The Case History of an Underground Flow Offshore Texas

An Interactive Group Learning Exercise

Developed by
John Rogers Smith, P.E., Ph.D.
Louisiana State University

Funded by
Minerals Management Service
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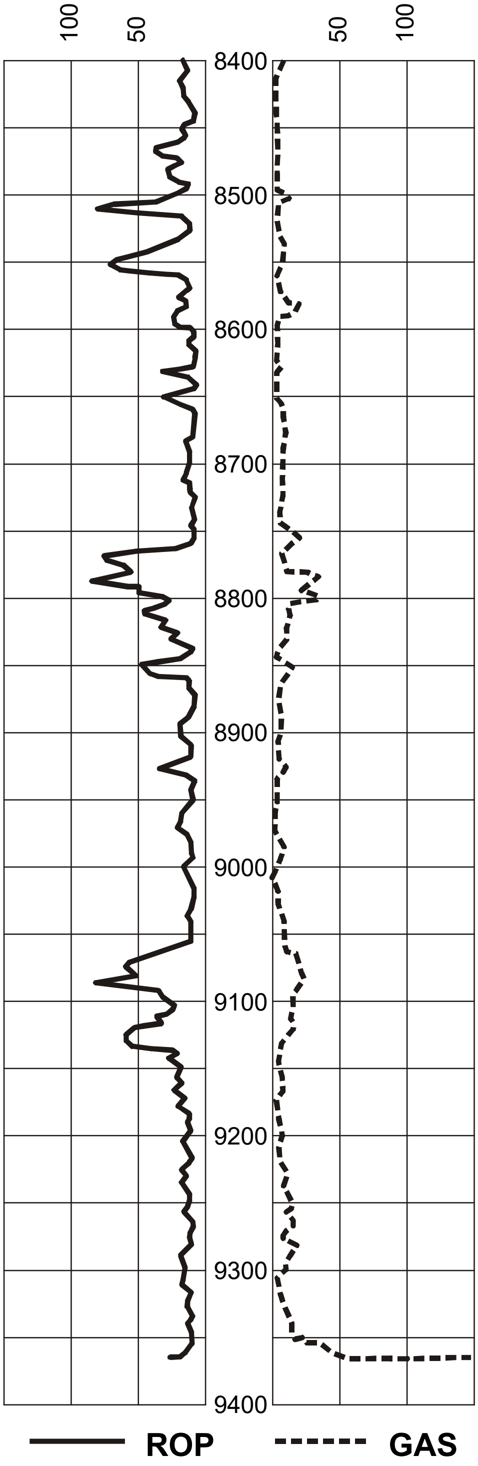
Overview

- Begins during platform development drilling during 1980’s
- The real beginning a few months earlier
- Focus on “Turning Points”

Mudlog

6th Well



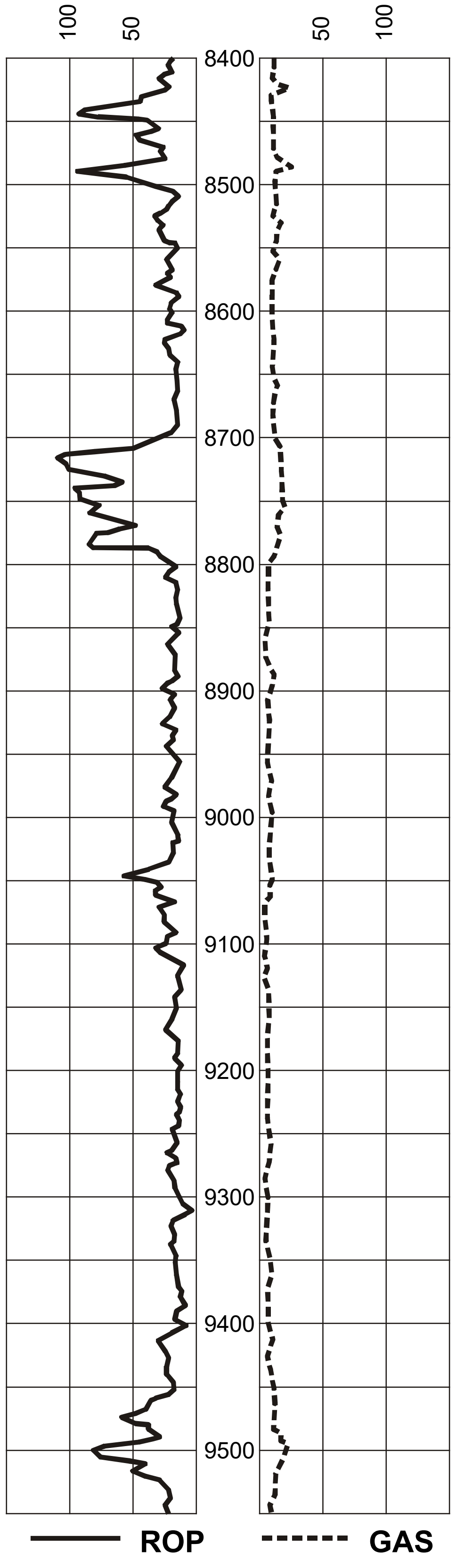
Unanticipated Pressure

- Kill wt. mud
  = mud wt. + (SIDPP/(.052 x TVD))
  = 9.8 + (600/(.052 x 8710'))
  = ______________________
- Drill pipe stuck
- Required 13.6 ppg mud to stop flow
- Cemented drillstring in hole

Offshore Texas Case History

Mudlogs

5th Well



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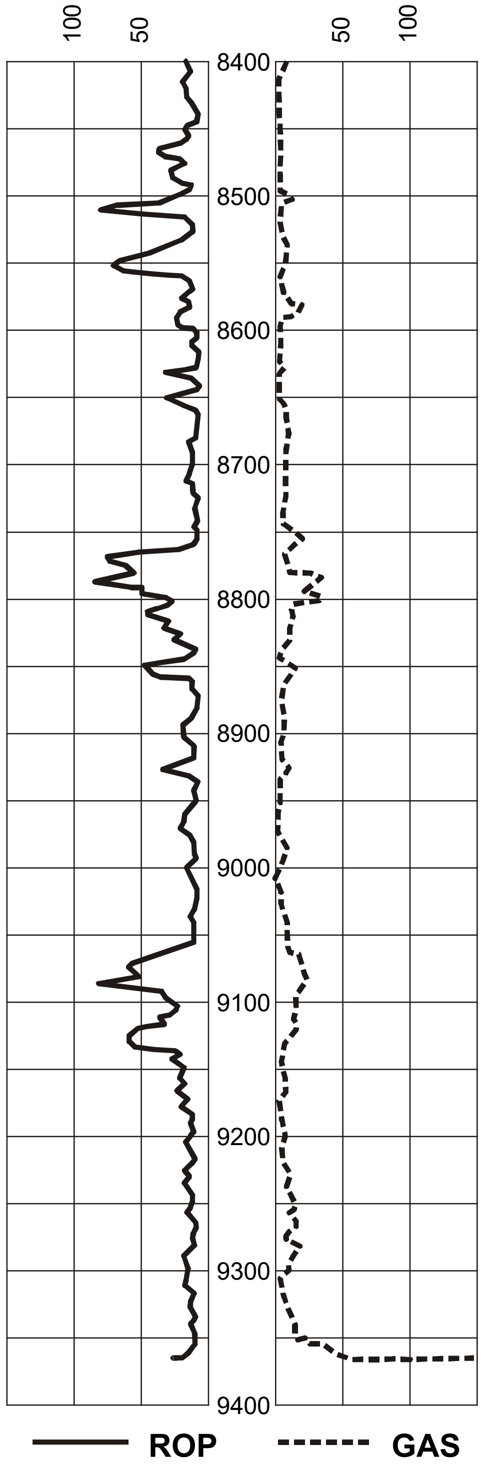


Unanticipated Pressure

- Moved well location
- Took kick 30’ shallower in same drilling break; shut in immediately; 3 bbl. gain
- Kill wt. mud
  $= 12.6 + (800 \text{ psi}/(.052 \times 8680'))$
  $= 14.4$ ppg
  (Note: Pressure at shoe exceeds the fracture pressure)
- Pipe stuck while working it through the Hydril
- Killed well with 14.4 ppg
- Cemented drillstring in well to plug back

What's Wrong Here?

Geologic Possibilities

- Pressures higher in section due to being in different fault block
- Pressures shallower than offsets due to missing stratigraphic section

Neither geologic possibility was supported by either geological or geophysical data

Man Made Possibilities

- Pressure transfer in offset well
- 5th well was one of the following:
  - closest offset
  - had seen this section normally pressured
  - had a major well control problem deeper

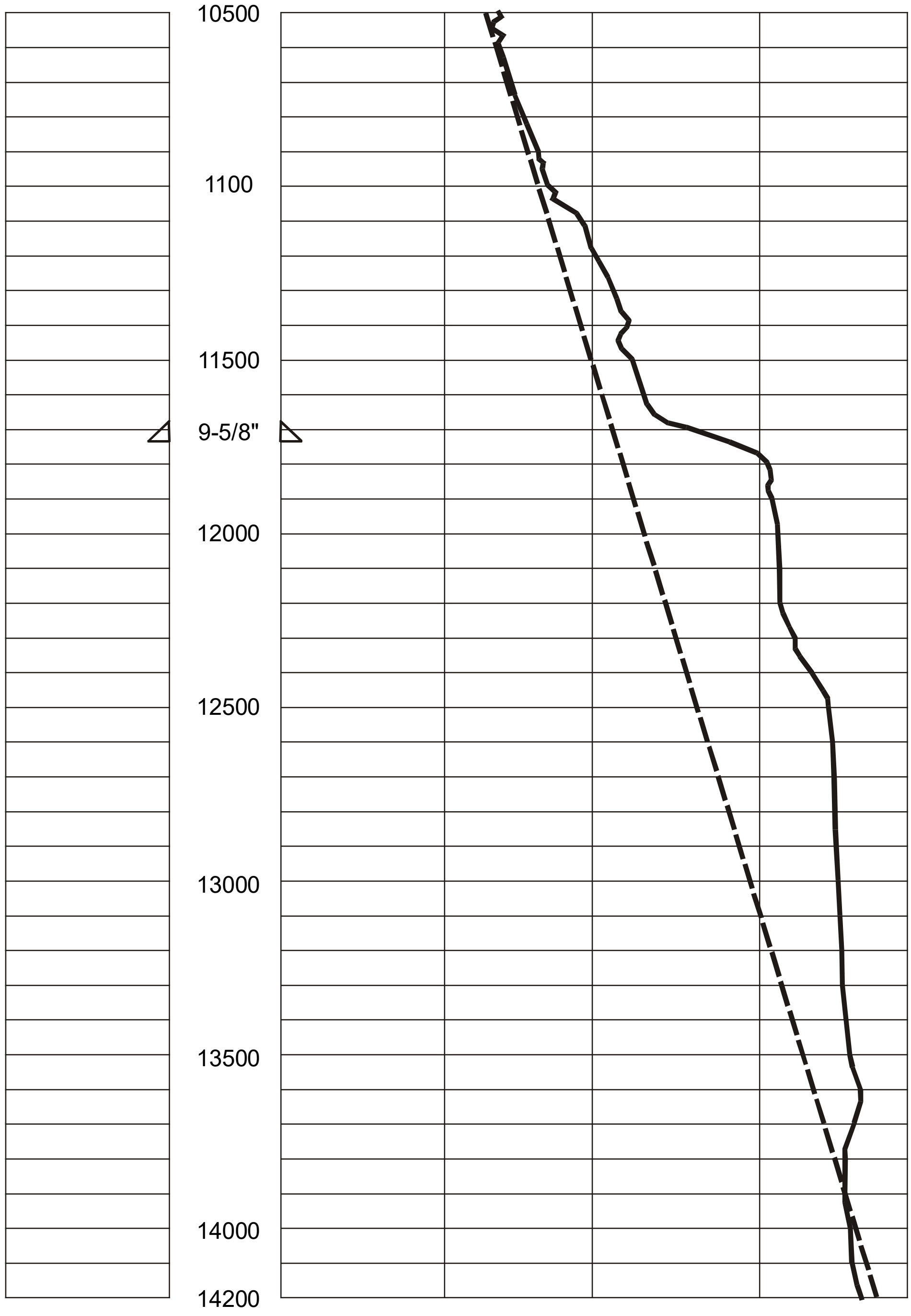
Reaction

- Establish ad hoc, multi-disciplinary team
  including division operations manager and assigned essentially full time to this problem
  - Drilling Engineers
  - Drilling Supervisors
  - Production Engineers
  - Log Analysts
- Re- enter 5th well
- Clean out to TD
- Run logs:
  - temperature
  - noise
  - cement bond
  - pulsed neutron
- Check annulus pressures

Offshore Texas Case History

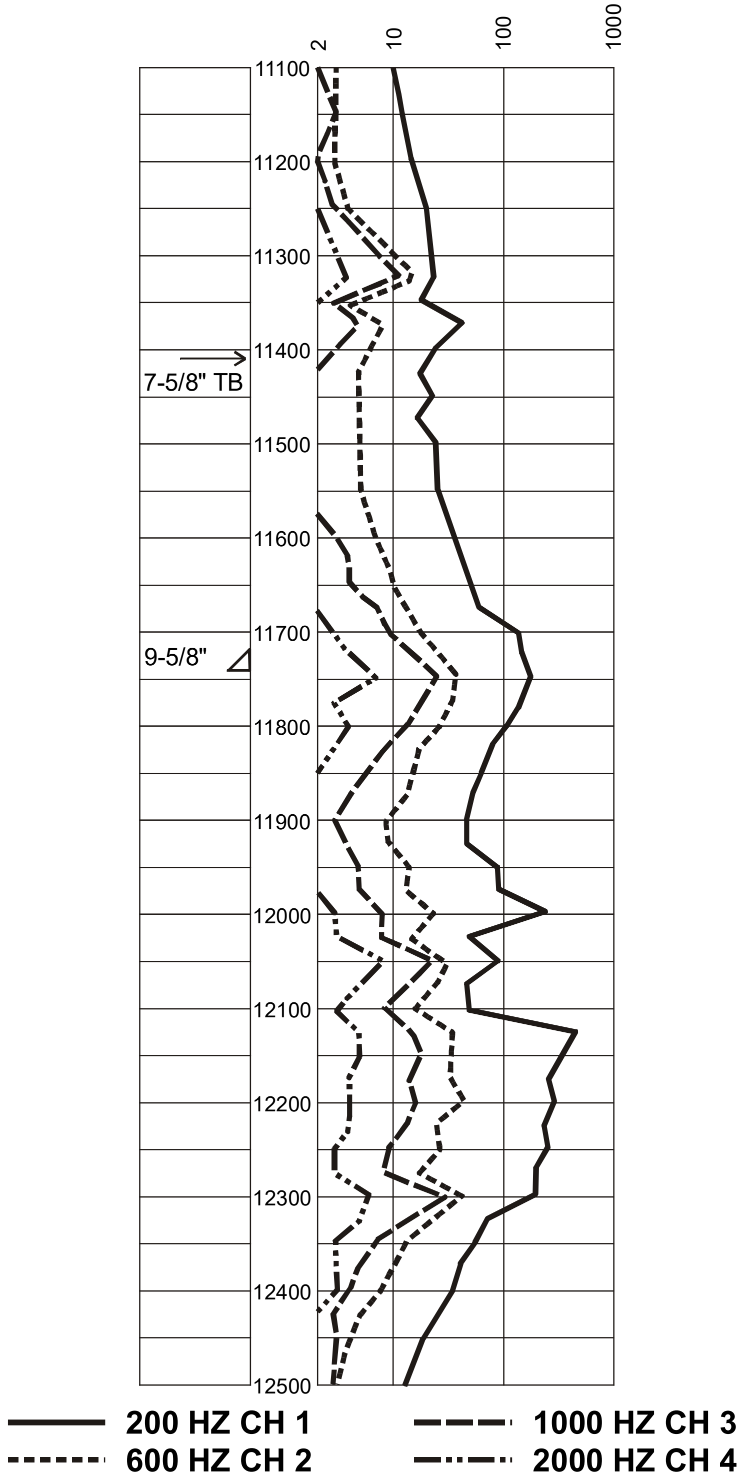
Temperature Log

Before



Noise Log

Before



Cement Bond Log

"Free Pipe" From 11900'

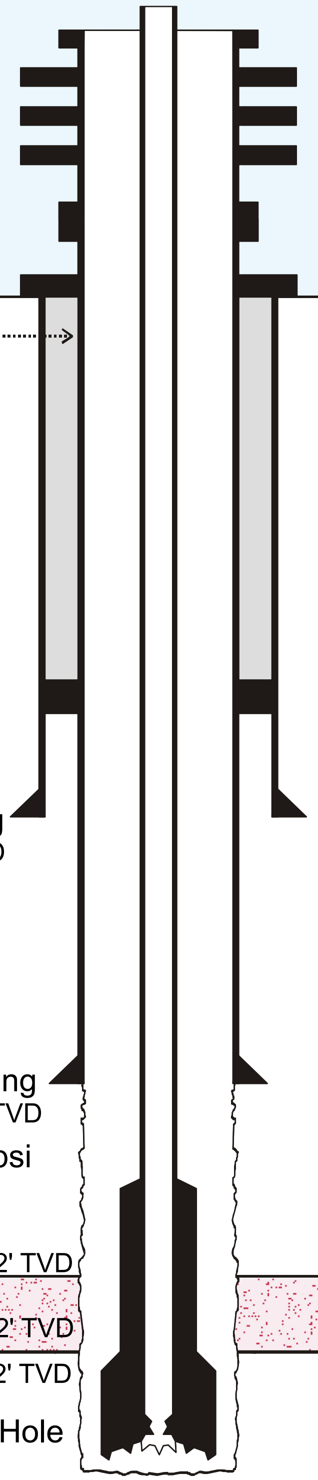
(170' Below 9 5/8" Shoe) To 14100'

How Did We Get In This Shape?

Let's review the "Well Control Problem" in the 5th well

Offshore Texas Case History

Well Plan



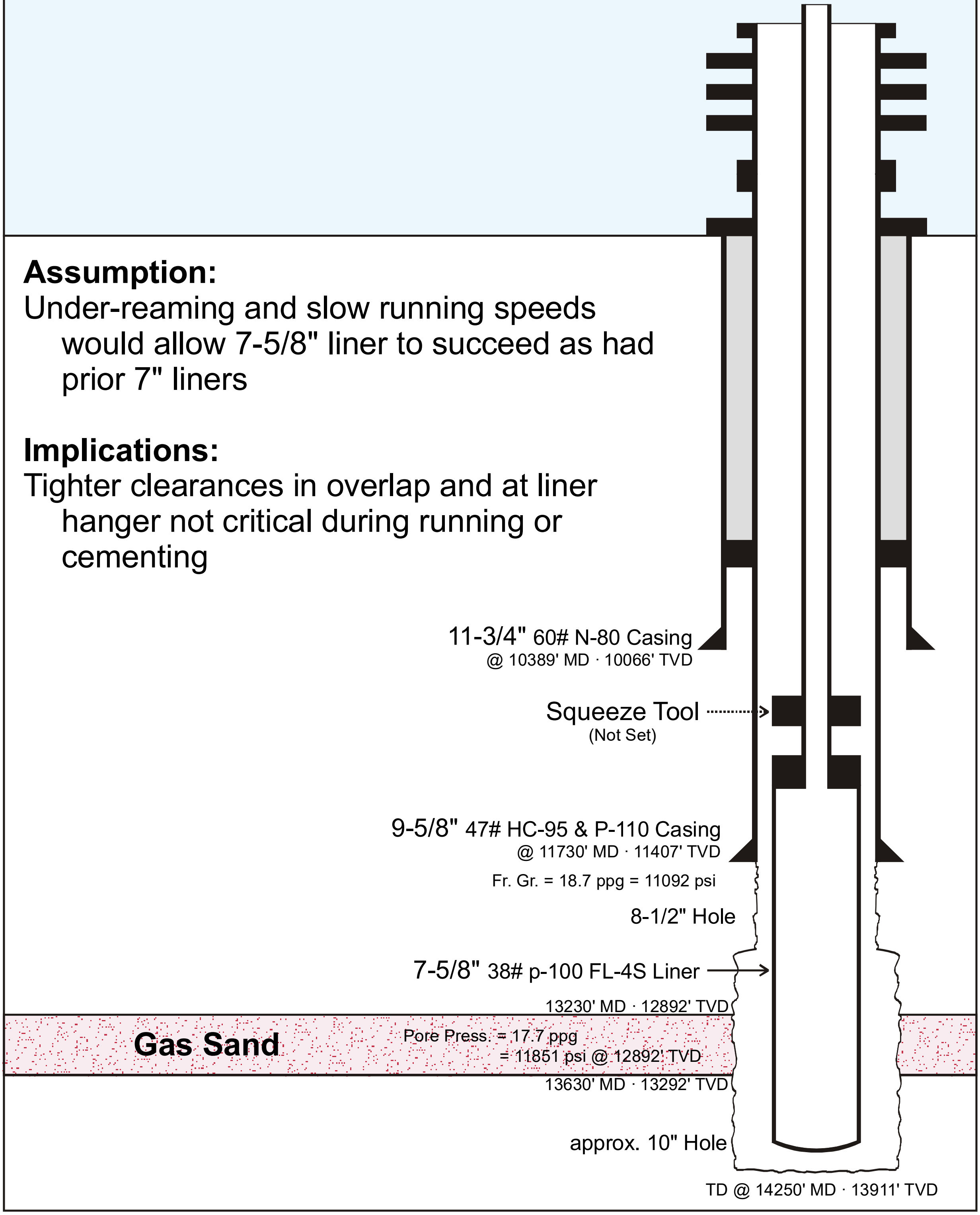
Implications:

1. Similar to four previous successful wells
2. Maximum possible SICP = 9723 psi
3. Kick tolerance = Gas Kick of 670' ~ 22 bbls

Well Plan

Assumption:
Under-reaming and slow running speeds would allow 7-5/8" liner to succeed as had prior 7" liners

Implications:
Tighter clearances in overlap and at liner hanger not critical during running or cementing

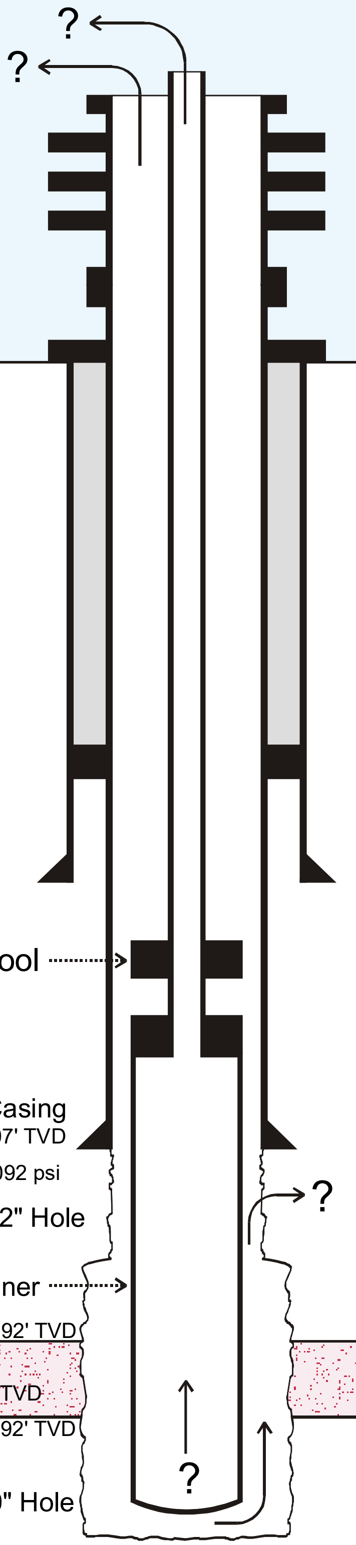


Running Operation

Known:
1. Run very slowly
2. Run with "pump open shoe"

Unknown:
1. Whether shoe was opened to allow inside flowback while running
2. Whether displacement was measured or was correct during running
3. Actual by-pass area on inside or outside of liner equipment

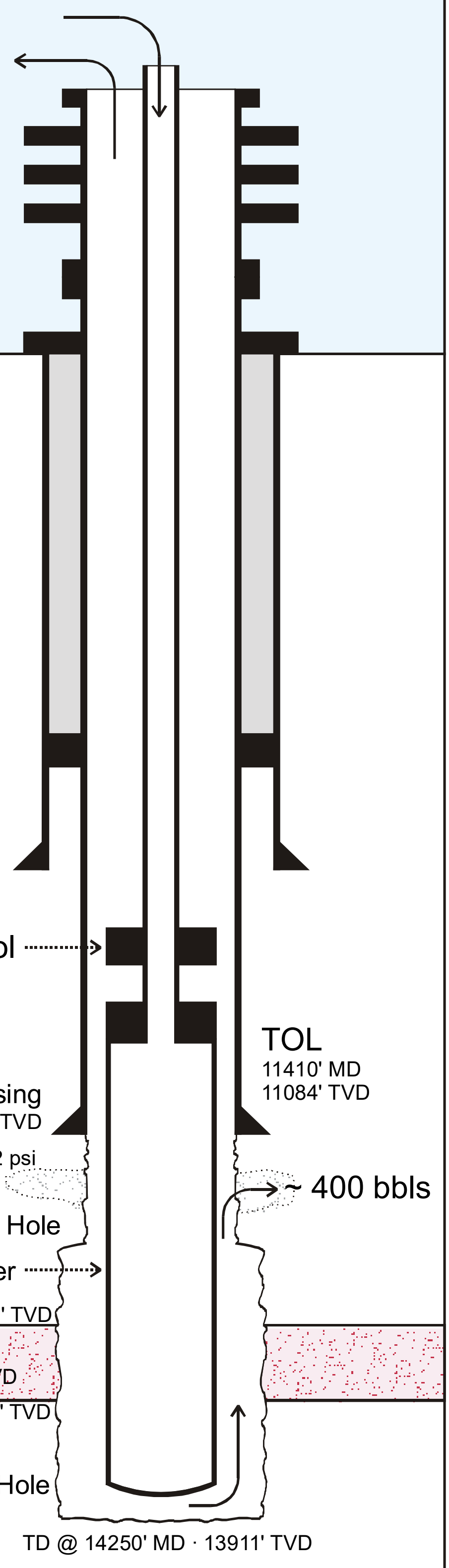
Results:
1. Run and hung OK
2. Could not get any returns around liner



Cementing Operation

Assumption:
Under-reaming would avoid excessive ECD

Result:
Almost no returns during cementing, no other indication of fluid level in annulus (only had to fall 140' take kick)

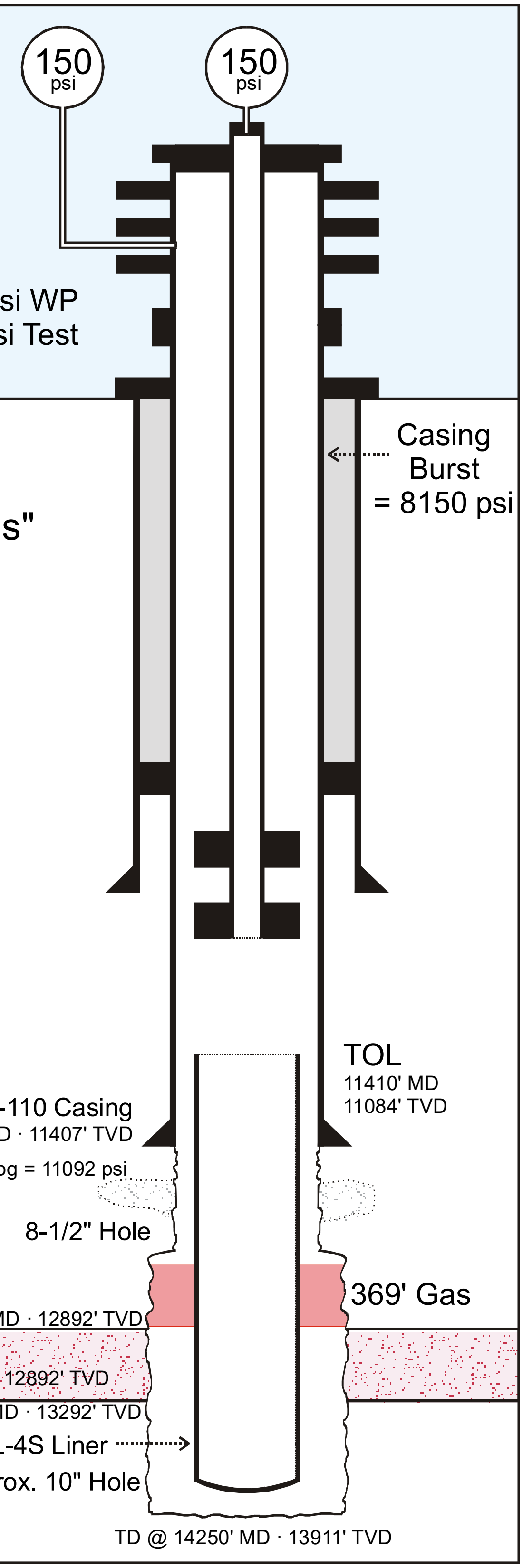


After Cementing

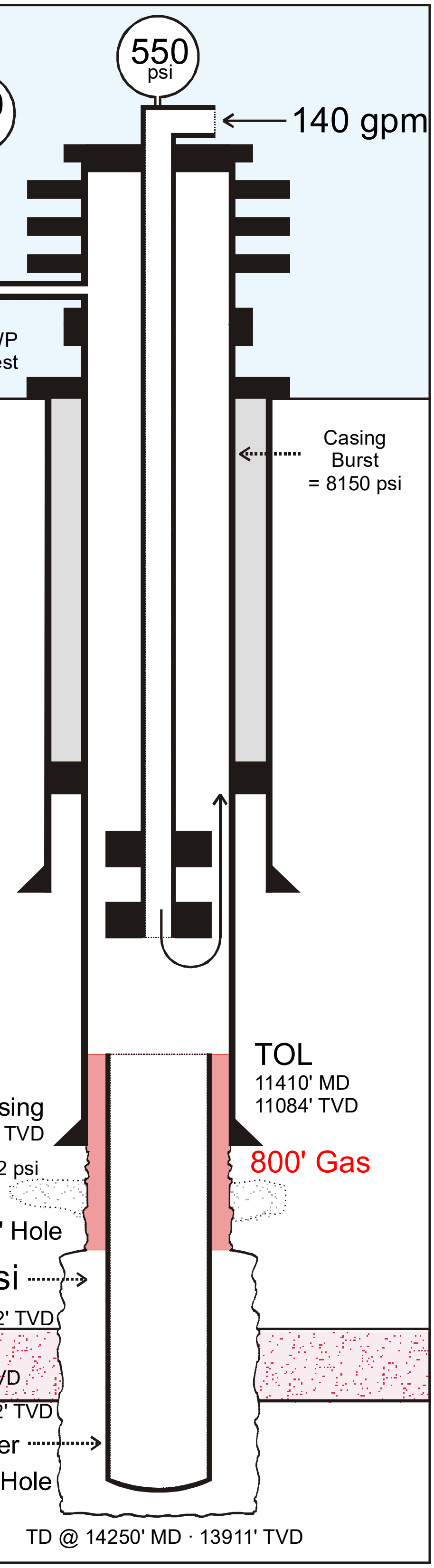
Operations:
1. Pick up 3 stands
2. Reverse out with "nearly full returns"
3. Open Hydril, well flowing
4. SIDPP = 150 psi
   SICP = 150 psi

Cause of Kick:
Flow after cementing
or
Loss of hydrostatic (If >140')

Implication:
Well probably static after shut-in



Attempt to "Control" – *a turning point*



Operations:
Attempt to circulate gas out with constant DDP

Implication:

Constant pressure at end of drillpipe

$\neq$

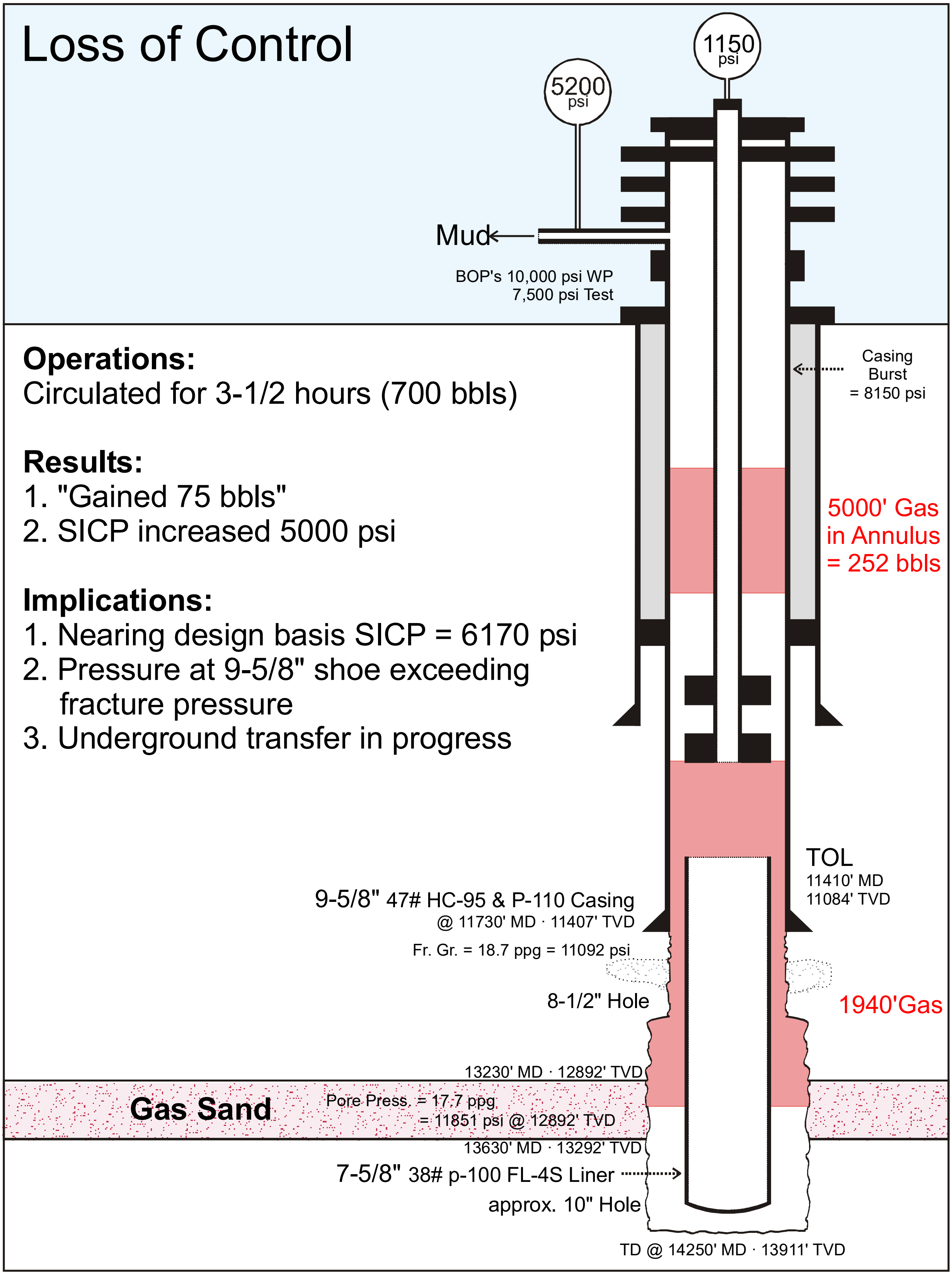
Constant pressure at gas sand

Loss of Control

Operations:
Circulated for 3-1/2 hours (700 bbls)

Results:
1. "Gained 75 bbls"
2. SICP increased 5000 psi

Implications:
1. Nearing design basis SICP = 6170 psi
2. Pressure at 9-5/8" shoe exceeding fracture pressure
3. Underground transfer in progress



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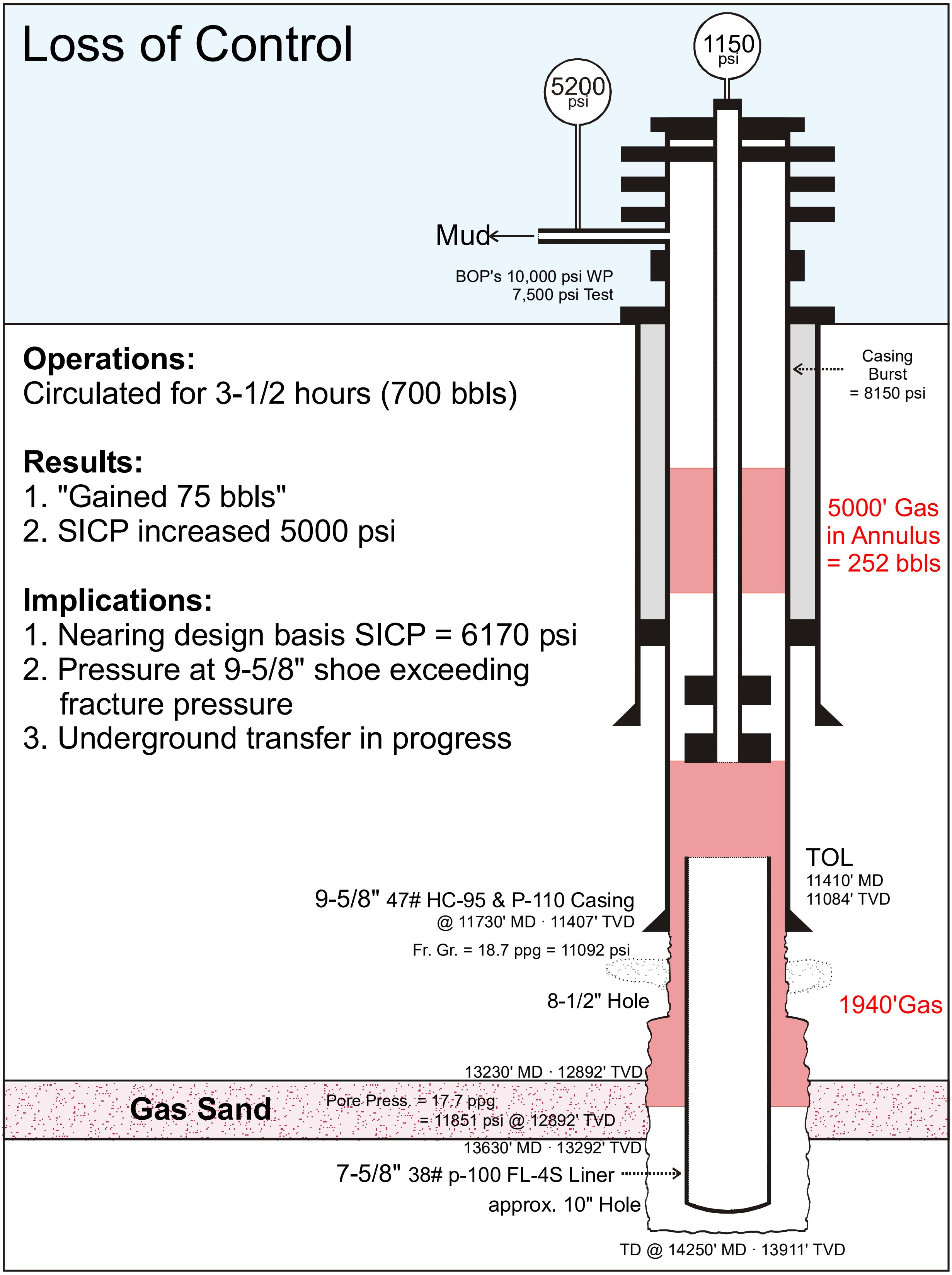
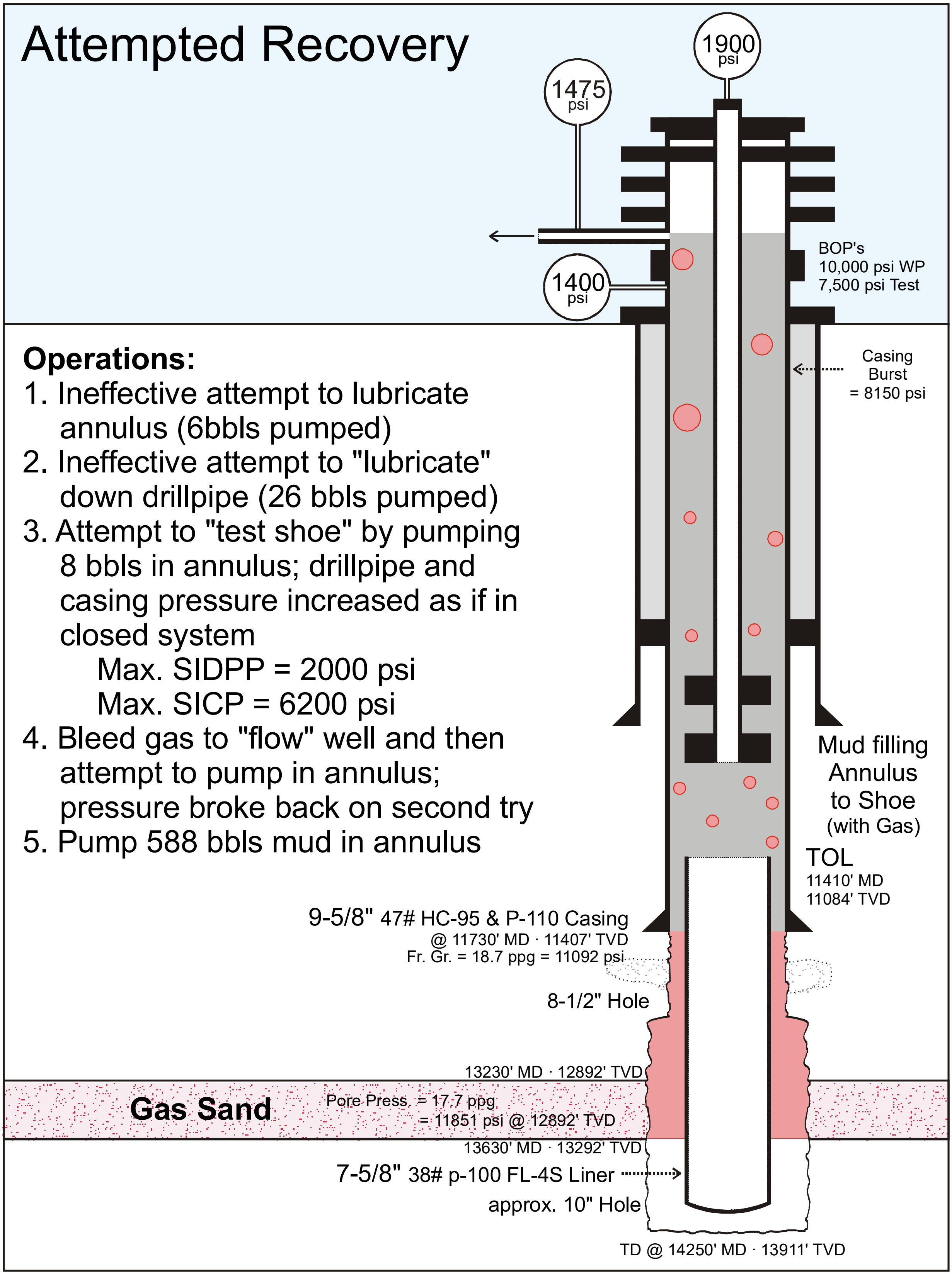


Attempted Recovery

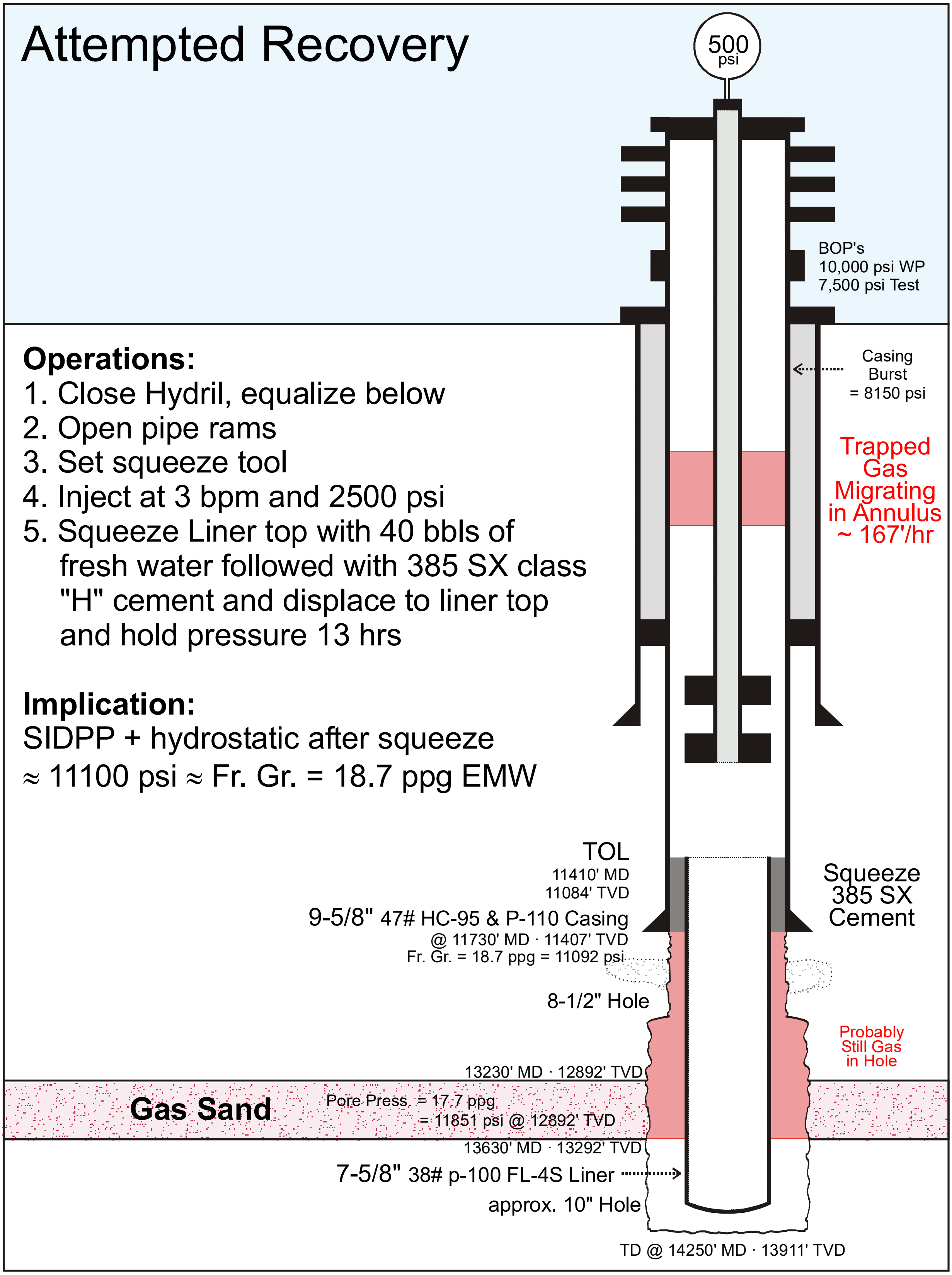
Operations:
1. Ineffective attempt to lubricate annulus (6bbls pumped)
2. Ineffective attempt to "lubricate" down drillpipe (26 bbls pumped)
3. Attempt to "test shoe" by pumping 8 bbls in annulus; drillpipe and casing pressure increased as if in closed system
   Max. SIDPP = 2000 psi
   Max. SICP = 6200 psi
4. Bleed gas to "flow" well and then attempt to pump in annulus; pressure broke back on second try
5. Pump 588 bbls mud in annulus



Attempted Recovery

Operations:
1. Close Hydril, equalize below
2. Open pipe rams
3. Set squeeze tool
4. Inject at 3 bpm and 2500 psi
5. Squeeze Liner top with 40 bbls of fresh water followed with 385 SX class "H" cement and displace to liner top and hold pressure 13 hrs

Implication:
SIDPP + hydrostatic after squeeze
≈ 11100 psi ≈ Fr. Gr. = 18.7 ppg EMW



Confirming Recovery

1. No flow from well
2. Cement tested to +3000 psi
3. Dressed off liner top cement and tested to +3200 psi for 30 min.
4. Test liner top with water cushion in stages to –2300 psi ~14.5 ppg EMW for one hour
5. Ran liner tieback

Turning point :

No attempt to confirm that probable (in hindsight) underground flow had been stopped or that pressure source on 11 ¾” x 9 5/8” annulus was shut off.

Recovery

Now we are back to where we started the review:

What are we going to to do to stop the apparent on-going underground flow?

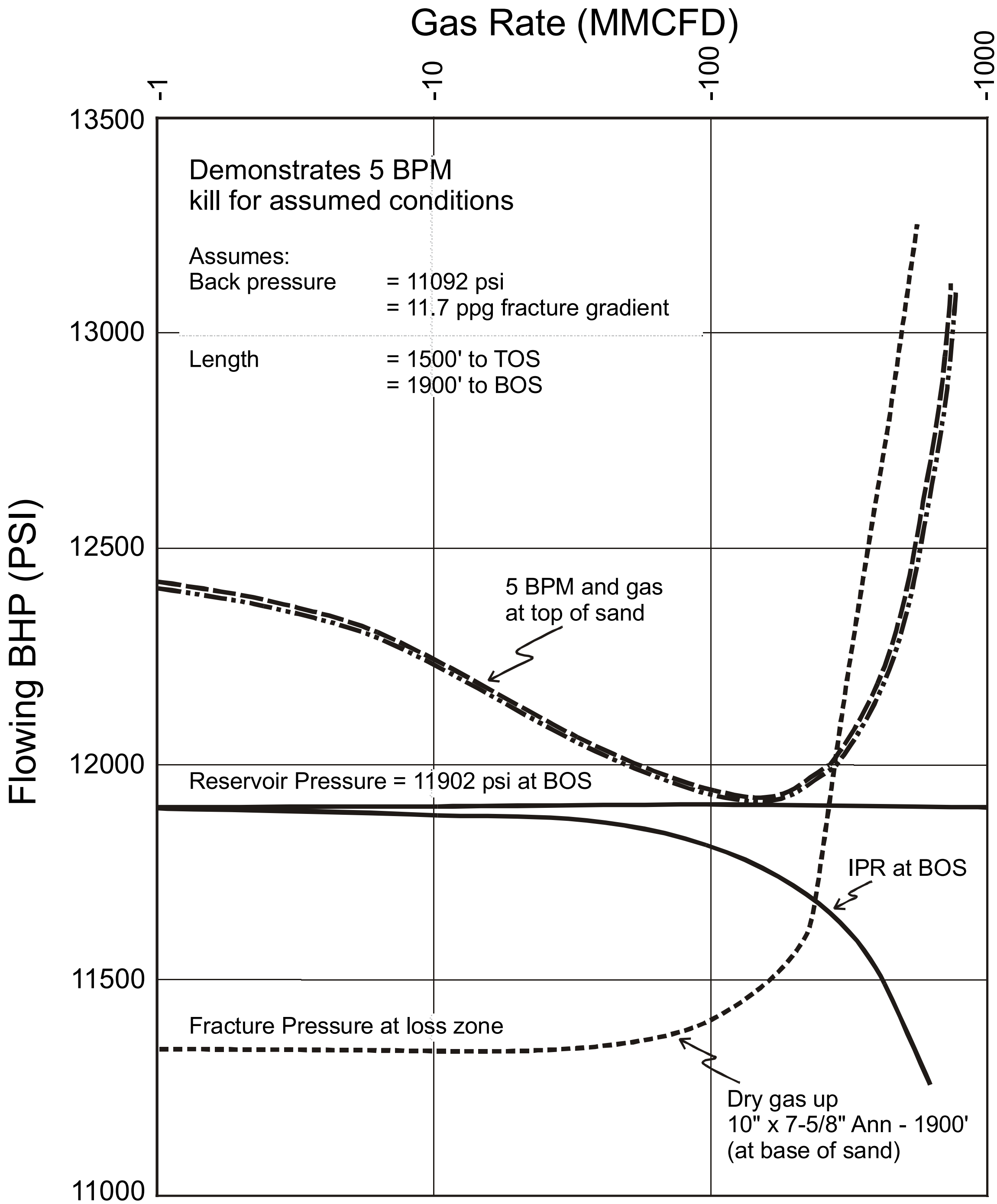
Kill it?

or

Bridge it?

Can we kill it?

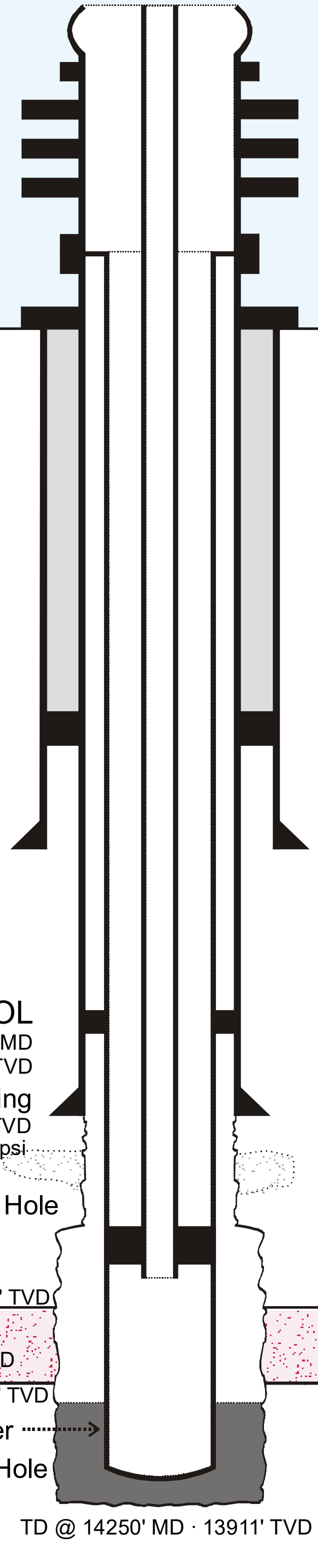
Flowing Bottom Hole Pressures For Dynamic Kill



Recovery

Operations:

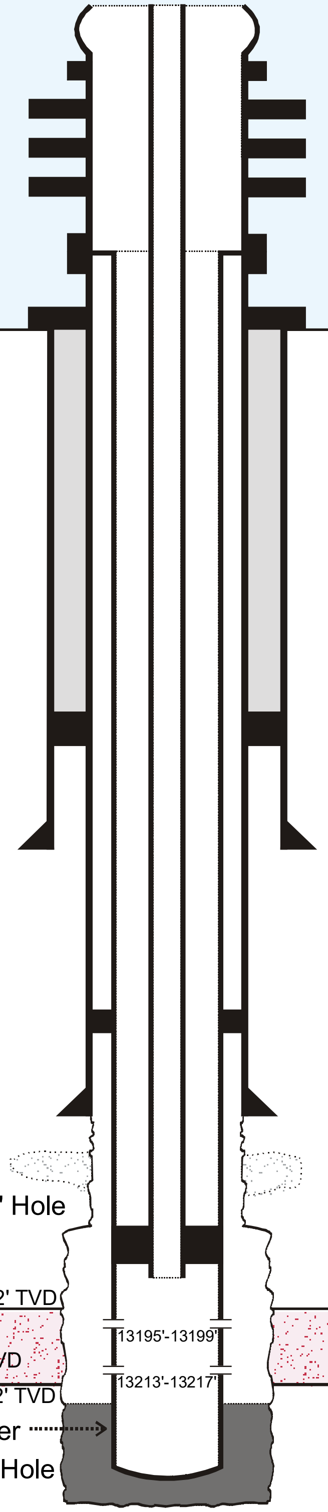
1. Pump 18 ppg mud thro drillstring to 5700 psi "breakdown" pressure; then pump 3 bbls at 300 psi thru 7-5/8" shoe -drillstring on vacuum- then "static" for rerunnung logs
2. Retest 7-5/8" shoe, broke down at 800 psi and bled to 0 psi
3. Cement through shoe with 500 SX thixotropic +300 SX class "H"
4. Test 7-5/8" shoe to 3350 psi
5. Rerun temp and noise logs
7. Run CBL



Recovery

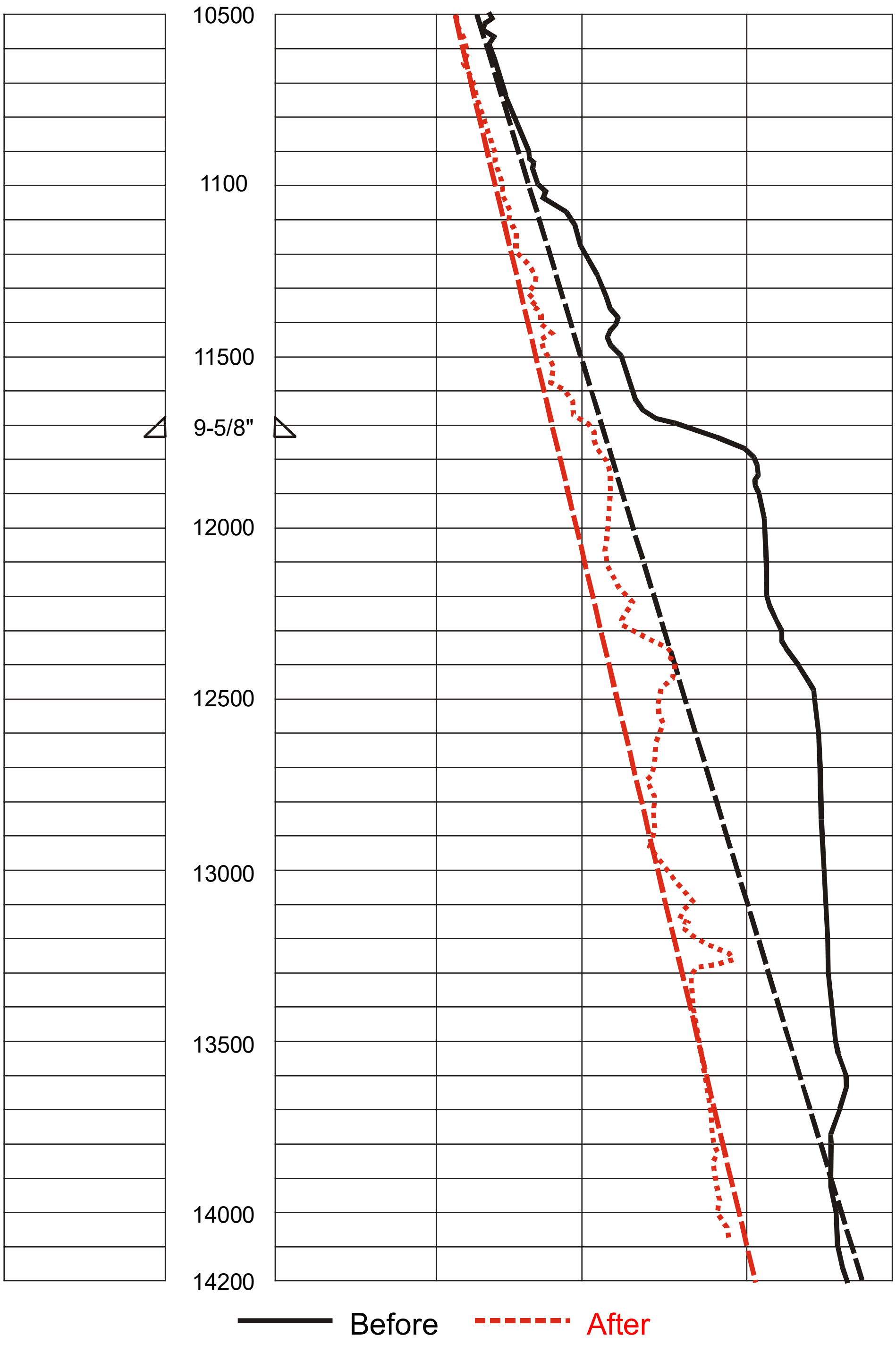
Operations:

1. Perforate and squeeze 400 SX class H cement at top of sand
2. Cleanout and run CBL
3. Perforate at top of prior squeeze and squeeze 400 SX class H cement
4. Cleanout and run CBL
5. Reperforate and squeeze interval with 400 SX class H cement and over-displace
6. Requeeze with 400 SX and over-displace
7.Resqueeze with 400 SX and leave cement in 7-5/8"
8. Cleanout
9. Run CBL, temp and noise logs



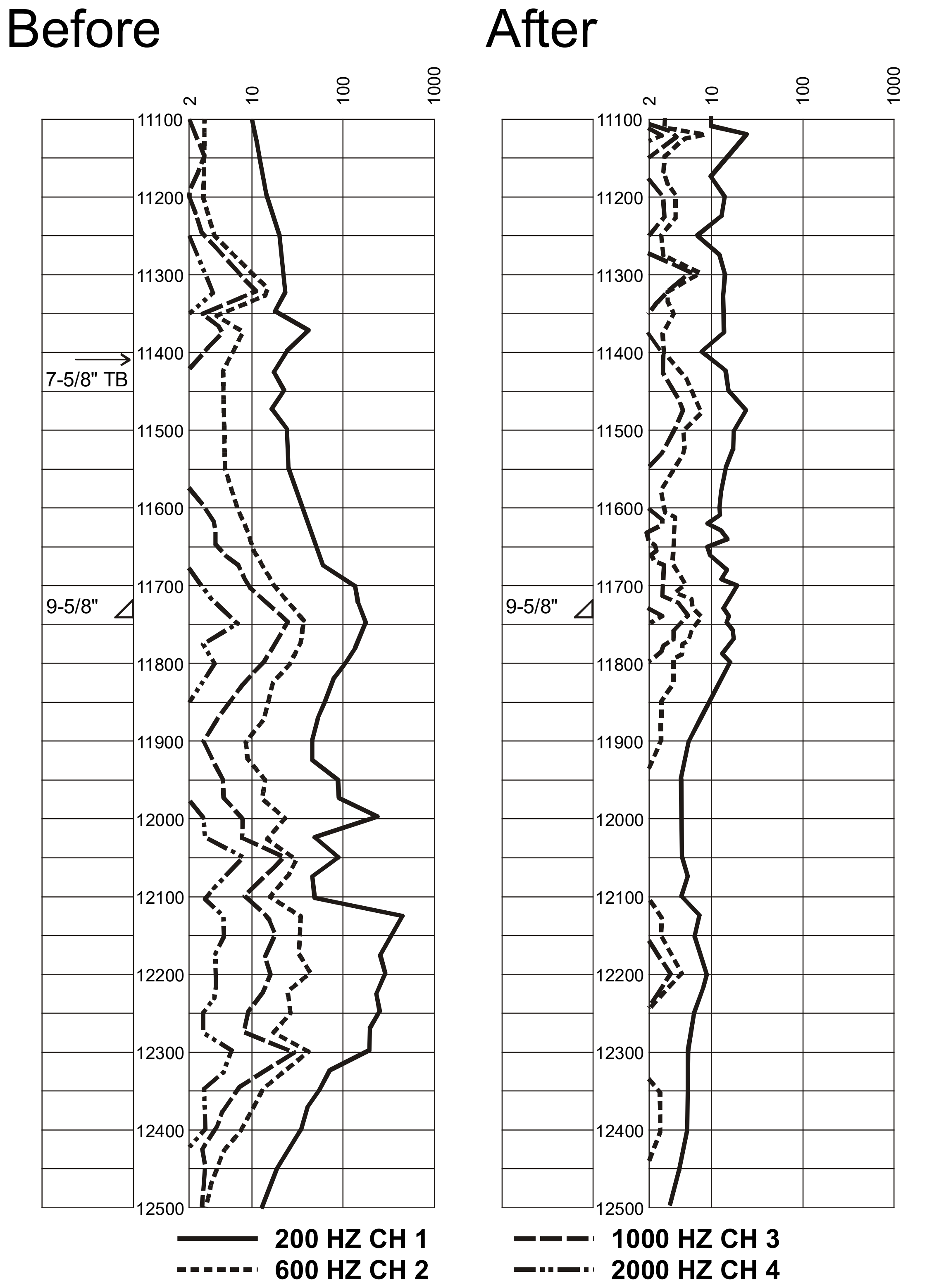
Temperature Log

Before vs. After



Offshore Texas Case History

Noise Log



Cement Bond Log

Before

- “Free Pipe” from 11900’
- (170’ Below 9 5/8” Shoe) To 14100’

After

- Cement with some bonding to both pipe and formation from 13200’ to 14100’ (Throughout major gas sand)
- 20’ cement seal at top of gas sand (where multiple “Squeezes” were performed)
- Some additional cement up to 12950’ (Confirmed with tracer)

Phase	Critical Issue
Planning	Risk of lost circulation with tight clearances not mitigated
Avoidance	No record of displacements
Detection	Poor, hole not kept full
Reaction	Good, shut-in when flow seen
Control	Poor, squeeze plan not followed, Driller’s method improperly applied
Original “Kill”:	
Loss of Control	Not identified
Recovery	None – only isolated
Confirmation	None
Second Kill:	
Loss of Control	Inferred by kicks, logs confirmed
Second Recovery	Planned, evaluated after each step
Confirmation	With comparison to baseline logs