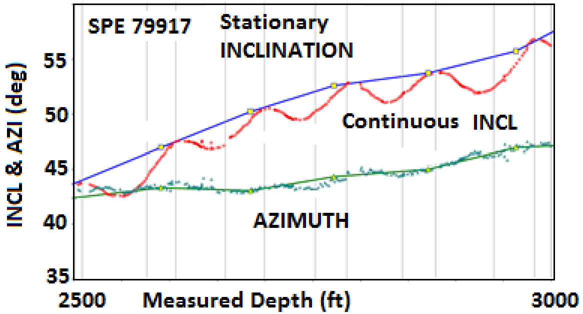


# Early Warning Signs?

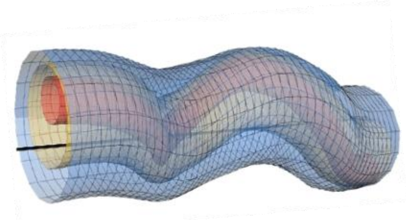


1. Record time drilling (poor wellbore inclination control)
2. Inadequate cement (TOC too low and poor seal)
3. Make-up problems (Joints # 1 leak problem)
4. Slim hole wells

# Smooth out the hole…
# Buckling Failure Points (symptoms & causes)




Causes?
Too much dog leg severity (DLS) – drilling too rapidly, Subsidence, etc.



(Graphic courtesy of Gyrodata – SPE Dec 2015)

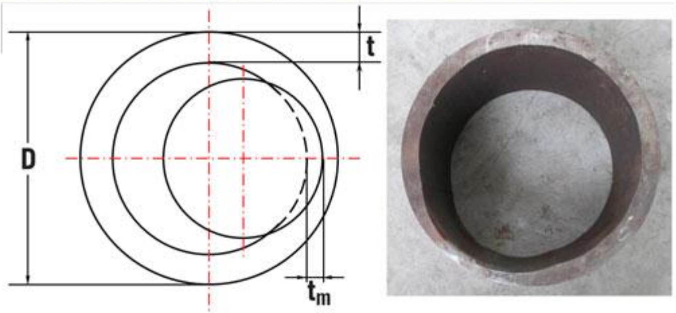
Source: Rassenfoss, S., “Drilling Wells Ever Faster May Not Be the Measure of Success,” SPE JPT

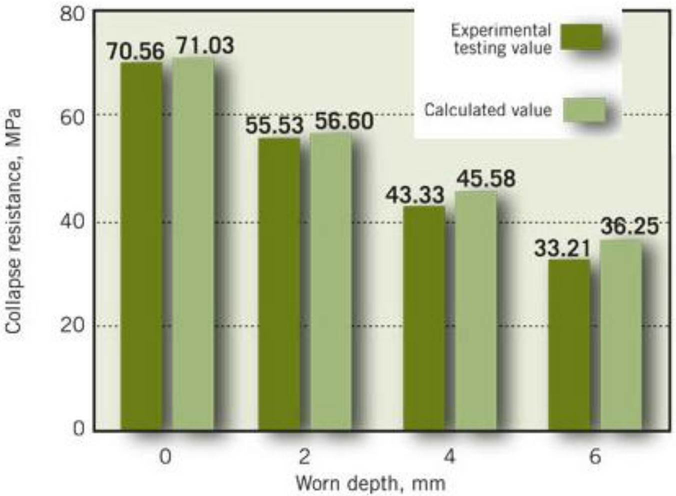
# Casing Wear During Drilling

http://www.ogj.com/articles/print/volume-111/issue-02/drilling---production/empirical-formula-given-for-collapse.html

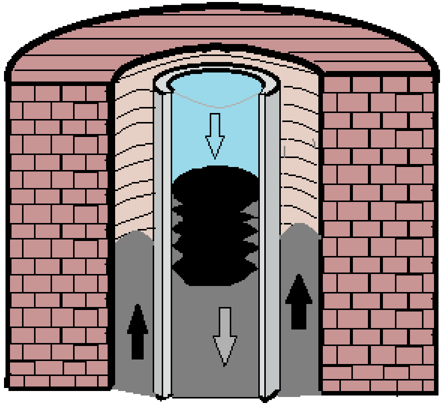
- Rotation, sliding, fishing can case abrasion wear. .

GEOMETRIC MODEL AND MACRO MORPHOLOGY OF SPECIMEN



# Cement Circulation



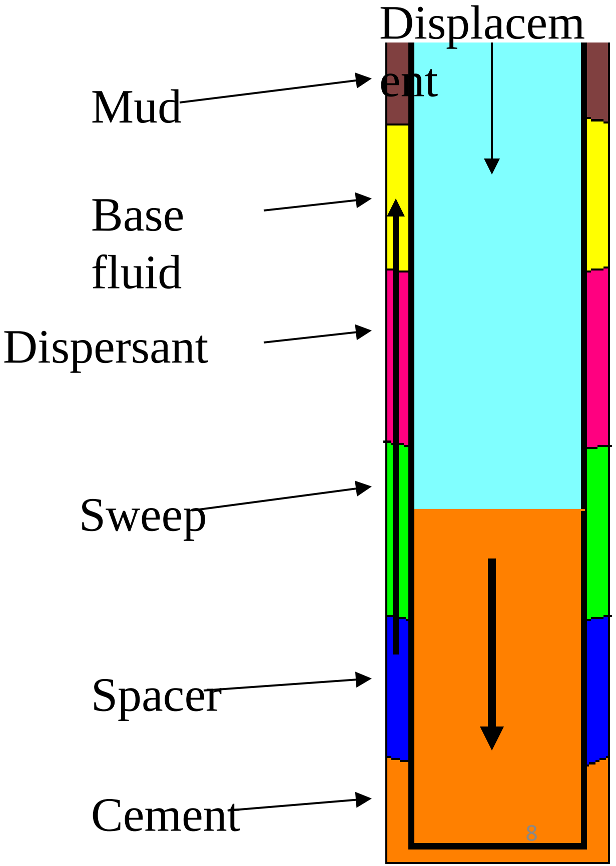
Major issues

1. Mud and hole conditioning
2. Chemical flushes to disperse, displace and separate cutting from mud.
3. Uniform displacement around the pipe
4. Hitting the top-of-cement goal
5. Avoiding fracturing the well with cement.

# Chemical Flush Basics

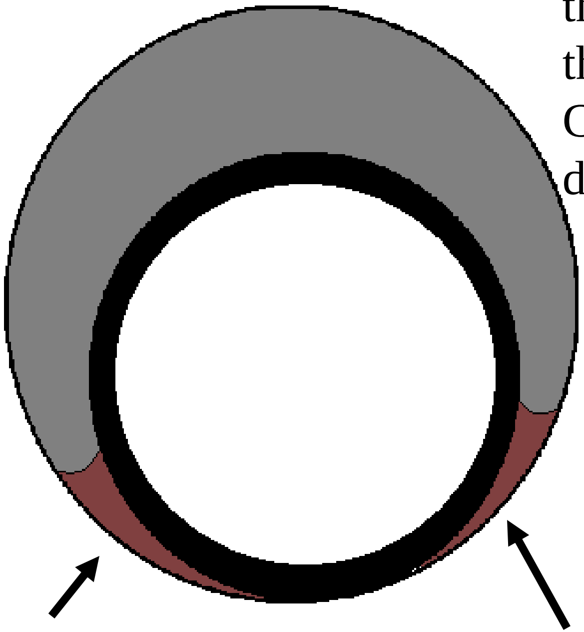
1. Base fluid condition
2. Dispersant
3. Sweep
4. Spacer
5. Cement

A properly designed flush focuses on time of contact, fluid mixing, lift of solids and avoidance of cement contamination.

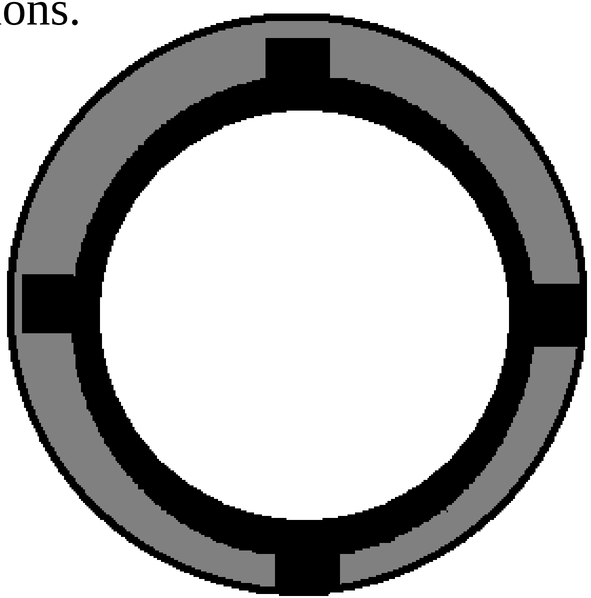


# Centralizers – require time and harder to run, but often better isolation.

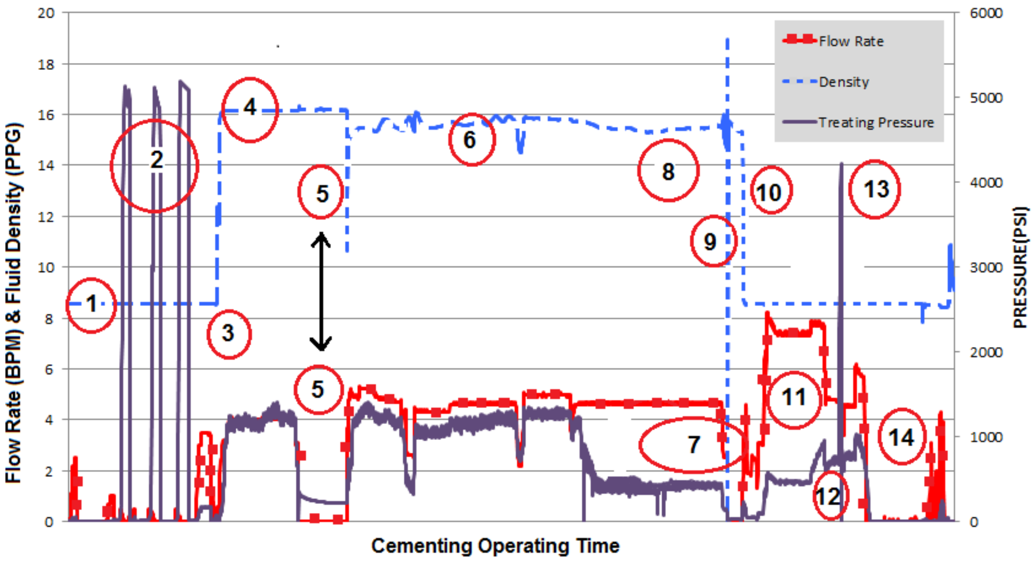
Use of centralizers improve the ability of the cement to surround the pipe, displacing the mud and creating a channel-free seal. Centralizers also assist running casing in deviated sections.



Area of undisplaced mud – a mud channel remains, requiring squeezing.



# Cement Charts: give me 1.) pressure; 2.) density; 3.) injection rates; 4.) Return rate; & 5.) press. test.




| |
|---|
| 1. Filling surface equipment with fresh water |
| 2. Pressure test – two leaks in surface piping followed by a successful test. |
| 3. Pump sweeps and spacers to clean mud and separate from cement. |
| 4. Constant density batch mixed cement |
| 5. Shut down to drop bottom plug & switch to on-the-fly mixed cement |
| 6. Pumping on-the-fly mixed cement, note density variance. |
| 7. Cement free-fall, heavy cement pushing out lighter mud. More fluid in than out. |
| 8. Near end of cement pumping. Density variance past 0.5 ppg. |
| 9. Shut down pumping, flush surface lines and drop solid top plug. |
| 10. Bottom plug lands, diaphragm ruptures, cement flows into annulus. |
| 11. Free-fall make up, more fluid flowing into well than flowing out. |
| 12. Cement displacement pressure too low. Check top of cement as a precaution. |
| 13. Top Plug “bump” (lands in shoe track). – cement placement complete. |
| 14. Hold pressure until cement sets. |



Valuable information can be gathered from the cement pump chart.

# How Much Cement is Needed for Isolation? Every inch of cement is NOT required to be perfect.

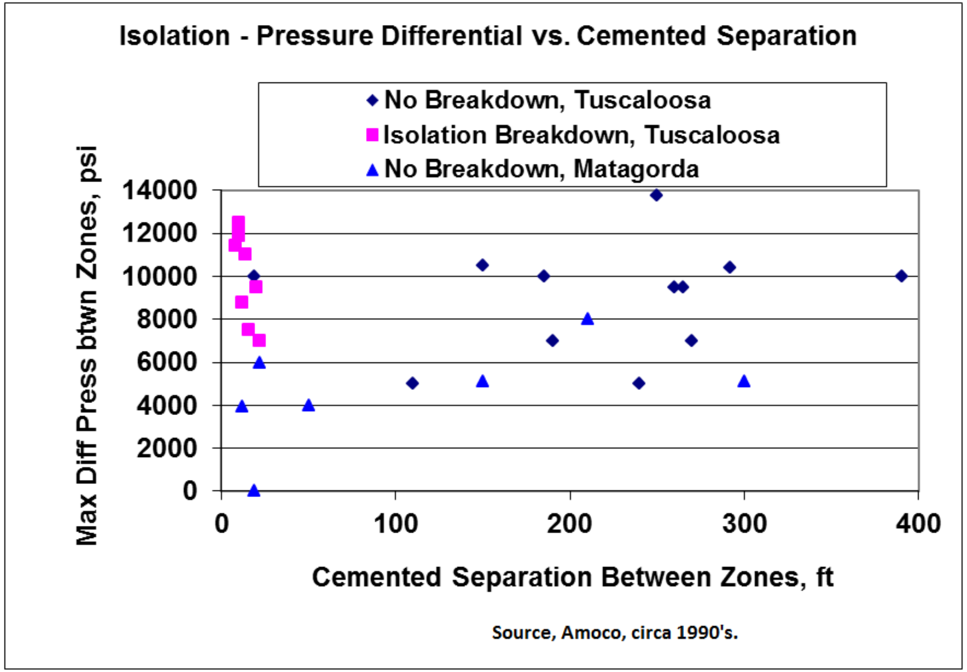
Quality of cement is more important than volume but large volumes are desired.

Isolation can only be measured with a pressure test.

**Bond logs are not always best tool**

- ~10% channels missed.
- Instances of false negatives & positives.

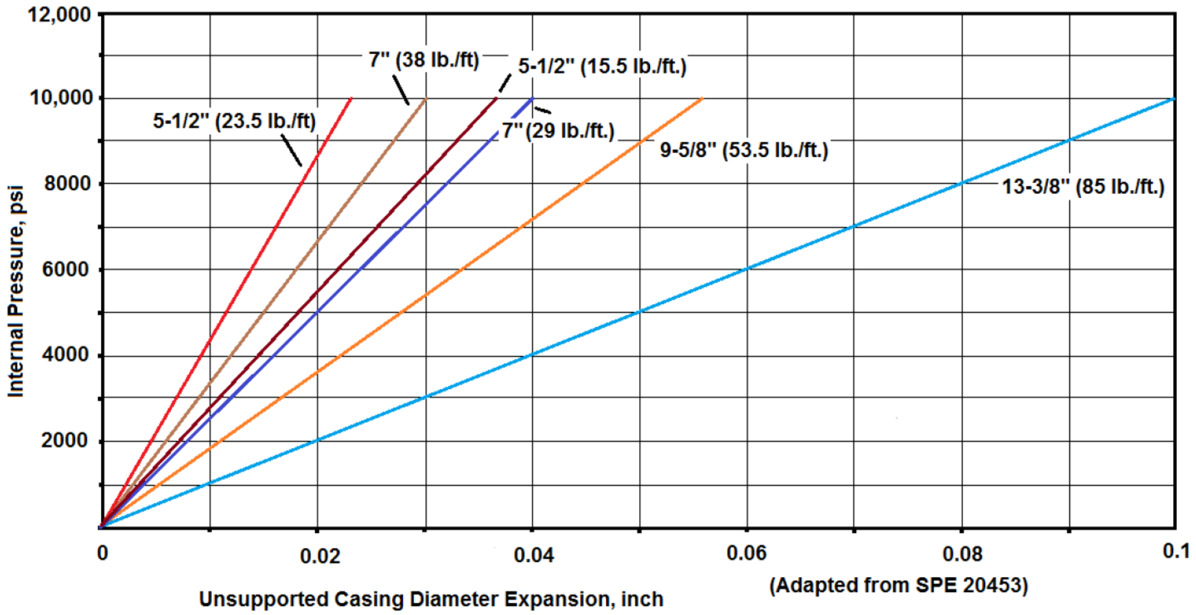
**Over 10,000 psi can be held with less than 50 ft of cement, but 200 to 300 ft is routinely used.**




SPE 166142, Barrier vs. Well Failure, King

# Expansion

## Casing Diameter  Deflection from Internal Pressure



# Severe Pressure Cycling
## Small time Interval, and pressure swing

Caution – this test is not equivalent to conditions found in a well

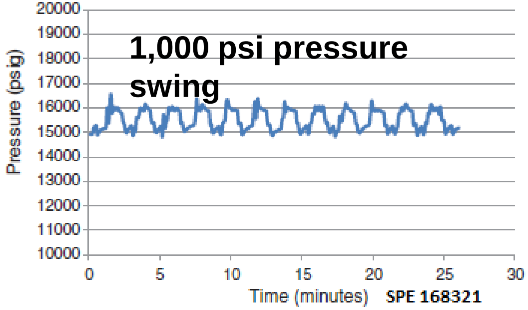



Fig. 6—HP/HT cement-sheath cyclical-loading test, 12 cycles of a 1,000-psi magnitude, Set A.

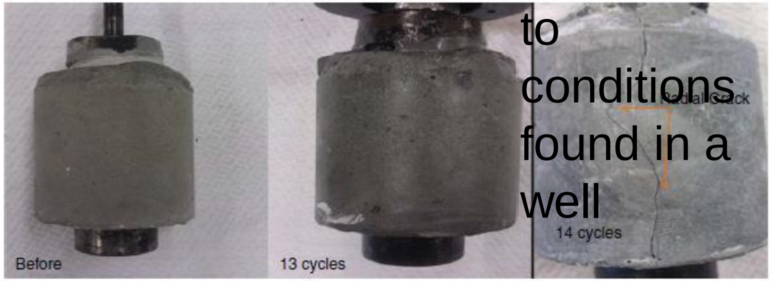



Fig. 7—Set A, 14 cycles created a radial crack in the cement sheath.

Both examples had sleeve type confining of 15,000 psi

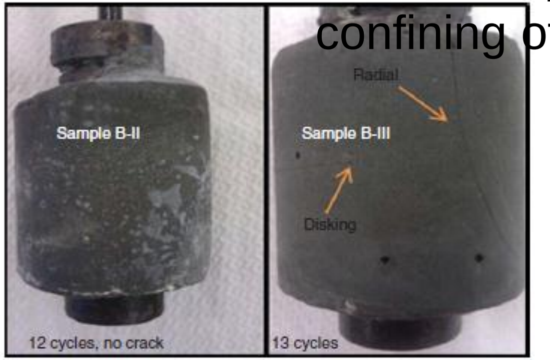



Fig. 9—The 13th cycle, the failure cycle under 2,000-psi differential.

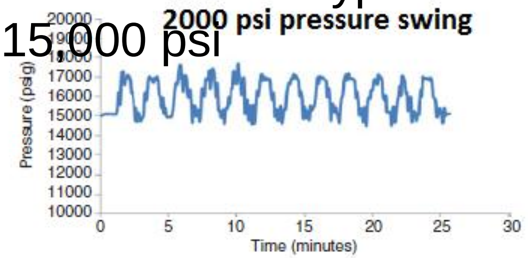



Fig. 10—HP/HT cement-sheath cyclical-loading test, 12 cycles of a 2,000-psi magnitude, Set B.

SPE 168321

Quick Overview

# 1st - Pre-Fracturing Checks…. Drilling & Completion

- Geological issues (faults, karsts, soft sands, high & low press).
- Pipe design suspect (corrosion resistance?/embrittlement ?).
- Unknown cause of frequent shoe test failures.
- Poor coupling make-up (evidenced by numerous thread leaks).
- Dog leg induced casing buckling.
- Casing wear from drilling, fishing, milling, etc.
- Hole washouts (drilled hole > ~4" over pipe OD).
- Inadequate vertical pipe centralization.
- Inadequate mud conditioning
- Chemical flush prior to cementing. (=> mud channels?).
- Gas cut cement.
- Cement top below design.

***<u>NOTE – these are lists to check, but not check lists.</u>***

# 2nd - Pre-Fracturing Checks… Fracturing History

Quick Overview

- Initial Frac or Refrac?
  - Application of pressure – sudden or incremental?
  - Cyclic pressure application
    - Highest pressure achieved.
    - Number of pressure cycles over 15? Over 30?
- Presence of uncemented section in the mostly cemented upper vertical (this is a special case, study needed)
- Erosion monitoring
- Very Old Wells?
- Frac Hits – problem?

***<u>NOTE – these are lists to check, but not check lists.</u>***

# $3^{rd}$ - Pre-Fracturing Checks Focuses on Previous Operations & Production History

- Unexplained annular pressure buildup.
- Cement squeeze history & cement squeezed perforations
- Packer setting points
- Cement isolation failure history – why and where?
- Wellhead Issues
- Production or proppant erosion of tubulars (> design velocity?)
- Pressure application and pressure cycling effects
- Subsidence effects

Quick Overview



***<u>NOTE – these are lists to check, but not check lists.</u>***

# Conclusions

- We can drill a well that we cannot complete and we can complete a well that we cannot produce – either way, we lose money - (Records don't mean a thing if the well fails.)
- Fracturing and particularly multi-fractured horizontal well development places an extraordinary burden on the casing and cement.

# THANK YOU

# QUESTIONS & COMMENTS