Chevron

human energy®

Deepwater Nigeria Acid Stimulation Case Study

Tony Oyewole, Deepwater Assets Production Engineering Supervisor

Presentation Outline

- Executive summary
- Intelligent well completion configuration
- Well surveillance & candidate selection process.
- Well damage mechanism.
- MPV vs Rig deployed acid stimulation.
- Case histories.
- Conclusion & key learnings

Executive Summary

Discussion Topics

- Well completion damage mechanism.
- Acid stimulation candidate selection.
- Acid stimulation case histories
- Best practices & challenges.

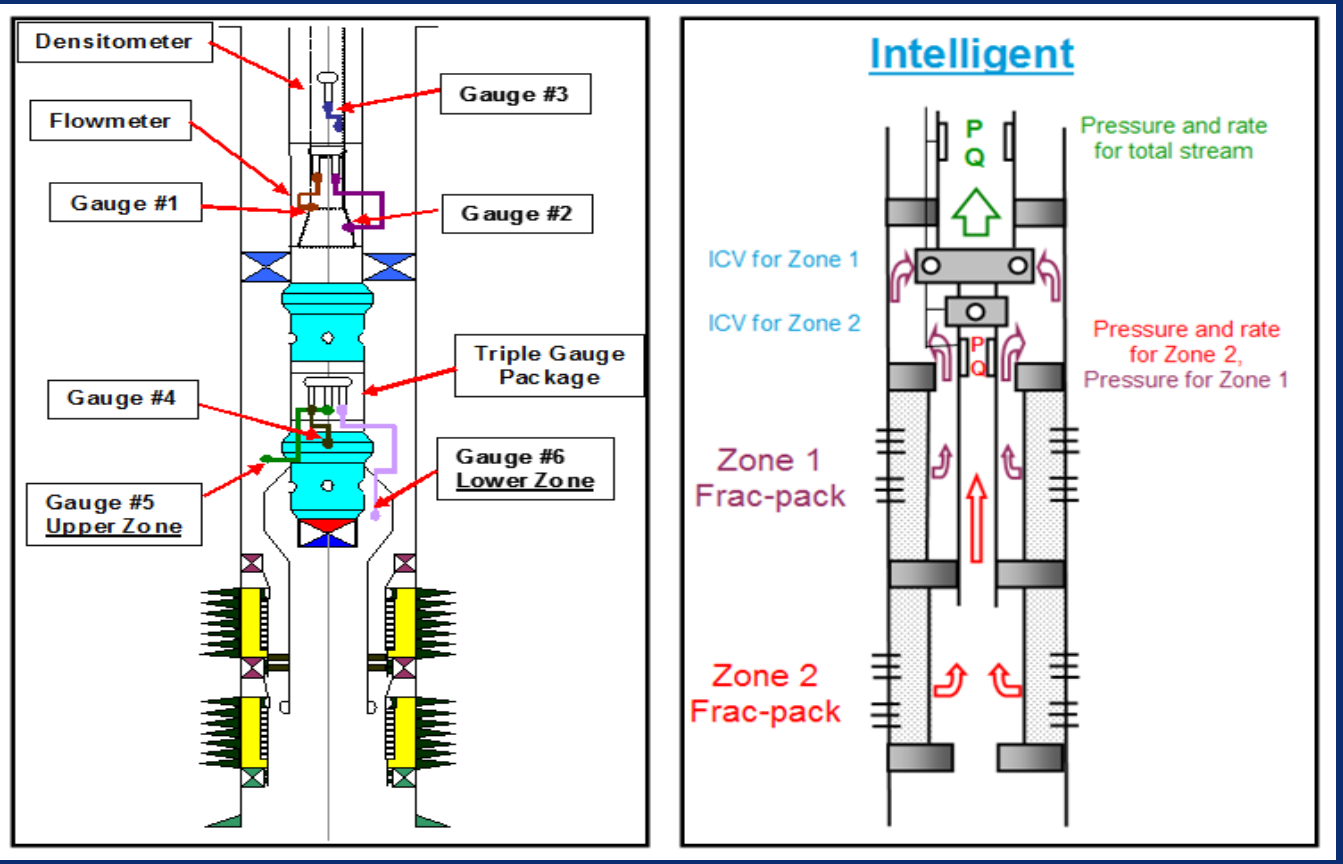
Key Messages

- Declining oil rates have been observed in a number of wells due to Large and Increasing skin.
- Increasing skin values have been as a result of fines migration during production.
- Skin damage has been successfully treated in 11 producers, helping to restore ~ 71 MBOPD of incremental production .
- Fourteen (14) of the acid stimulation jobs were conducted utilizing a rigless acid stimulation system, while one job was performed from a drill ship.
- Compared to the rig option, the rigless system provides $7MM – $8MM/ job savings and much lower deferred production from shut-ins.
- Detailed design of acid recipe and flowbacks ensured no adverse impact to topside process equipment and acid stimulations Ops can be safely performed.

Desired Outcomes

- Share the successes of acid stimulation campaigns in the deep water field offshore west Africa using a Multi-Purpose Vessel [MPV] & the tremendous execution efficiencies & cost saving advantages over a conventional rig.
- Demonstrate the value of diligent data gathering and provide insights into a systematic, data driven candidate selection process
- Share lessons & best practices & demonstrate how diligent application of look backs & lessons learned resulted in outstanding results.

Intelligent Well Completion Configuration

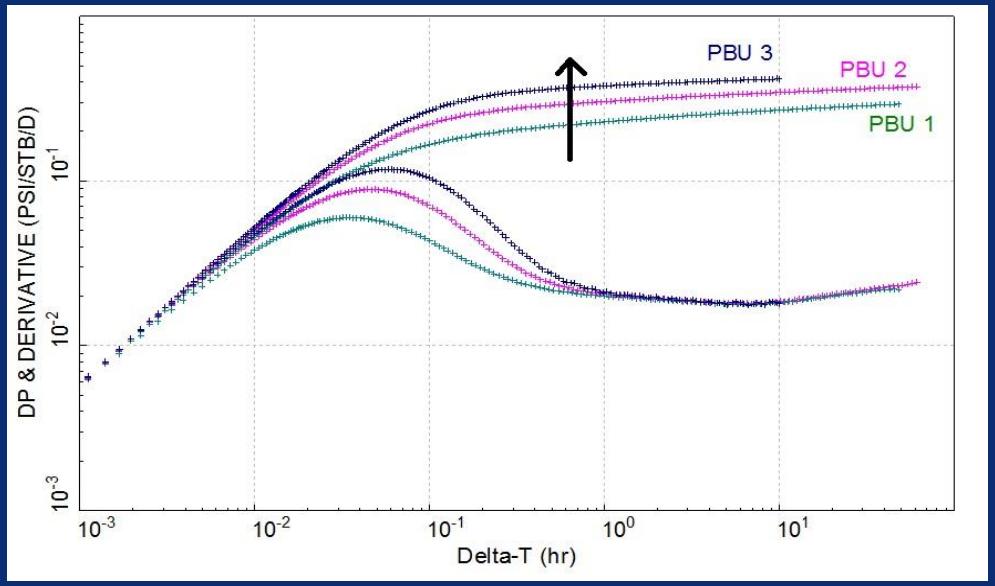


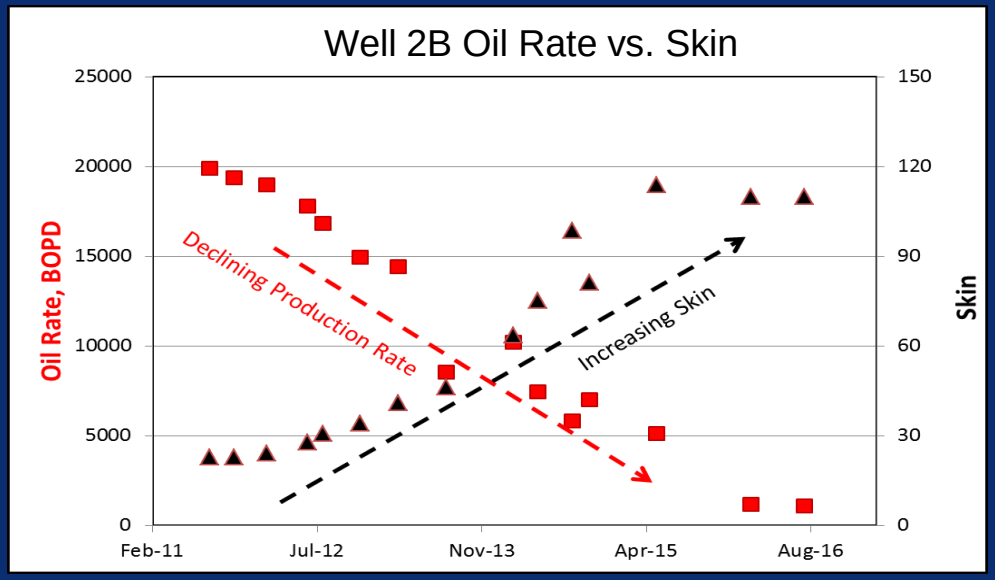
- Allows real-time pressure, temperature, density and flowrate measurements.
  - Enables effective well performance modeling & monitoring.
- Provides downhole/ Sand-face Shut-in capability via ICV's
  - Zonal production optimization
  - Facilitates accurate data capture for PBU analysis.
- Configured to take advantage of opportunistic shut-ins to obtain build-up data for analysis.

All Wells (Producers & Injectors) are equipped with intelligent completions

Data Gathering & Pressure Build-up Analysis

- Planned Pressure Build-up tests & pressure data from ESD's provide multiple data points for well performance analysis.
- High skin wells & zones are identified from PBU data & a preliminary list of candidates is generated.
- Candidates are monitored & the list is kept evergreen. As skin increases, wells are choked back to honor the flux constraint and prevent completion failures.
- Candidate wells & zones are further evaluated based on expected rates.

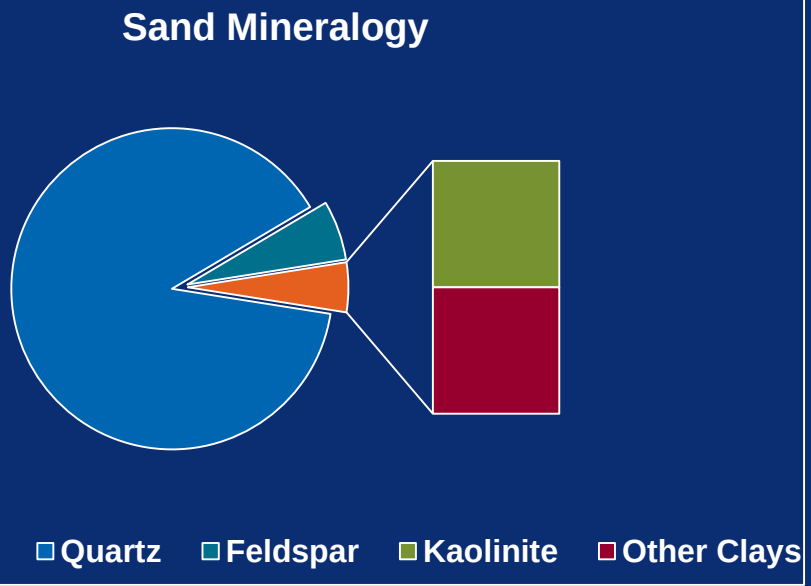




Why So much Skin ?

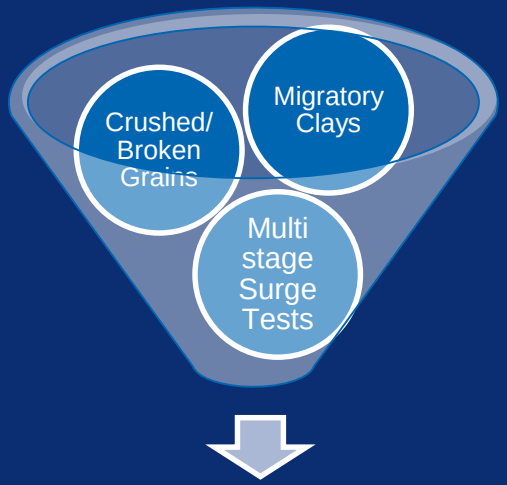
Rock Mineralogy

- Reservoir is composed primarily of quartz, with smaller amounts of feldspar and clay.
- Approximately 50% of the clay is kaolinite, which has the potential to migrate during high rate flow



Surge & Compaction

- Multistage Surge Tests reveal that:
  - Emergency shutdowns (ESDs) & rapid well restarts cause grain fracturing in the near wellbore area.
  - Permeability decrease in the range of 14-18% was observed on cores samples

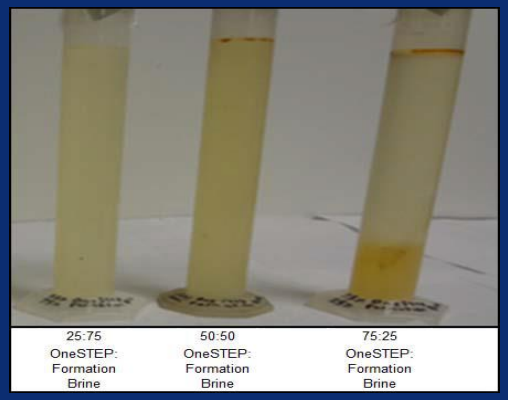


Acid Sensitivity Test

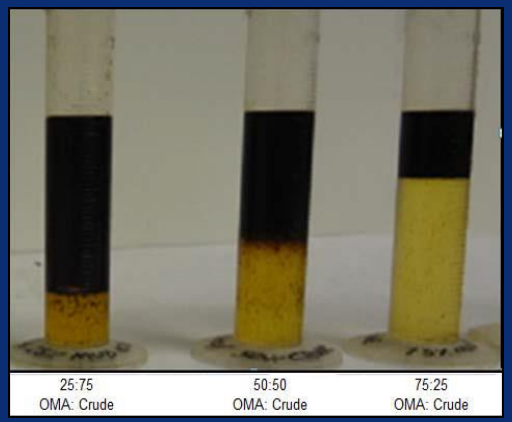
- Two acid systems where identified & tested for use:

1. **OneSTEP Acid**
   - Core sample showed slightly improved permeability after treatment
   - If the expected cause of damage is crushed, fractured grains or fines migration, the OneStep System is recommended.
2. **Organic Mud/Clay Acid**
   - Higher Strength.
   - Core sample showed significant permeability increase after treatment.
   - Recommended If damage from crushed, fractured grains & fines migration is excessive.

Organic Mud Acid (OMA)

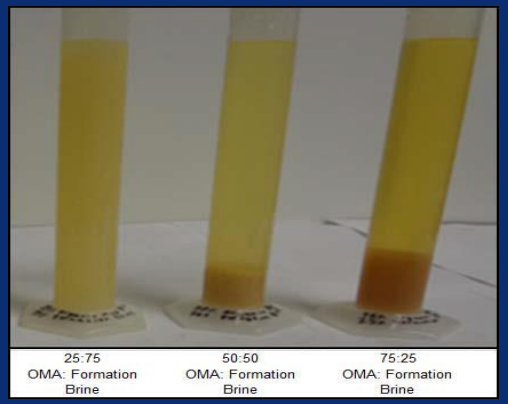


OMA and Formation Brine

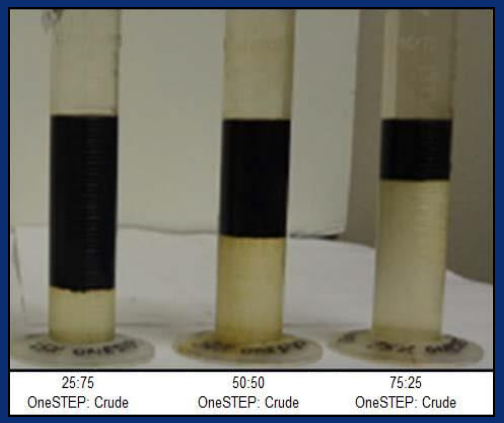


OMA and Crude Sample

One-Step



OneSTEP and Formation Brine



OneSTEP and Crude Sample

- **Both acids systems showed no signs of emulsion or incompatibility with crude & formation brine**

Acid Stimulation Candidate Selection Criteria

Three questions to answer when planning an acid campaign:

Which well or zone to acidize?

- High Skin: >20 & history of increasing over time.
- Low Oil rate wells.
- Low GOR & BS&W
- Sufficient Riser Capacity: (bottlenecked system).
- Well bore concerns. (EV, Completion integrity, etc.)

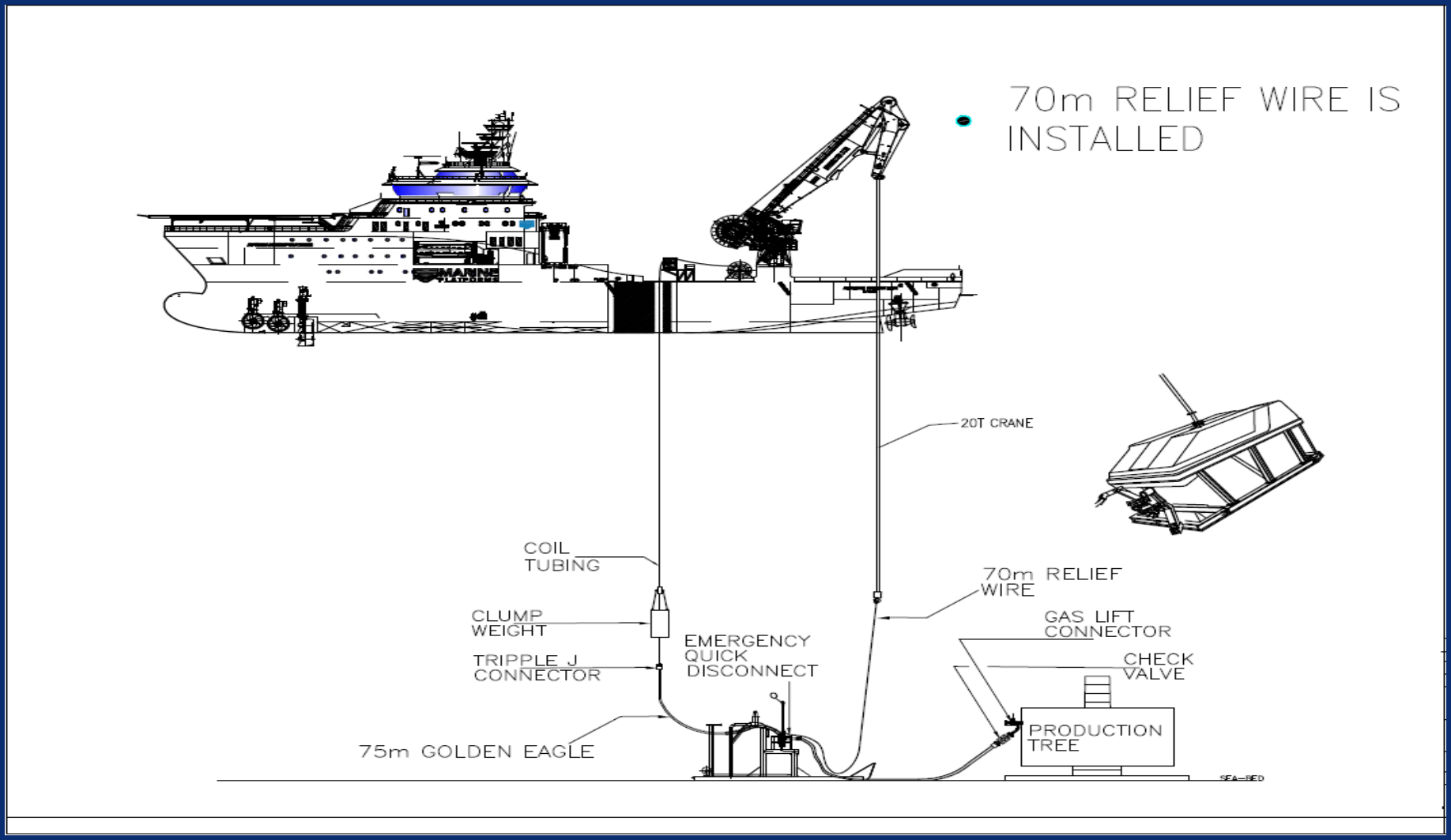
When to perform the acid job?

- Field Below Capacity
- No new wells/production coming on.
- Host Facility Readiness to receive flowback.
- Reservoir Mgmt. considerations – Voidage etc.

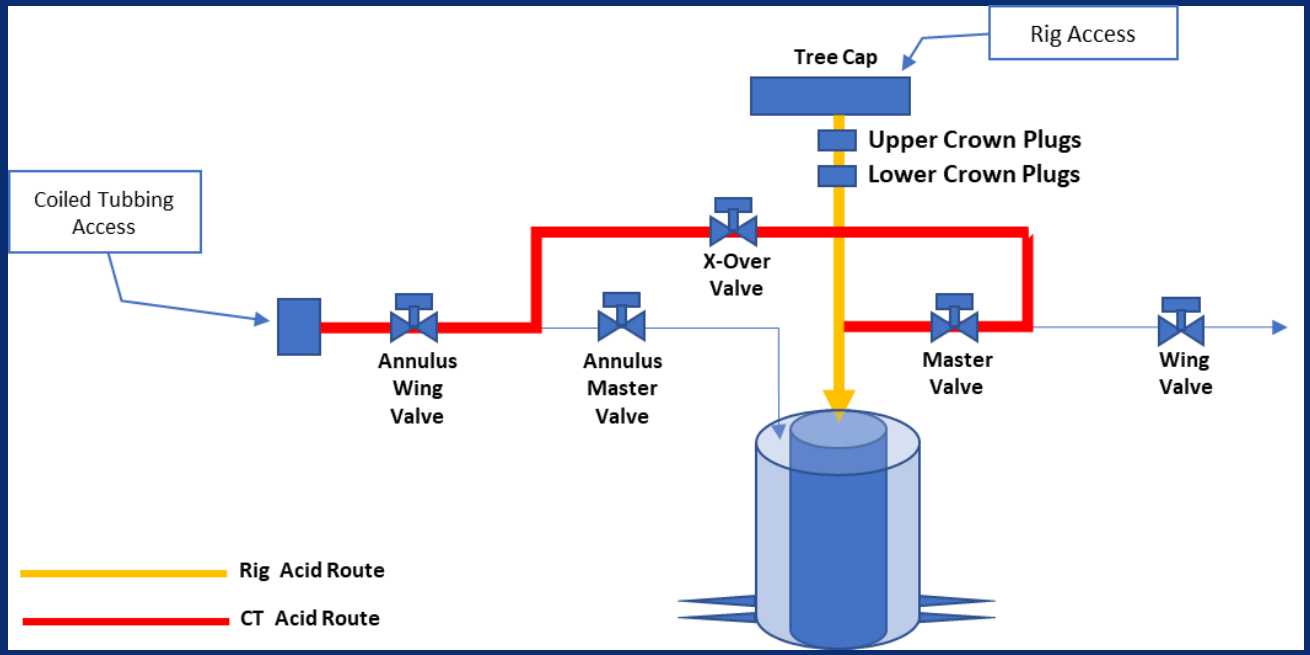
What type of acid to use?

- Pump **mildest** acid that will successfully treat the skin.
- Utilize Core tests results.
- Historical performance of each acid recipe on individual wells.
- Work vessel capacity (deck space, tank capacity, etc).

Configuration of Rigless (MPV) Acid Stimulation



Acid Stimulation: Multi-Purpose Vessel vs. Rig



	RIG	RIGLESS
Cost	$1 MM/DAY	$0.1 MM/DAY
Days (Well Shut-in)	6-7	1-2
Deferred Production	BIG	SMALL

MPV Time Benefits:

- Fewer runs.
- No need to pull crown plugs.
- Well access is through Gas Lift Connector (GLC) on Xmas Tree.
- BOP Run/Hook-up/Testing much faster. (<1 day vs. 2-3 days from rig).
- Lower execution days (3 days vs 7 days from rig).

specific acid stimulation cases

Acid Stimulation Case 1

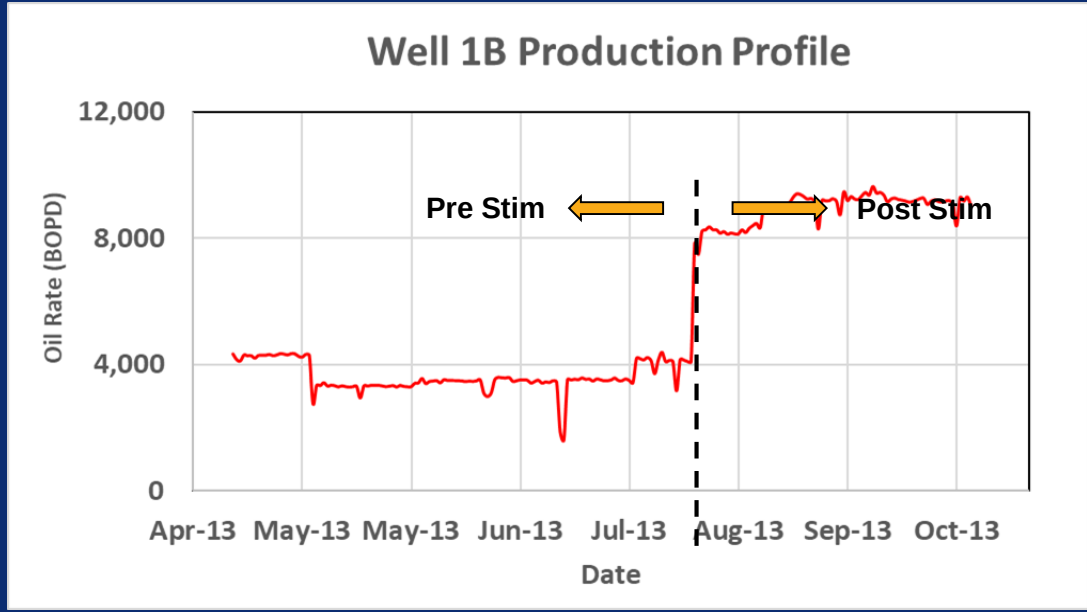
Discussion

- The well started production in Aug 12 & the UZ tested ~8,000 bopd with a PI of 7.6 stb/day and skin of 29,
- 6 months later the oil rate had halved while the skin had doubled with the PI @ 4 bbls/day/psi.
- Analysis revealed SKIN damage was due to fines migration.
- A rig-less acid stim intervention from a MPV using One Step acid was conducted.

Results

- Safely executed – no incidents
- 4300 BOPD increase (+90%)
- Skin decreased from 59 to 14
- LPO – 1 day <7,000 BO
- Successfully flowed back to FPSO
- Economic Payout - < 1 month

EXCELLENT RESULTS!!!



Pre-Acid			Post-Acid			Actual Incremental
BOPD	Skin	PI (b/d/psi)	BOPD	Skin	PI (b/d/psi)	BOPD
4,740	59	4.0	**9,002**	14	11.4	**4,262**

Acid Stimulation Case 2

Well 2B Discussion

- Well 2B started production in 2010 at ~16 MBOPD & peaked @ ~19 MBOPD in 2012
- 2012: Skin had increased from 18 to > 70
- Oil rate declined to 7.5 MBOPD.

Acid Stim -1 (2014)

- One-Step mixture deployed.
- Not successful : Skin increased to 95
  - ***suspect acid mixture was weakened due to delay in pumping acid after mixing.***

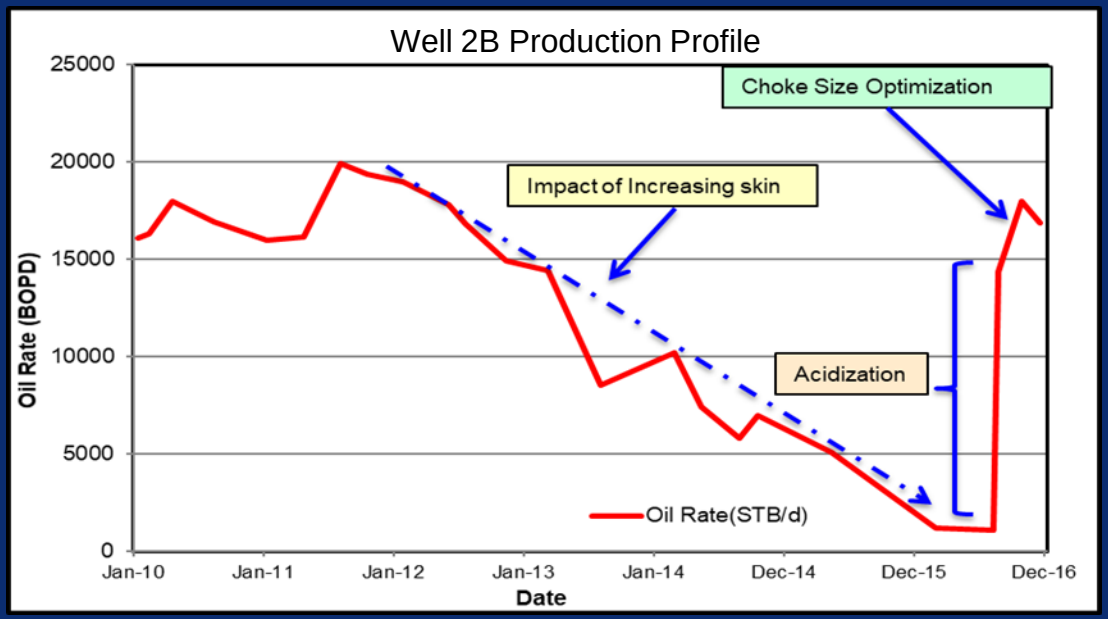
Acid Stim -2 (2015)

- One-Step mixture pumped
- Following 'lessons' learned from first attempt, acid was pumped immediately after mixing.
- Not Successful – ***Commissioned core analysis.***
- OMA/OCA was recommended for this well.

Acid Stim -3 (2016)

- Rate = 1,100 BOPD, skin >100 & PI ~0.5bopd/psi
- OMA/OCA/Acetic cocktail deployed.
- No Delays between mixing & pumping.
- Post acid rate = 18,300 BOPD
- Skin Dropped from 110 to 24

EXCELLENT RESULTS!!!



Pre-Acid			Post-Acid			Actual Incremental
BOPD	Skin	PI (b/d/psi)	BOPD	Skin	PI (b/d/psi)	BOPD
1077	110	0.4	18,257	24	11.7	**17,180**

Finally! After 2 unsuccessful attempts

Acid Stimulation Case 3

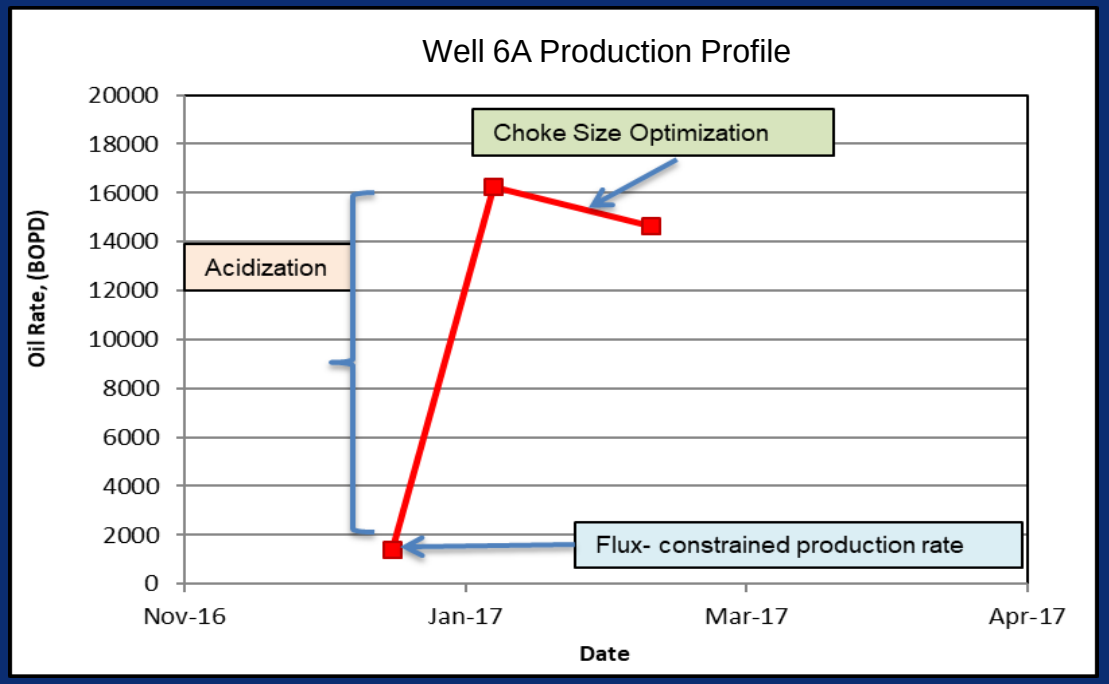
Discussion

- Well completion damaged from LCM pumped to control fluid losses during completion operations.
- Rig attempted to deploy acid after completion but aborted due to failure to pump into well.
- Well started up & the LZ Cleaned up but UZ High skin (207) & Low rate 1,460.
- A rig-less acid stim intervention from a MPV using Acetic/OMA/OCA cocktail was conducted.

Results

- 13,079 BOPD Increase (+900%)
- PI increased from 3.5 to 15.8 BOPD/PSI
- <1day of actual pumping operation
- LPO: 1/2 day – 3,800 BO (LZ SI)
- Successfully flowed back to FPSO
- Economic Payout - < 1 month

EXCELLENT RESULTS!!!



Pre-Acid			Post-Acid			Actual Incremental
BOPD	Skin	PI (b/d/psi)	BOPD	Skin	PI (b/d/psi)	BOPD
1,460	206	3.5	14,500	24	15.8	13,079

Process improvement from application of Lessons

Campaign	Lesson	Action	Results
3	Increase in well skin after application of One-Step.	Conducted core Studies & selected Appropriate acids.	• Significant skin reduction. • > 1000% increase in oil rate
4	Inadvertent Flowback of unspent acid despite sufficient soak time.	HBSW zones opened & their flow rate increased during flowback	• Preserved riser and topside equipment.
2	Acids got spent on deck before pumping leading to poor results.	Doubled work crews – added a night crew.	• Improvement in efficiency & prep time reduction by 50%. • Mitigated risk of deploying spent acids.
1	Initial campaigns utilized Anti-foaming & Increased Emulsions Breaker injection to mitigate topside issues.	Conducted fluid compatibility tests which eliminated the need for anti-foam.	• Reduced costs from chemical application.

Key Lessons

Well Selection:

- Properly identifying and quantifying well damage requires data & analysis from pressure build up (PBU) well tests & analysis.
- High Skin & Low rates wells are not always the best candidates. The impact on the entire field production has to be considered as well as possible impact of increased Gas & water.
- A structured Multidisciplinary approach is critical in candidate selection, planning & execution.
- Proper analysis of core is required to understand the damage mechanism.

Acid Selection:

- Understanding damage mechanism will enhance the right selection of acid for the stimulation job. Core studies and acid compatibility tests are crucial to a successful cocktail selection. One size does not fit all!

Acid Deployment:

- Ensure sufficient over-flush of acid into formation to minimize live-acid contact with completion jewelry & prevent damage.
- Develop contingencies in the event the formation is unable to take the acid. Consider pumping acid into other zones.
- Top sides should be prepared to receive live acids. – increase corrosion inhibitors dosage etc..
- Design a topsides flowback path that minimizes contact with process equipment.
- Ensure acid compatibility with produced fluids & ensure issues such as foaming etc. are identified & mitigated adequately.

The End

Thank You!