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MENAPS 2022

MIDDLE EAST AND NORTH AFRICA PERFORATING SYMPOSIUM

The Application of Calibrated Energetic Casing Expansion to Mitigate Annular Pressure/Flow

W. T. Bell International

an explosives specialty group

MENAPS-17-22 AUTHORS: Jim Rairigh, WT Bell Int. Inc. Mark Brinsden, Vektor Energy Inc.

AGENDA

- Overview of Expansion Technology and Applications
- Two Tool Types
- Importance of Pre-testing and Job Planning
- Casing Integrity
- Track Record
- The Capability to Expand Multiple Casing Strings
- Expanding Larger Casing Strings
- Further Developments?
- Conclusions and Questions

OVERVIEW OF EXPANSION TECHNOLGY AND APPLICATIONS

- Energetic Expansion of Casing – Achieved by calibrated and focused release of energy.
- Casing is expanded into surrounding annulus – cement, micro annulus space, channeled cement etc.
- Ideal expansion point is where reasonable cement exists but is perhaps compromised by micro annulus or channeling.
- Casing is plastically deformed radially against the cement densifying the cement closing off flow paths.
- There is no integrity damage to the casing and the gas flow is sealed with typically 3 expansions run together or individually depending on application.
- Performed on wireline, the operation may be performed rigless.
- 94% Success rate on first attempt on over 30 wells.
- Compare Perf & Squeeze 30% success rate (SPE-106765)

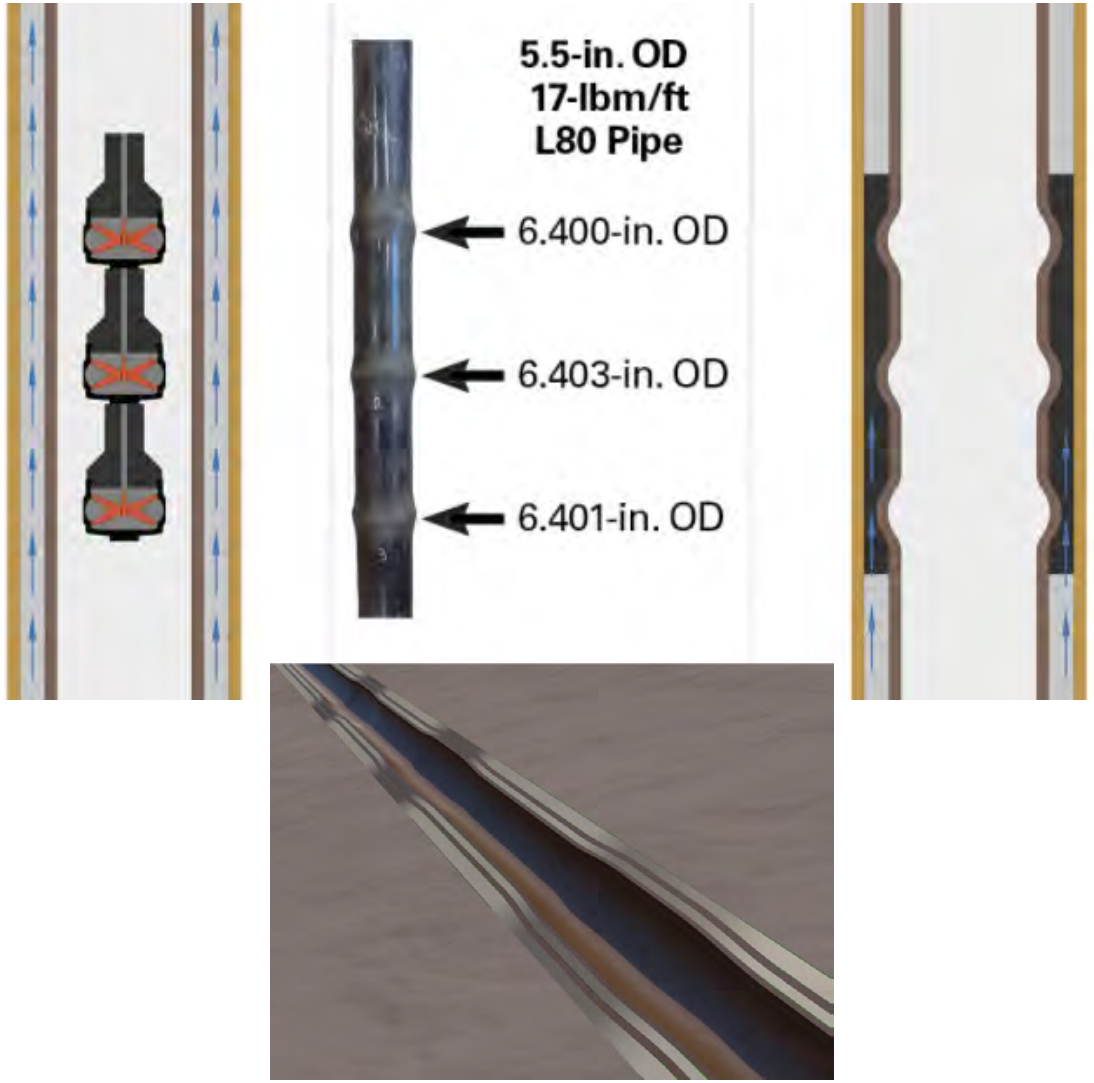
OVERVIEW OF EXPANSION TECHNOLGY AND APPLICATIONS

- How does cement behave under these conditions? Generally, the feedback is crushed cement – more cracks, but cement under very high levels of confinement cement behaves interestingly.
- Prior to the expansion cement contains water and is porous. The free porosity enables compression.
- When expansion occurs, cement is highly compressed very quickly and the cement become more malleable. Cement mechanically deforms by reduction in pore space and induced cohesive shear bands.
- After the expansion, chemistry remains unchanged but there is some dehydration and rehydration of the cement phases.
- Pore spaces and small stress cracks or micro-annuli are closed without visible fracture or macroscopic dilation.

- More detail of this work can be found in SPE-168056-PA

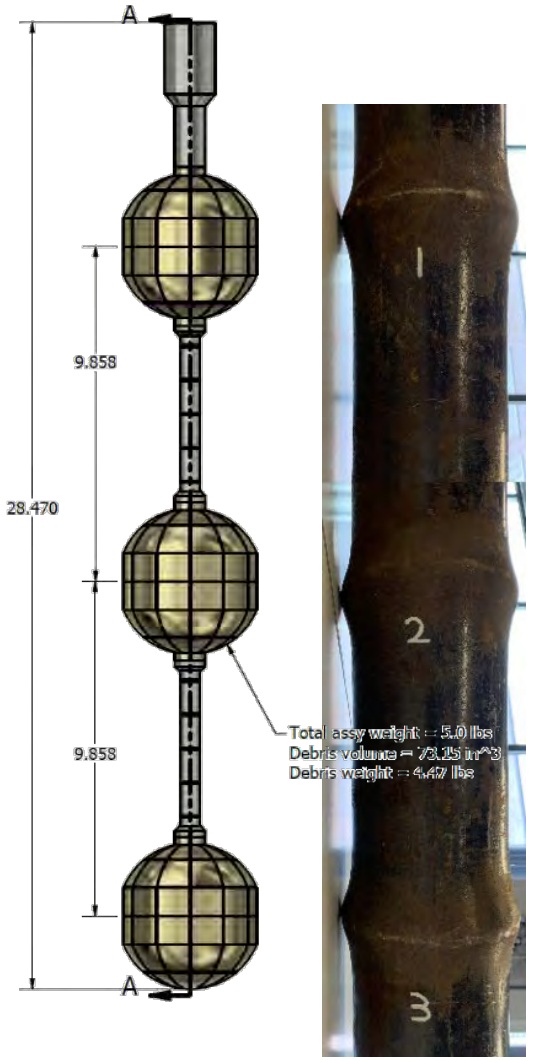
TWO TOOL TYPES EE (Energetic Expander). DEFEC (Dual End Fired Expansion Charge)

- There are two distinct types of energetic casing expansion tools with similar results but using significantly different energetic tools.
- The Energetic Expander and the Dual End Fired Expansion Charge.
- To start with a collaboration between Shell and WTBI led to the development of a customized jet cutter technology for which WTBI is the technology leader.
- The Energetic Expander was tested extensively in smaller casing sizes, 3.5,4.5, 5, 5.5 and 7in and has been shown to be very effective in sealing off gas flow first time in 96% of 29 field jobs in Canada, the US and The Netherlands including N2 injector wells.
- >200 Expansions in 30 wells as of August 2022.



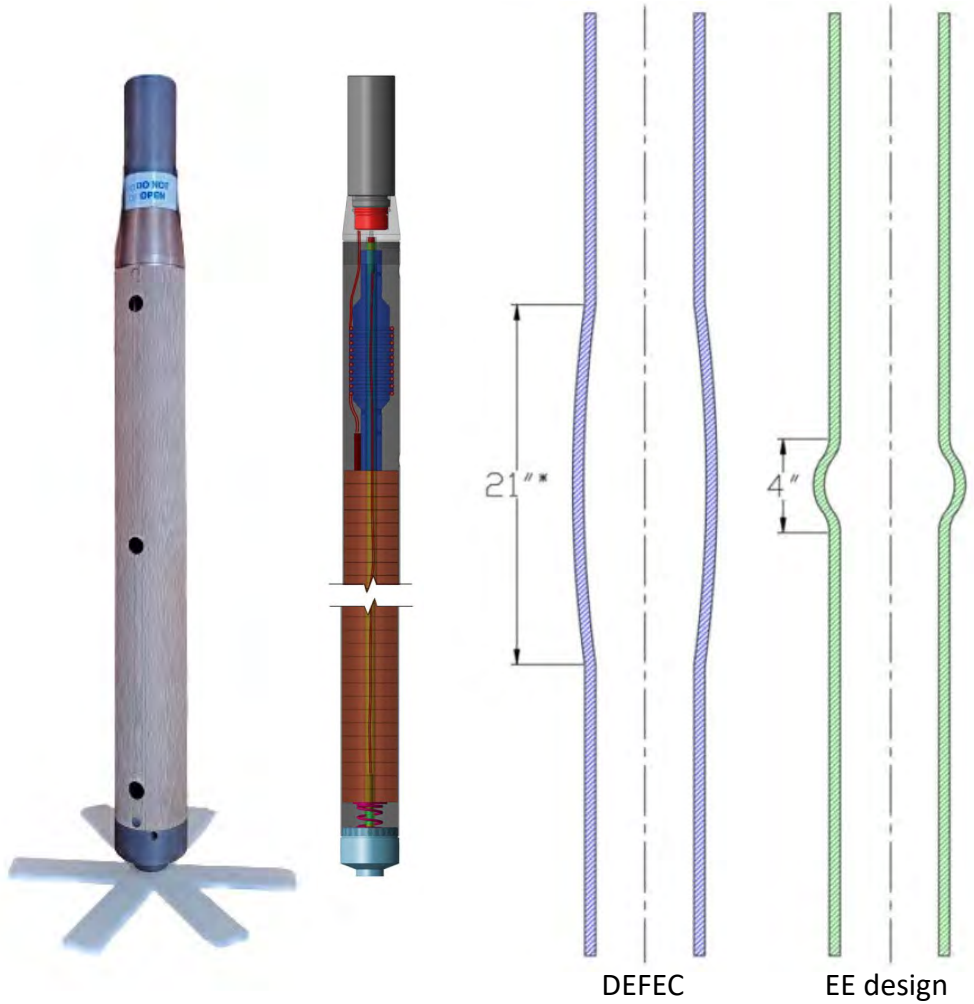
TWO TOOL TYPES

- This is the Dissolvable Multi-Shot Expansion Charge – everything dissolves except the O-rings.
- Using either of the multi-shot tools provides 3 instant expansion seals, with 10-12 in spacing between expansions.
- Less runs, less HSE exposure, also known distance between expansions.
- Confined cement trapped between expansions enhancing seals.
- Easy wireline deployment.
- Track record of 24 expansions in 4 wells.

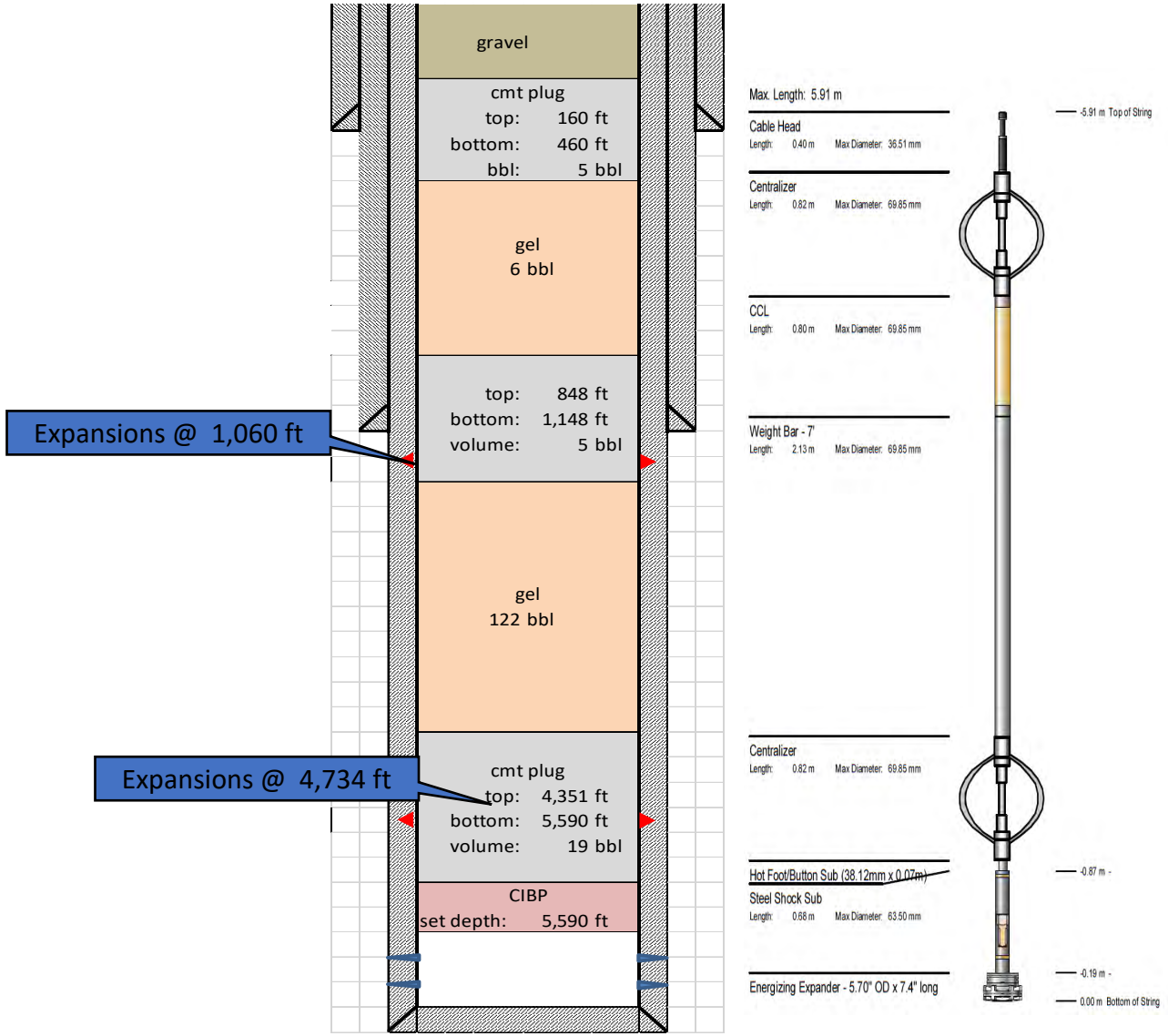


TWO TOOL TYPES The Dual End Fired Expansion Charge (DEFEC)

- The DEFEC is the latest Expansion tool and serves two very important sectors. Larger casing sizes and through tubing applications.
- The DEFEC has currently been run and tested in casing sizes up to 16in and down as low as 5-1/2in.
- Expansion is longer and more gradual than the single and multi shot tools.
- The DEFEC has the ability to expand to a higher percentage expansion while maintaining full integrity!
- The DEFEC generally requires multiple runs while the multi-shot EE can provide full isolation in one run but restricted to 7in and lower casing sizes.
- The difference in expansion and contact area between the DEFEC and EE can be seen on the right.



IMPORTANCE OF PRETESTING AND JOB PLANNING



- Job planning is essential
  - Identify cement location and quality CBL etc
  - Identify likely depth/source of annular flow
  - Confirm casing wear, corrosion risk is low
  - Confirm Casing size, weight and grade are suitable
  - Confirm and wellbore restrictions
  - Confirm number of intervals to expand, typically 3
  - Confirm hydrostatic at expansion depths for charges
  - Pre-test similar size, weight and grade if not already tested
  - Make well centralized wireline tool string design
  - No expansion of casing collars CCL required or near to bridge plugs.
  - Use CCL to confirm expansion.
- Critical Success Criteria
  - Absence of vent/annular flow or sustained annular pressure post expansion
  - Venting plan may be required for trapped gas
  - Casing pressure test if required to confirm casing integrity
  - Perform a CCL or even caliper log to verify expansions

CASING INTEGRITY OF EXPANSION VS SQUEEZE CEMENTING

- Conventional Annulus Perforation and Cement Squeeze – The casing is punched with multiple perforations and the perforations are squeezed off with cement which is often contaminated. The casing is damaged by the perforations losing full integrity, relying on imperfect cement to maintain pressure integrity and hopefully managing to seal or partially seal the annulus flow.

- Energetic Casing Expansion – The casing is expanded energetically by a calibrated amount to seal the annulus. The casing itself retains full integrity maintaining performance within, or above API specification, or within parameters agreed, or specified. There is no breaching or perforating of the casing.

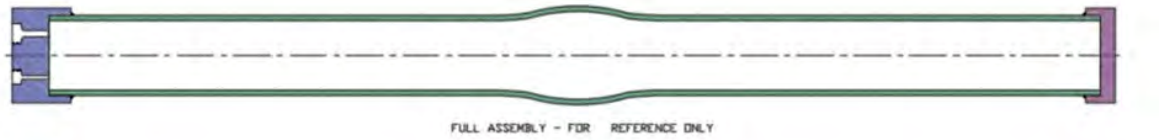
- This is an easy choice, even without considering the cost and time.

CASING INTEGRITY

- Specification of Unexpanded Section
  - Casing: 5-1/2in 20# P110
  - Min internal yield API: 12,640psi
  - Calculated yield pressure: 16,000psi

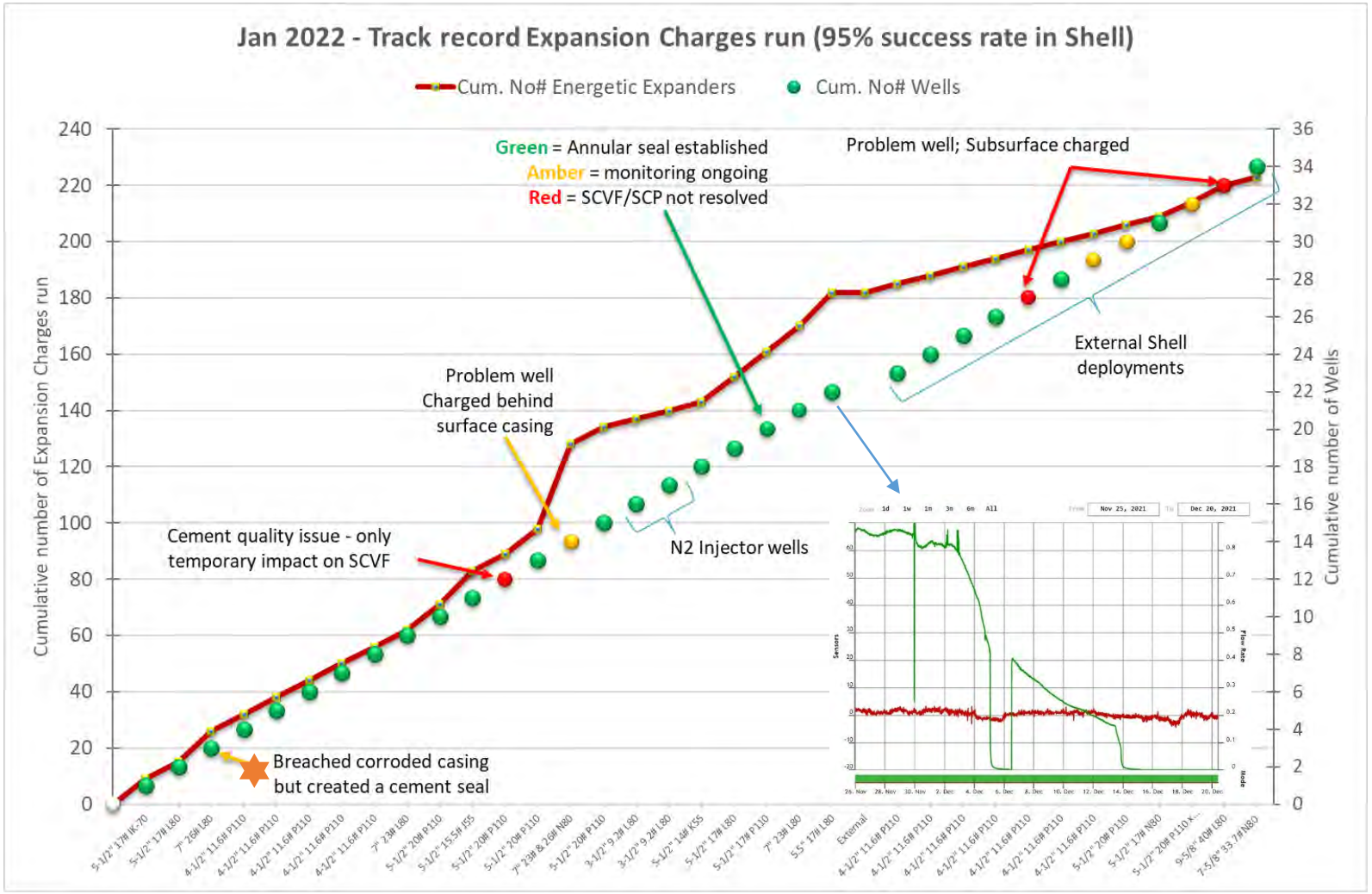
- Specification of Expanded Section of same casing
  - Maximum OD Expansion: 6.379in
  - Length of expanded section: 21in
  - Wall thickness at max OD: 0.298 – 0.318in (0.361in nominal)
  - Tested Burst pressure 15,500psi.

- Casing Expansion Demonstrated 5.5in to 6.379in
  - Radial Expansion 0.44in (0.4395in)
  - Percentage radial Expansion 16%
  - Testing indicates good integrity maintained up to 20% expansion and in some materials >20%



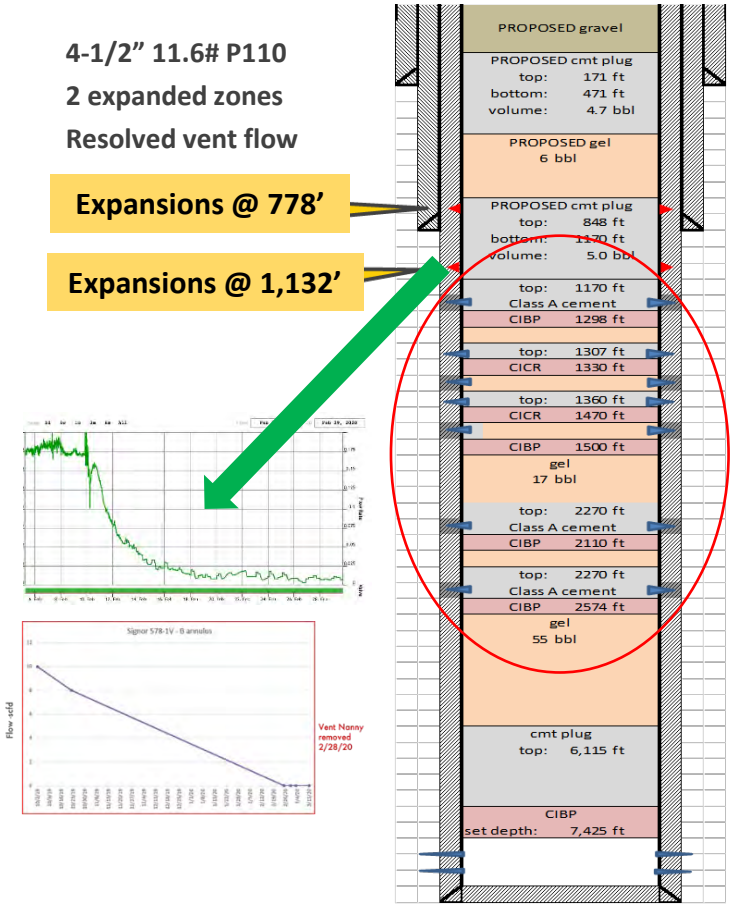
Expanded Casing after hydrostatic burst test at 15,500psi.

TRACK RECORD – January 2022



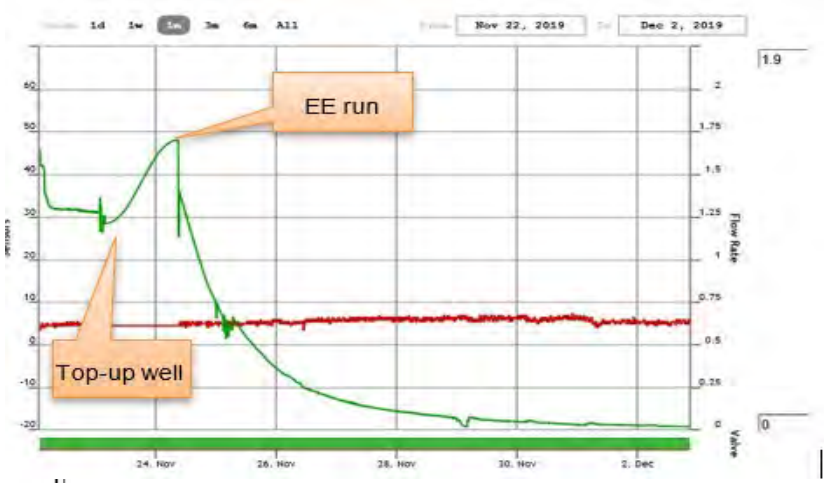
Comprehensive test / field trial record YTD

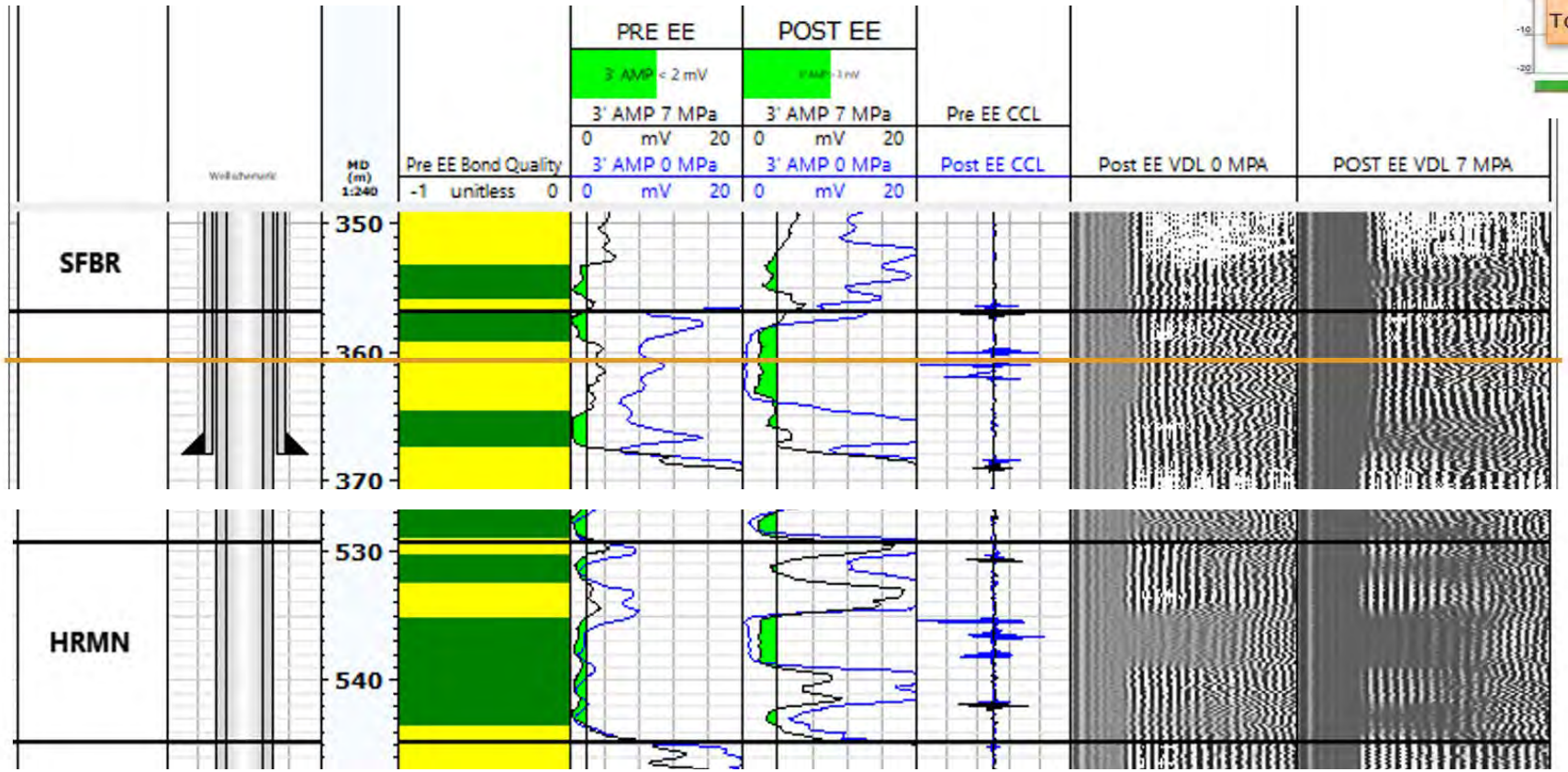
- Total no# of expansion tests performed in lab: >165
- Total no# of downhole MF-calliper measurements: >91
- *Only once was a casing breach observed on heavily corroded casing, which already had severe pitting prior to expansions, nevertheless the vent flow was resolved.*



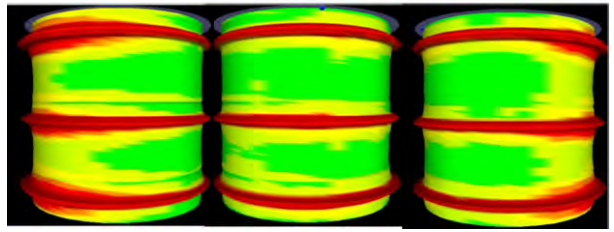
TRACK RECORD

- Example Deployment of Multi-Shot Expansion Charge 7in Casing.
  - CBL 5.7in Tool Expanded 7in to 7.7in with 4in spacing
  - Stronger VDL ‘formation arrivals’ indicate excellent casing to solids contact
  - 98% SICP & 93% SCVP drop within 1 week

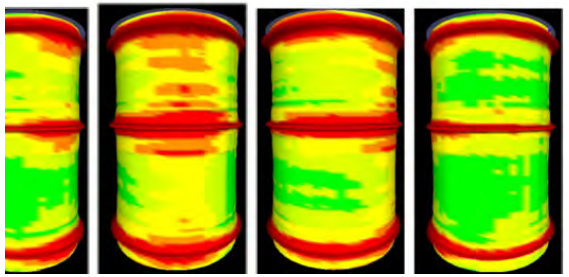




Dent 2.1-2.2-2.3 – 360-362m

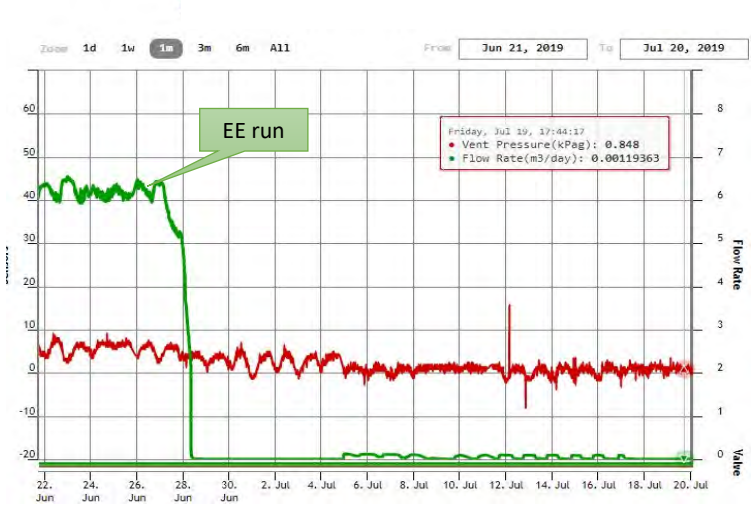


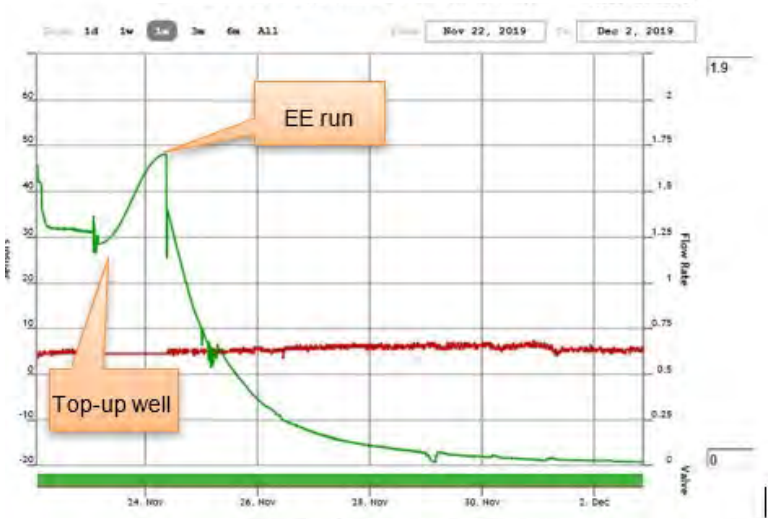
Dent 1.1-1.2-1.3 – 536-538m

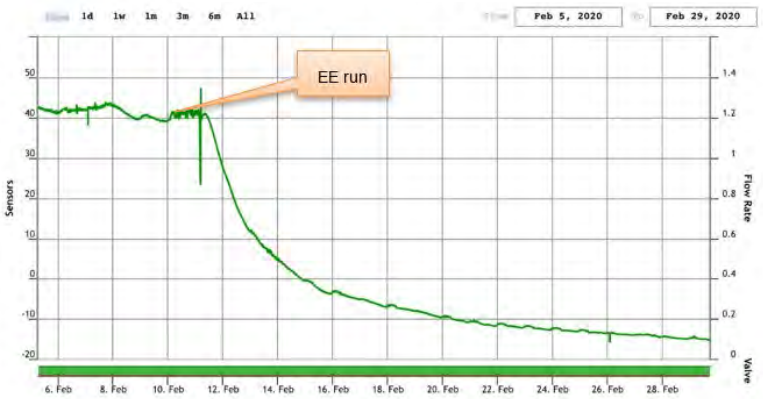


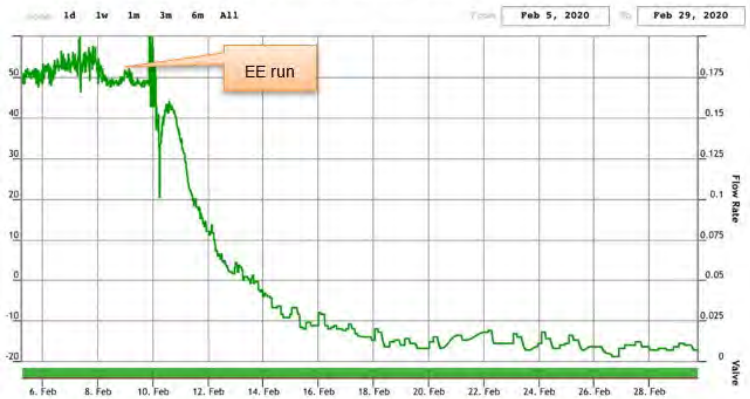
TRACK RECORD – Vent Flow Tests

☑ All passed 10 min bubble test





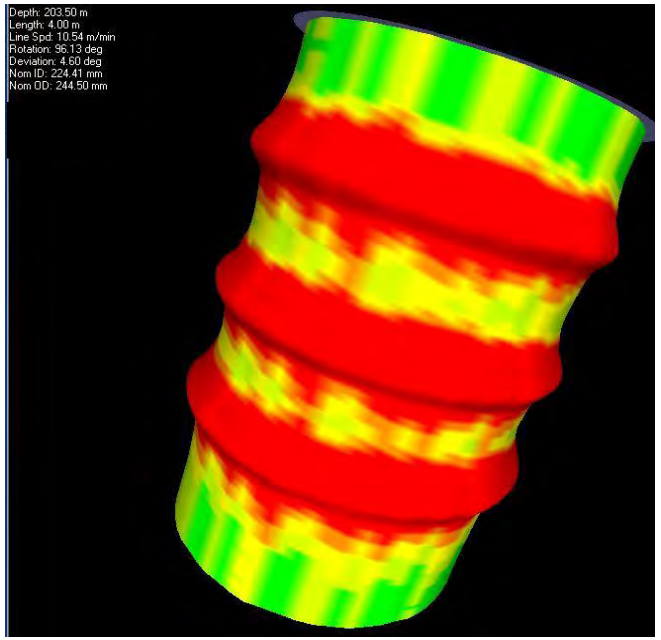


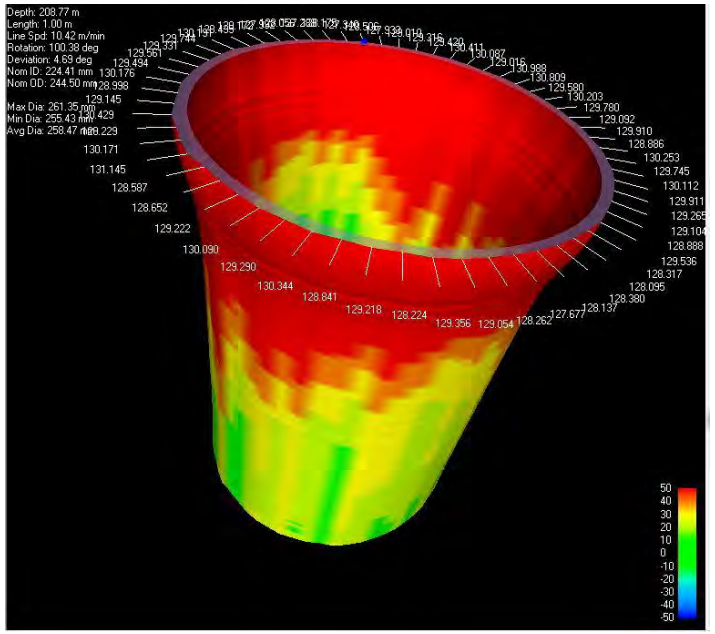


TRACK RECORD – DEFEC Tool. #D Images from Caliper Log

Field test 1

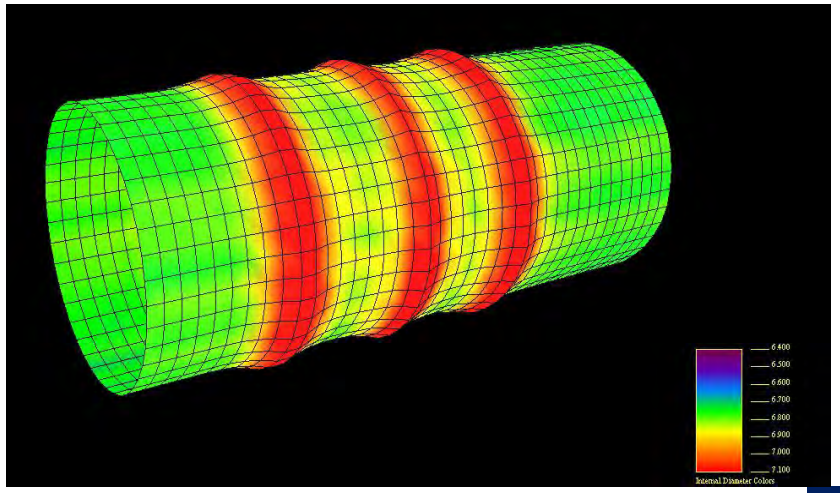
- Casing: 9-5/8”, 40#, L80
- DEFEC: 2.1250” tool
- 2 intervals (5 expansions)
- No breaches
- Calculated OD (max): 10.916”





Field test 2

- Casing: 7-5/8”, 40#, L80
- DEFEC: 1.750” tool
- 1 intervals (3 expansions)
- No breaches
- Calculated OD (max): 8.389”



TRACK RECORD – Operational Report Card

Last updated: August 2022

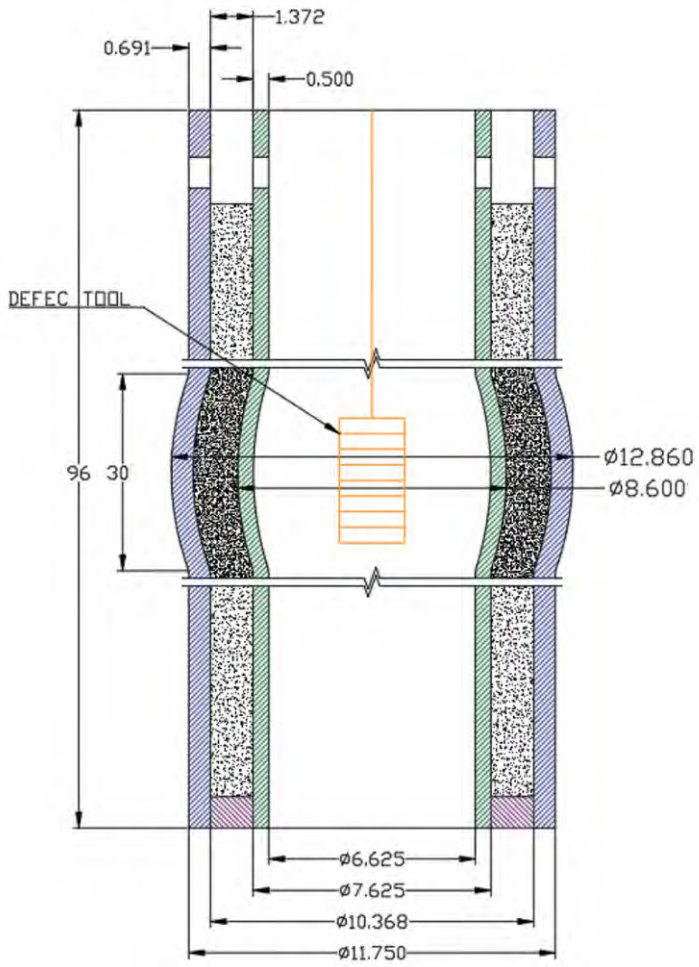
Casing Size [in]	Depth Range [ft] (hydrostatic pressure)	Number of wells	Number of ECs	Number of Successes	%	Comments
All regions (Canada, Pennsylvania, Permian, New Mexico, Netherlands)						
3.5”	1500 – 1600	2	6	2	100	N_2 injector wells
4.5”	700 – 4100	10 (+4*)	57	10	100	1 omitted (other gas source) 3 waiting on update
5.5”	1300 – 5300	13 (+2*)	105	12	92	1 unsuccessful - only temporary impact 2 waiting on update
7”	1200 – 5500	3 (+1*)	38	3	100	1 omitted (low POS job, other gas source)
7-5/8”	440	1	3	1	100	DEFEC design
9-5/8”	607 - 700	1*	6	TBC	TBC	DEFEC design
	TOTALS	29 (+8)	215	28	96	36 wells total (2 omitted, 6 TBC)

Operators:

- Shell, Chevron, Seneca, Chesapeake, Ovintiv, Devon, Centennial, Cenovus, Crescent Point, Range Resources

THE CAPABILITY TO EXPAND MULTIPLE CASING STRINGS

- The capability to expand multiple casing strings is one of the most important developments of the technology.
- The incidence of annular flow in subsequent annuli is a significant issue for operators and can be mitigated swiftly and cost effectively by the DEFEC tool.



7 5/8” O.D. x 6.625” I.D., 39#, Q-125
11 3/4” O.D. x 10.282” I.D., 82.69# Q-125

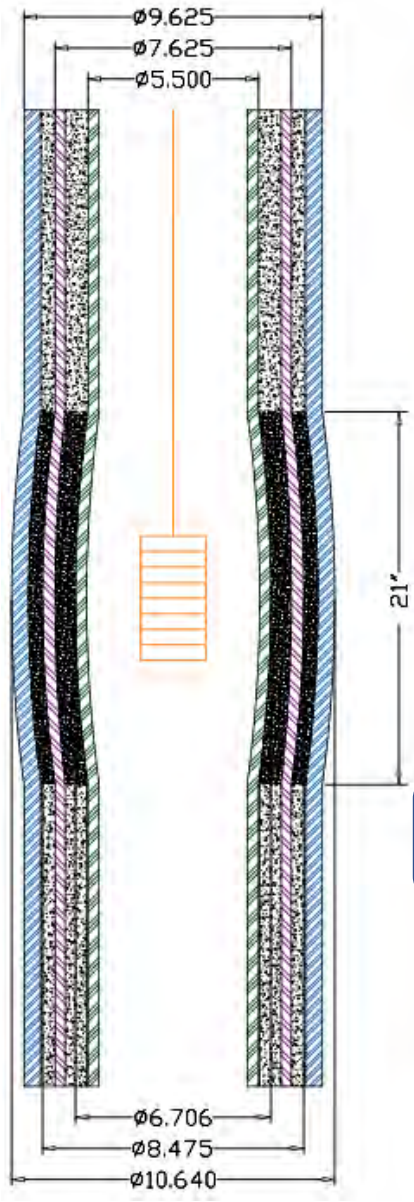
THE CAPABILITY TO EXPAND MULTIPLE CASING STRINGS

- The application of the DEFEC tool to Multiple Casing Strings has been tested on up to three casing strings.
- This expansion test shows the third heavy wall casing being strongly expanded by the tool to provide a potential seal against a channeled cement job in open hole, or at minimum a significant reduction in flow, without any damage to the casing.

THE CAPABILITY TO EXPAND MULTIPLE CASING STRINGS

- Taking a closer look at the numbers
- A > 20% expansion in the inner casing leads to a > 10% expansion in the next two casing strings.

Pipe OD in (mm)	Expanded OD In (mm)	Radial Expansion In (mm)	% Expanded OD
5.500 (139.700)	6.706 (170.33)	0.603 (15.32)	21.93
7.625 (193.675)	8.475 (215.265)	0.425 (10.79)	11.15
9.625 (244.475)	10.640 (270.256)	0.507 (12.88)	10.55



EXPANDING LARGER CASING STRINGS

- Success with the DEFEC tool enabled casing expansion to be applied to larger casing expansion.
- Extensive testing has recently been completed with early field trials with great success.
- Further refinement and detailed study of casing expansion technology and how it operates in various casing weights, grades and sizes enables a refinement in tool design and selection.
- Up to 20% Expansion with the DEFEC is the target with 15% being a good guideline for expansion. That is removing 1 in. of radial annulus in a 13-3/8in casing.

CS OD	Weight	Grade	OD exp.	Expansion	Expansion
in	lbs/ft		in	in.	%
9.625	40	L80	10.832	1.207	12.54
9.625	40	L80	10.456	0.831	8.63
9.625	40	L80	10.588	0.963	10.01
9.625	47	L80	10.990	1.365	14.18
11.750	82.6	Q125	12.860	1.110	9.45
13.375	68	L80	13.730	0.355	2.65
13.375	54.5	K55	13.915	0.540	4.04
13.375	68	L80	14.218	0.843	6.30
13.375	68	L80	14.389	1.014	7.58
13.375	68	L80	15.060	1.685	12.60
13.375	54.5	K55	15.420	2.045	15.29
16.000	105	X50	17.344	1.344	8.40

FURTHER DEVELOPMENTS

- Further refinement and detailed study of casing expansion technology and how it operates in various multi-casing annuli expansions is open to exploration.
- It is clear that second and third casings can be expanded very effectively with and without cement in between the casing strings.
- Casings up to 16in have been tested successfully, 18-5/8in and 20in should also be possible to expand both individually and as part of a multi-casing expansion.
- The application of the smaller OD DEFEC as a Thru-tubing tool is a key new application. A quick method of isolating flow behind liner or casing for water or gas shut-off.
- Liner to casing leak can also be sealed by expanding the liner into the casing.
- There are also many more opportunities to further develop safe cost-effective applications in drilling and completions.

CONCLUSIONS AND QUESTIONS

- Energetic Casing expansion could appear to be a reckless pursuit, with images of large packages of explosives being unleashed on casing causing the casing to be torn apart. However, with the application of many years of experience and the scientific application of carefully calibrated and focused amounts of energetics, WTBI have been able to develop not one but two unique casing expansion devices, which provide this highly reliable, calibrated and focused expansion.
- Not one of the 30+ jobs to date have resulted in any casing failure.
- Every job has operated smoothly – work has been completed successfully.
- 96% of jobs to date have resulted in the desired restriction to flow, or pressure build up (not every well has a completely ideal expansion seat in terms of cement, formation etc.)
- There are so many wells with sustained casing pressure or vent/annular flow in the world, it is impossible to count, and this is a cost-effective mitigation.

- Thank You

Cairo. Egypt. November 7-8, 2022

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Q&A

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