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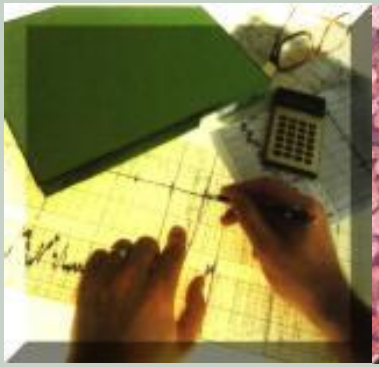

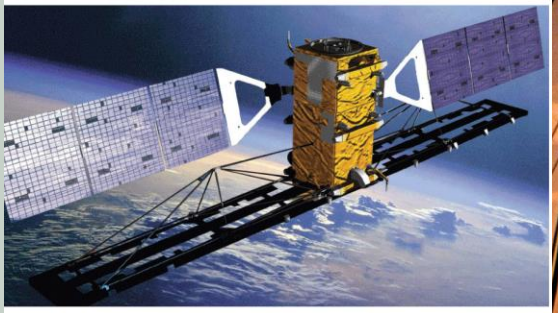

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an explosives specialty group

Founded in 2002 by William T. Bell and James (Jim) Rairigh

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

The objective of this project is to eliminate the potential effect of expandable-casing technology on the cement sheath and remediation of sustained casing pressure (SCP) caused by micro-annular gas migration.

AUTHORS:
Jim Rairigh, WT Bell Int. Inc.
Mark Brinsden, VektorEnergy Inc.

Covered by U.S. and international patents.

Calibrated Energetic Casing Expansion to Mitigate Annular Pressure/Flow

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?

Expansion Charges

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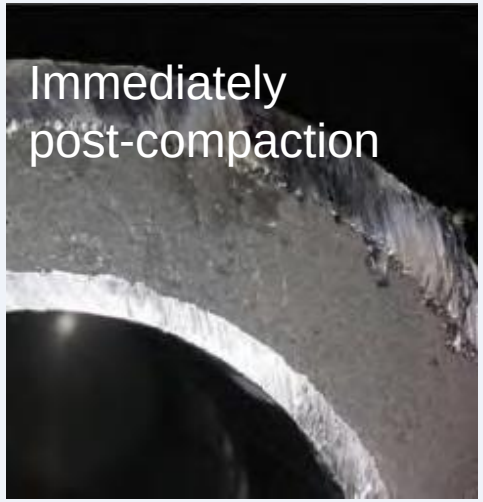
Dent at 1.8 m presenting measurements of Vickers hardness for cement (red) and steel (yellow). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

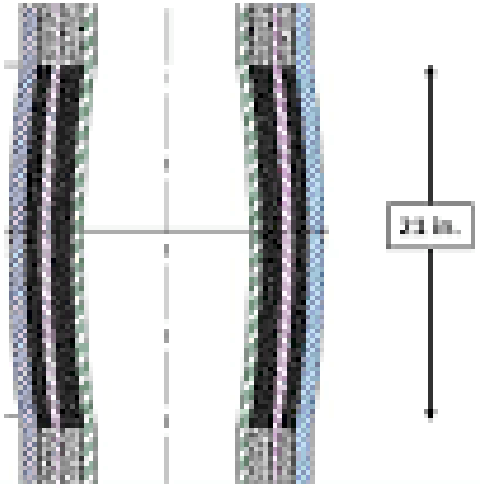
OVERVIEW OF EXPANSION TECHNOLGY AND APPLICATIONS

- 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



Dual End Fired Expansion Charge (DEFEC) tool expands pipe to reduce annulus pressure and water production

9.625 in., 40 lbm, L80 casing
Calculated OD (max) 10.916 in.



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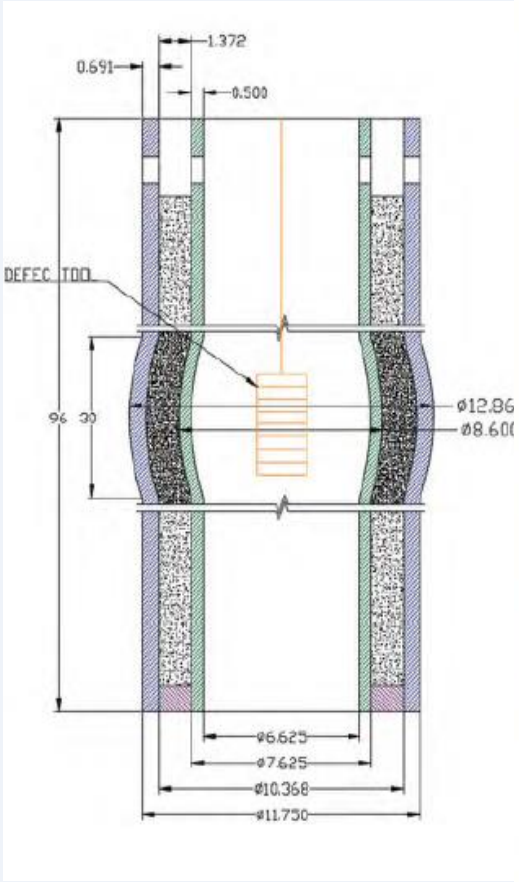
THE CAPABILITY TO EXPAND MULTIPLE CASING STRINGS

- 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

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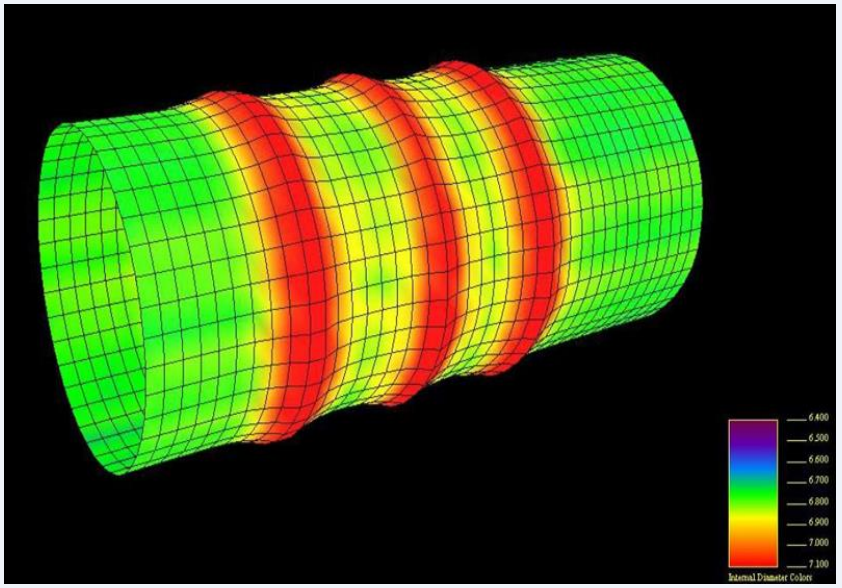
A Dual-End Fired Expansion Charge (DEFEC) job in a well successfully remediated unwanted annular pressure behind 7.625-in., 33.7-lbm, N80 casing. The multi-finger caliper log proves there were no breaches in the casing, the expansions were consistent and



the maximum expansion achieved was 0.65 in. And best of all, there was no pressure buildup after the job. Successes like this demonstrate that tens to hundreds of thousands of dollars can be saved when Expansion Charges are used to safely and reliably expand pipe to seal leaks without a squeeze job or section milling.

OVERVIEW OF EXPANSION TECHNOLGY AND APPLICATIONS

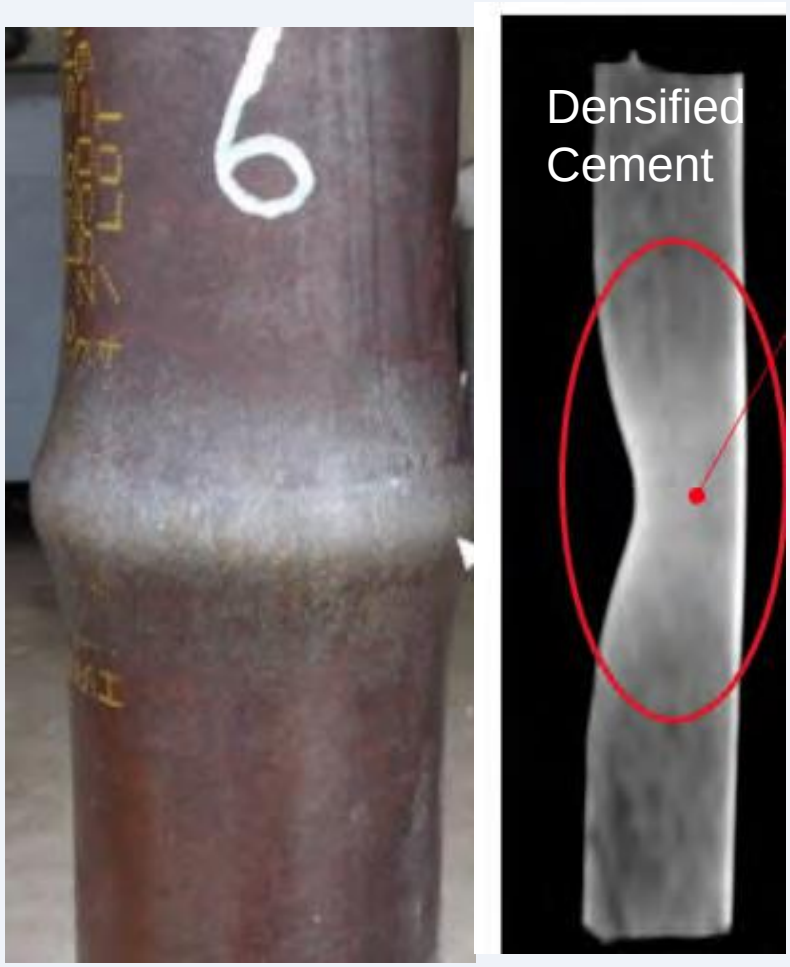
Energetic Expansion of Casing –Achieved by calibrated and focused release of energy.

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 rig-less. 94% Success rate on first attempt on over 30 wells.

Compare to Perf. & Squeeze 30% success rate (SPE-106765).

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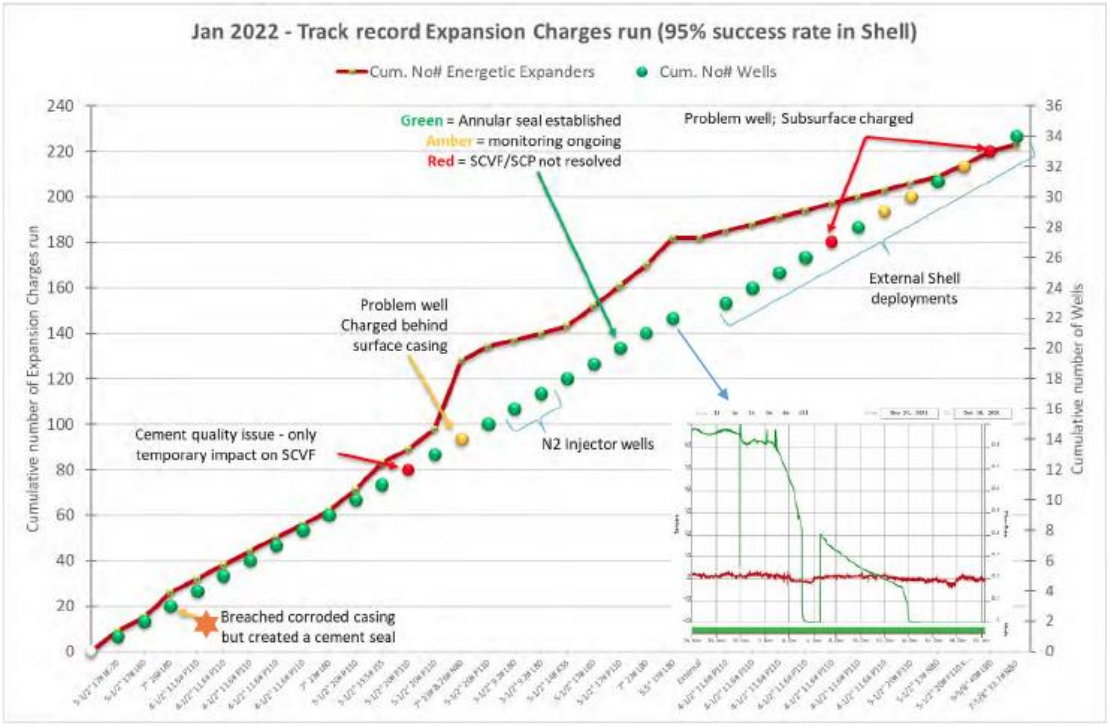
The Application of Calibrated Energetic Casing Expansion to Mitigate Annular Pressure/Flow

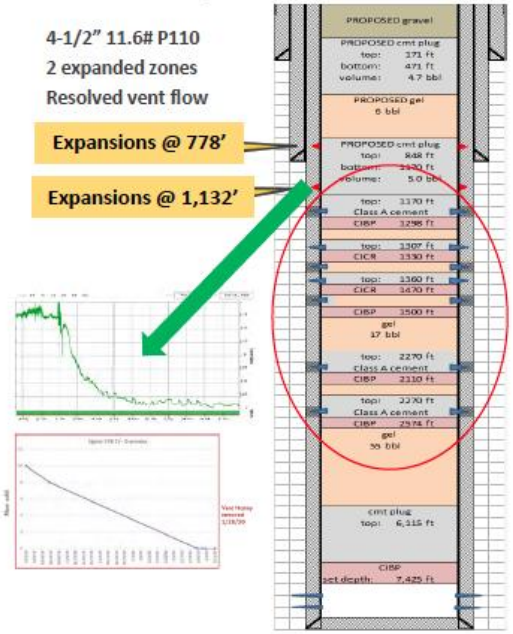
MENAPS 2022
MIDDLE EAST AND NORTH AFRICA PERFORATING SYMPOSIUM

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.*



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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

Who we are ?

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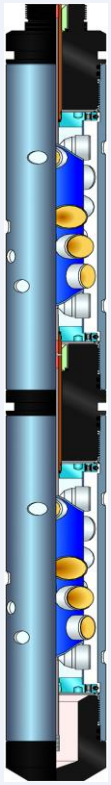
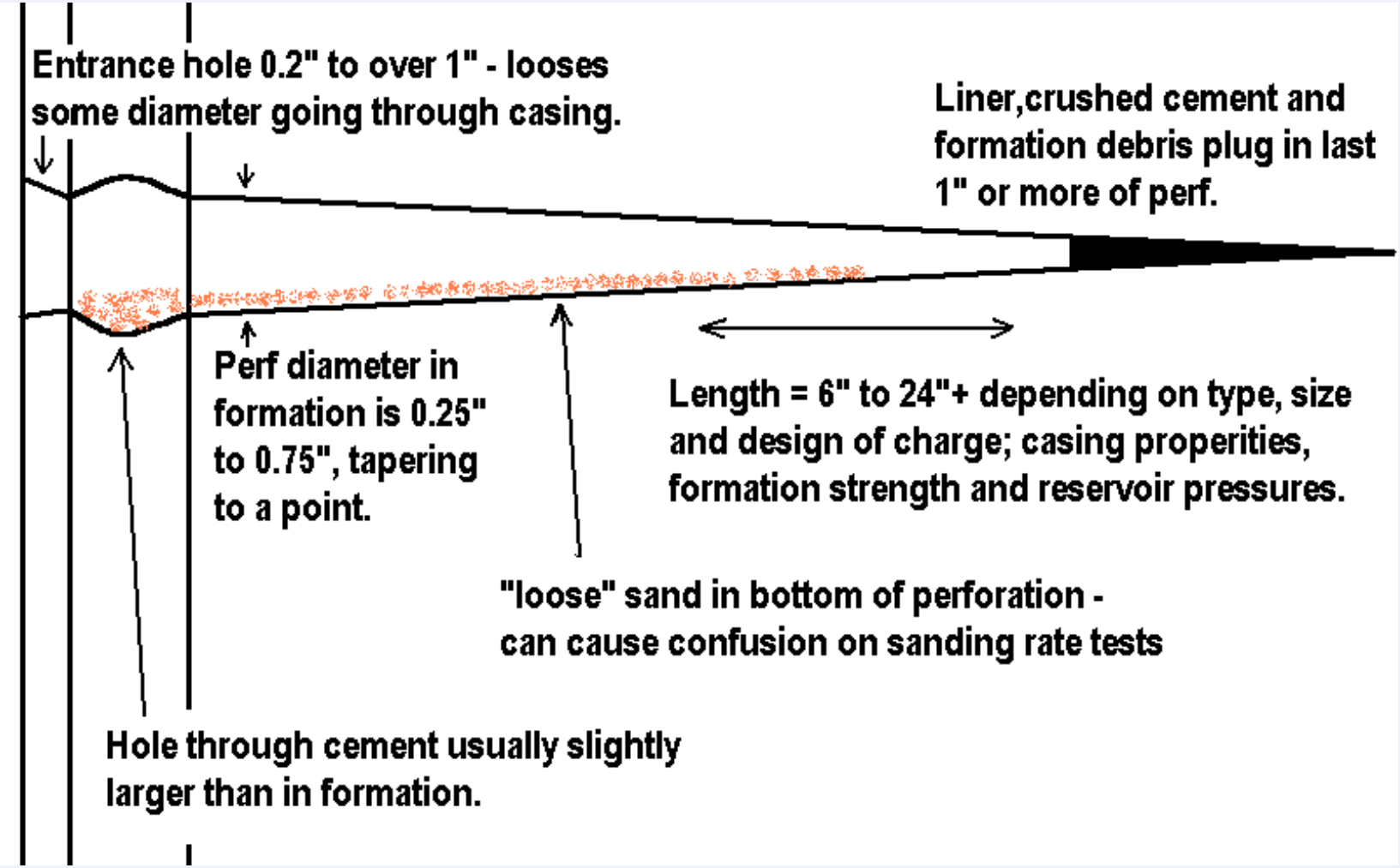
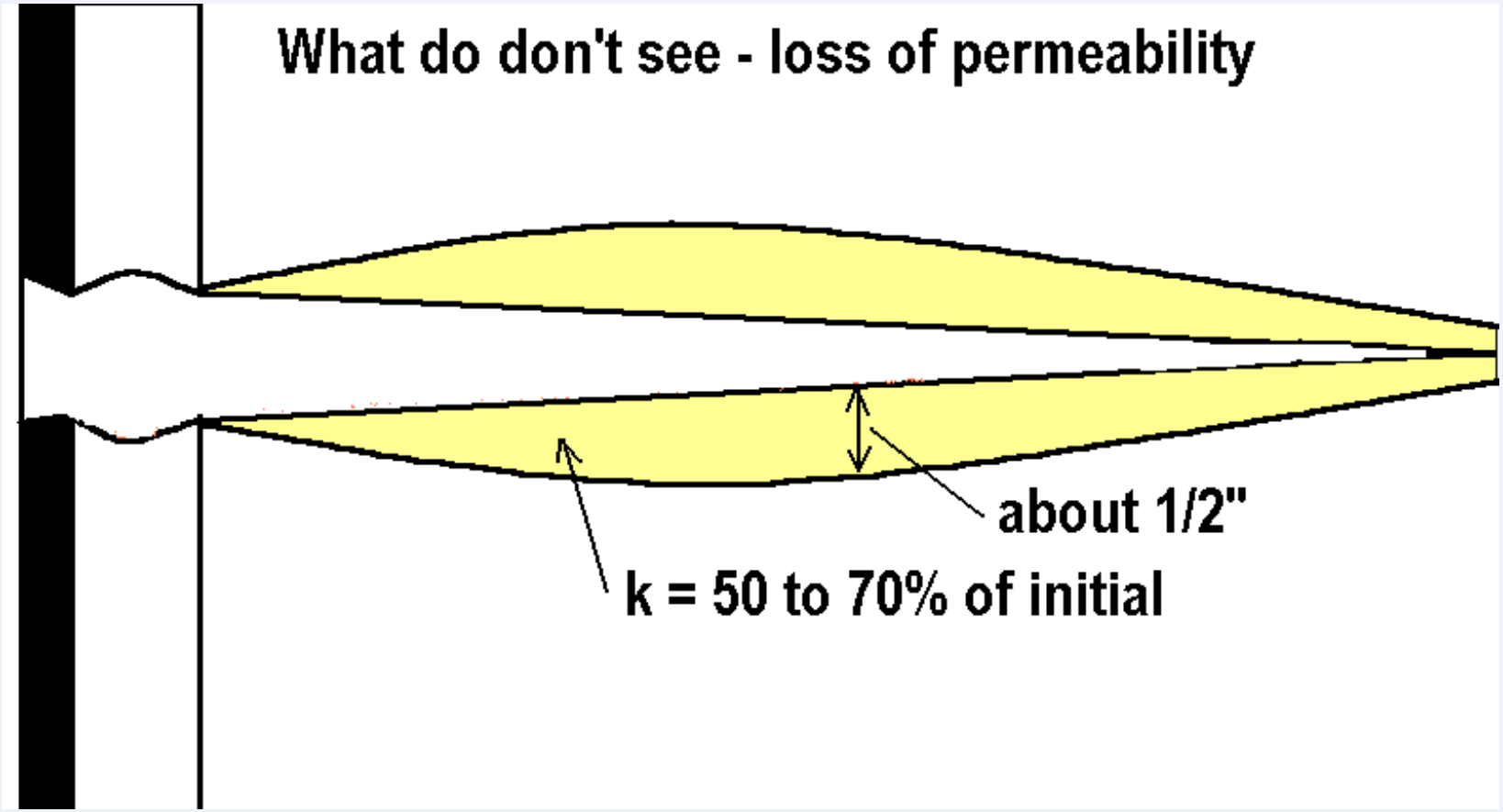


PERFORATING with
Underbalance "Static and/or Dynamic"
Reactive Charges with The Gas Gun,
A Better passage for your oil production

A Case Study: PDS has a case of well located in Red Sea that has a tight reservoir of poor properties. The formation is Nukhul Carbonate with Porosity from 6 - 12 % and Permeability ranges 0.2 - 1 md. randomly. The Reservoir pressure is 1000 psi.

Anatomy of a Perforation




What do don't see - loss of permeability
about 1/2"
k = 50 to 70% of initial

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So, The Target is to deliver **Long debris-free** tunnels depending on underbalance if achievable. The result will incredibly increase the perforating efficiency, superior productivity, enhanced injectivity, and dramatic improvements in stimulation parameters and performance.

1. **Underbalance** ”Dynamic or Static”.
2. **Reactive Perforating**

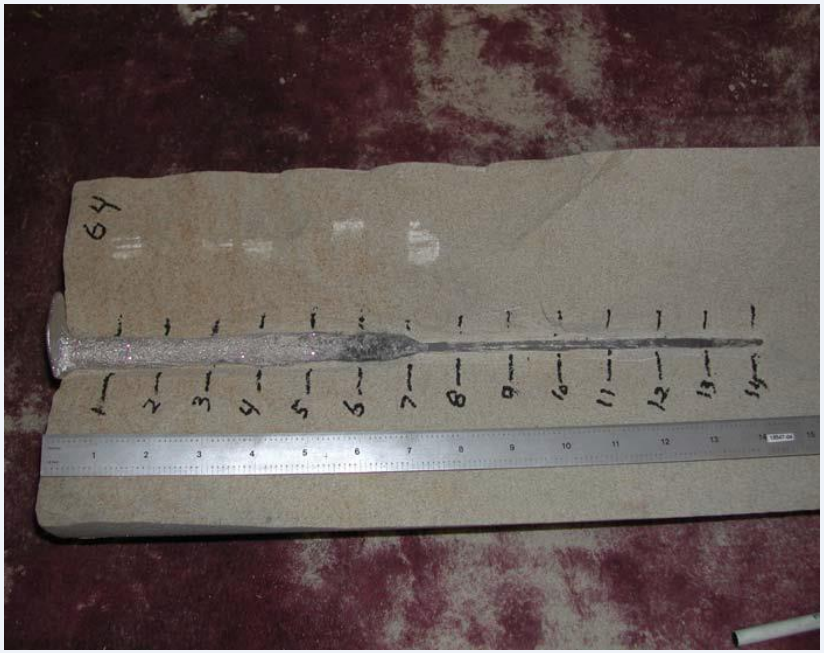
“Considering debris removal from the perforating Tunnels”.

1. **Gas Gun Fracturing.**

Underbalance effect

Castle gate Sandstone

- *Balanced* *3,500 psi U/B*



After Dudly Vann

Reactive Perforating System

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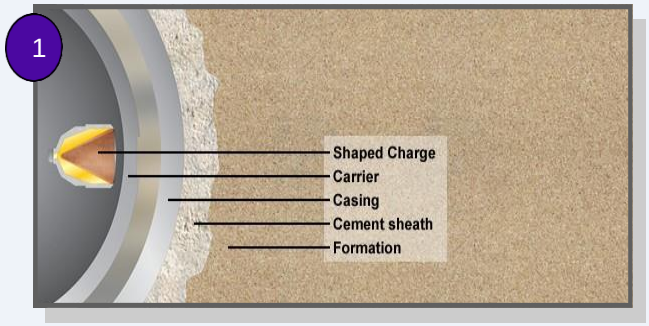
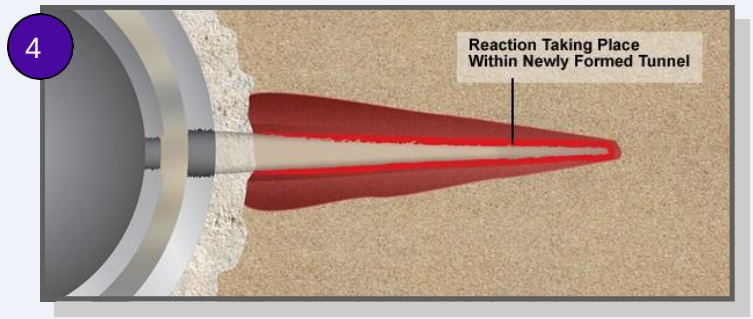
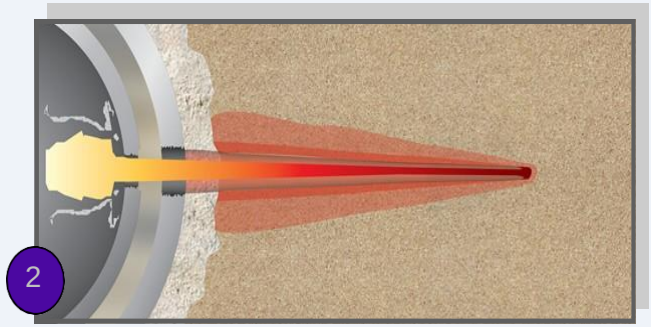
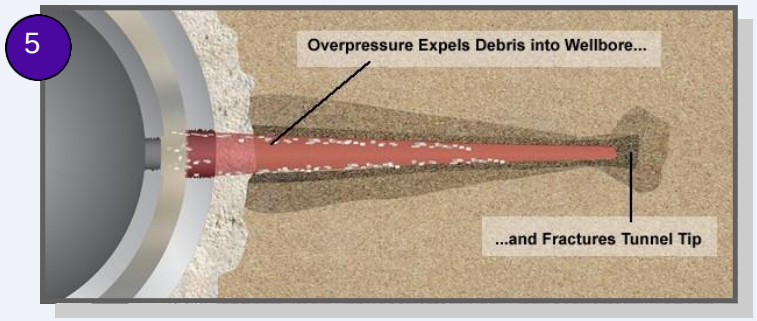
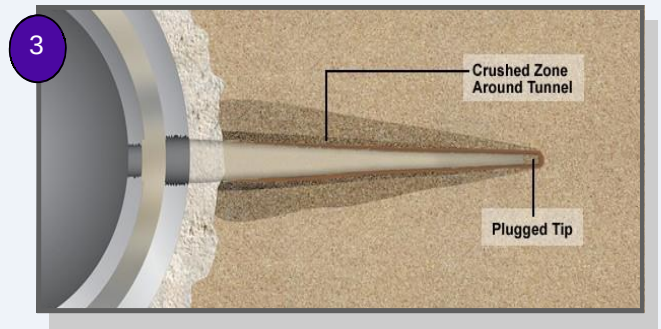
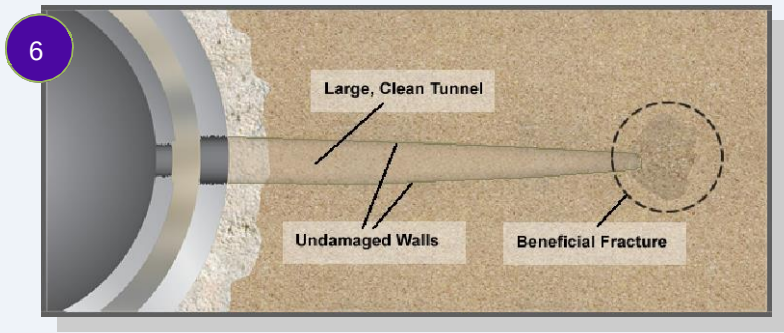




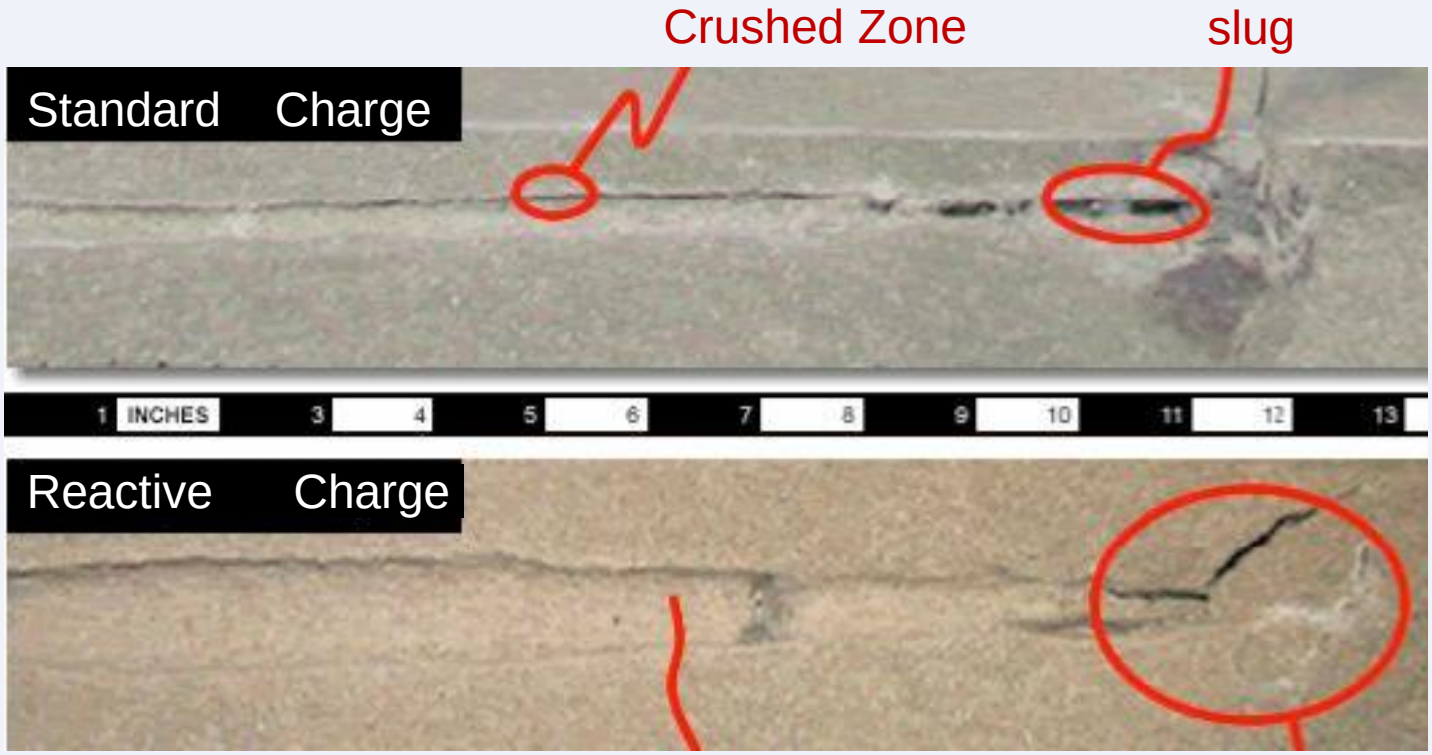








PDS is the introducer of the Reactive Perforating System to the Egyptian Oil Industry. The new class of Reactive TM shaped charge that delivers a step change improvement in perforation geometry and performance. The Reactive perforating product generates a secondary reaction in the perforation tunnel thanks to proprietary liner metallurgy and charge design.



شركة الخدمات لتنمية البترول شركة ذات مسئولية محدودة بنظام المناطق الحرة

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Gun System Pressure Calculation Sheet

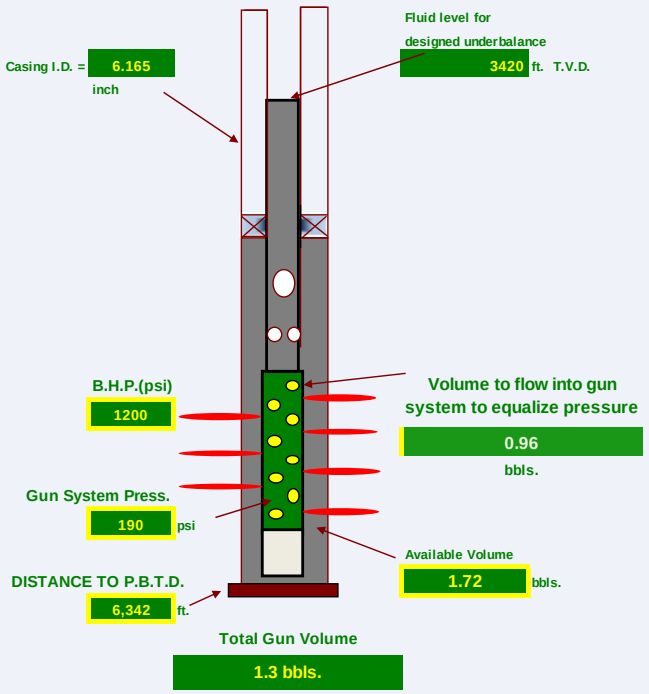
Input Data

Well Name =	AZ-1	
Company =	HQ	
Casing I.D. =	6.165	inch
Gun Size (O.D. in) =	4.5	inch
Shot Density =	5	S.P.F.
Charge Wt. =	39	gram
Explosives Type =	H.M.X.	(ex. R.D.X., H.M.X., etc...)
Depth of Penetration =	35	inch
Diameter of Perforation =	0.47	inch
Bottom Hole Temp =	170	^{O}F
length of loaded section =	10.00	FT.
length of Blank section =	90	FT.
Bottom Hole Pressure =	1200	p.s.i.
Fluid Weight =	8.3	#/gal.
Underbalance =	300	p.s.i.
Applied Tubing Gas Pressure =	100	p.s.i.
Top Shot @ =	5,505	ft. T.V.D. 4070 ft. M.D.
P.B.T.D. =	6,342	ft. T.V.D. 5217 ft. MD

Resulted Data

Volume Of Perf/ft. =	0.50	Lt./ft.
Volume of Loaded section V_1=	1.825	Lt.ft
Pressure in loaded Section P_1=	1932	p.s.i.
Pressure in loaded Section & Perfs. P_2=	1518	p.s.i.
Volume of Loaded section & Perfs. V_2=	2.323	Lt/ft
Pressure in blank section P_3=	14.7	p.s.i.
Total Volume of blank section V_3=	176.0	Lt.
Pressure in all guns, blanks & perfs. P_4=	190	psi
Volume of all guns, blank & perfs.V_4=	199.2	lt.
=	1.3	bbls
Desired annulus pressure to get proper dp. P_5=	800	p.s.i.
Volume to be filled in guns to reach P_5, V_5=	151.9	lt.
=	0.96	bbls
Available volume around guns =	1.72	bbls

Summary :-



In grattitude to Mr. Edd Colle

Now, We have ;

1. Deeper initial penetration.
2. More active perforated tunnels.
3. Cleaner tunnel with fractured tips that reduces the breakdown Gas Gun pressure.
4. Improve injection rates at minimum pressure for followed up acidizing job.
5. Ensures reliable fracture initiation and maximum fracture coverage

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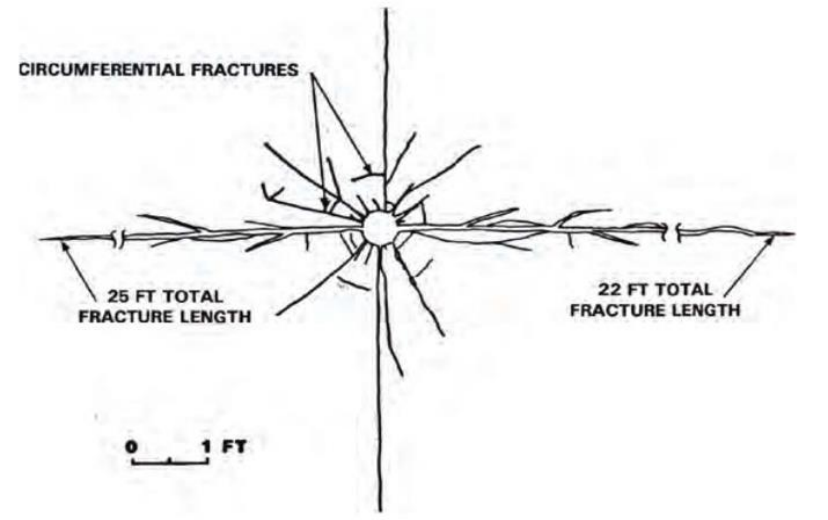
Utilizing the **Gas Gun**, The extra depth of the perforating tunnels over 20 ft. has tremendously assets the planned acidizing job improving the cleanout treatment process.



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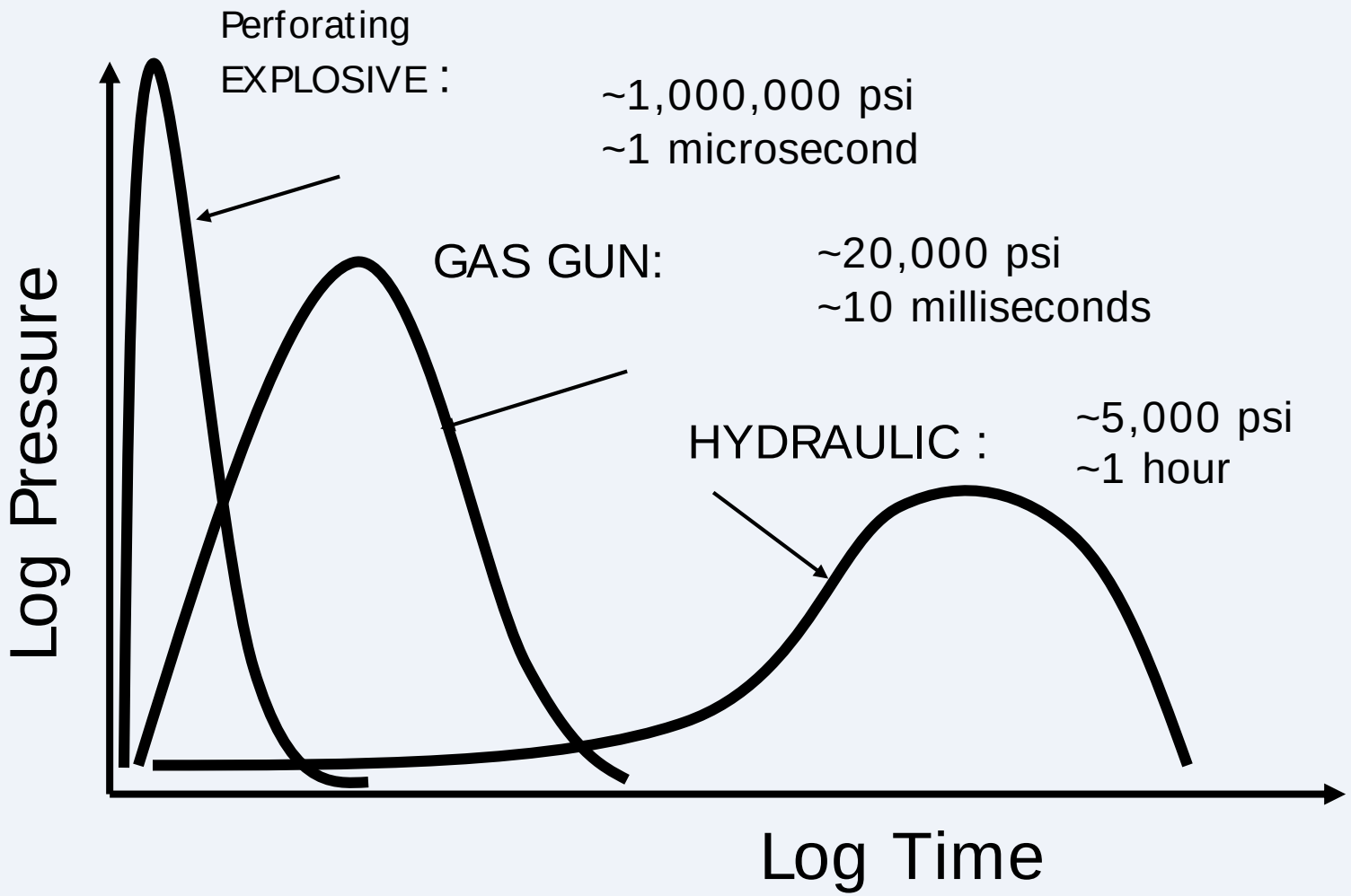
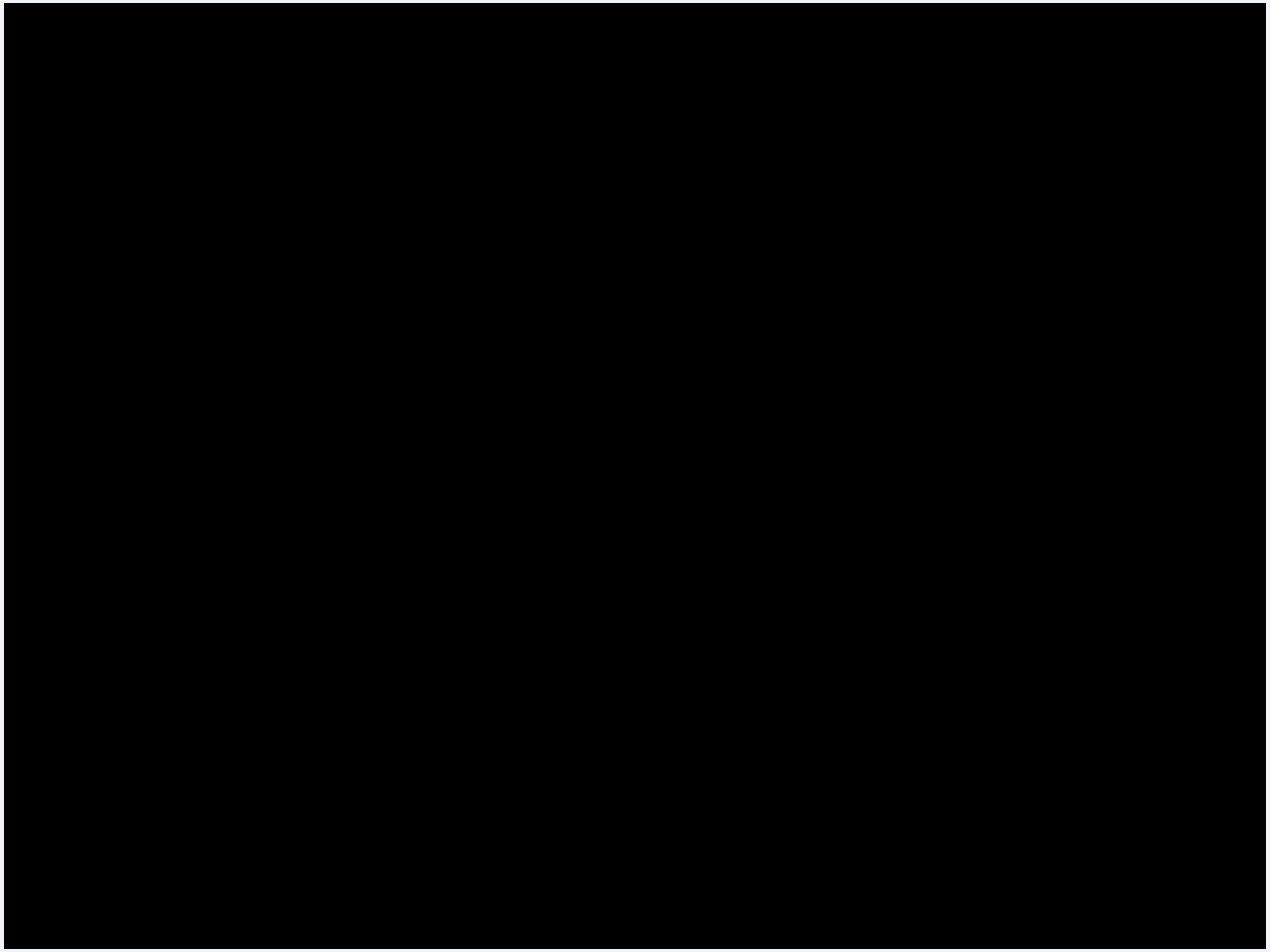
The Theory is in the Pressure-time profiles of three stimulation methods





The **Gas Gun** propellant burning rates and pressure-time profiles are different from explosives and hydraulic fracturing so that it can create multiple fractures that are not governed by in-situ stresses. Hitting the undesired water zone is mostly unlikely.

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The Gas Gun

Other

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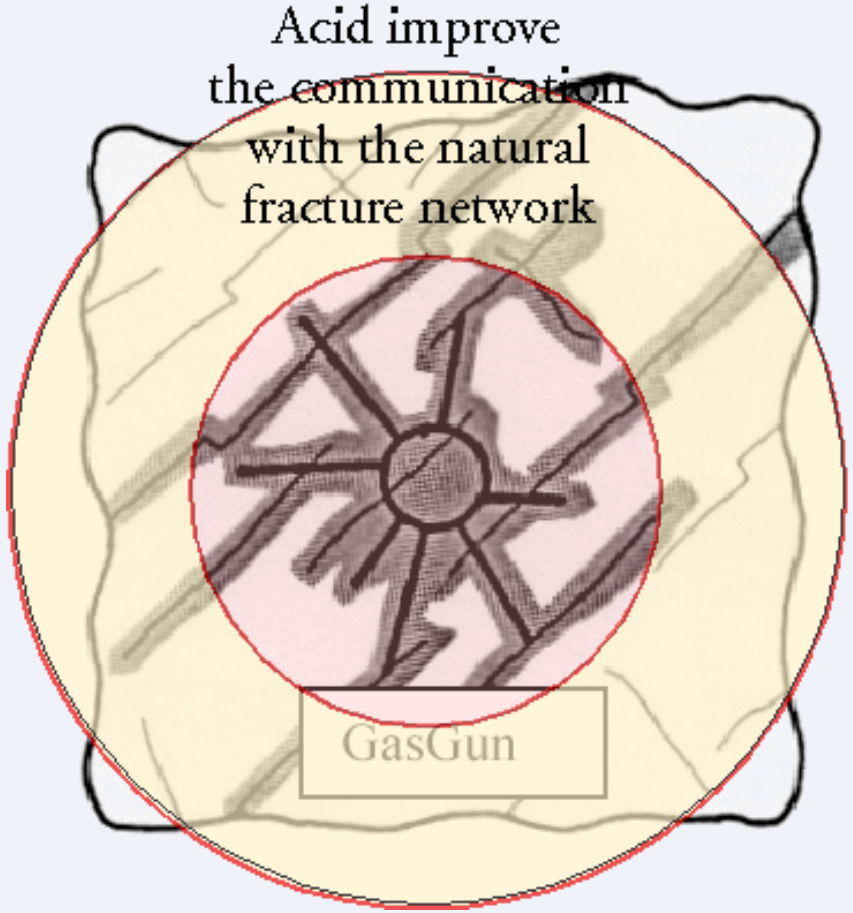
Now, ready for the Acid Job;

Volume of acid should fill the fracture pattern to a such distance to accommodate a good communication with the well bore.



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2. Down hole Tools,
3. Cased hole Logging,
4. Exploration,
5. Machining,
6. Well Testing.


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Who ?

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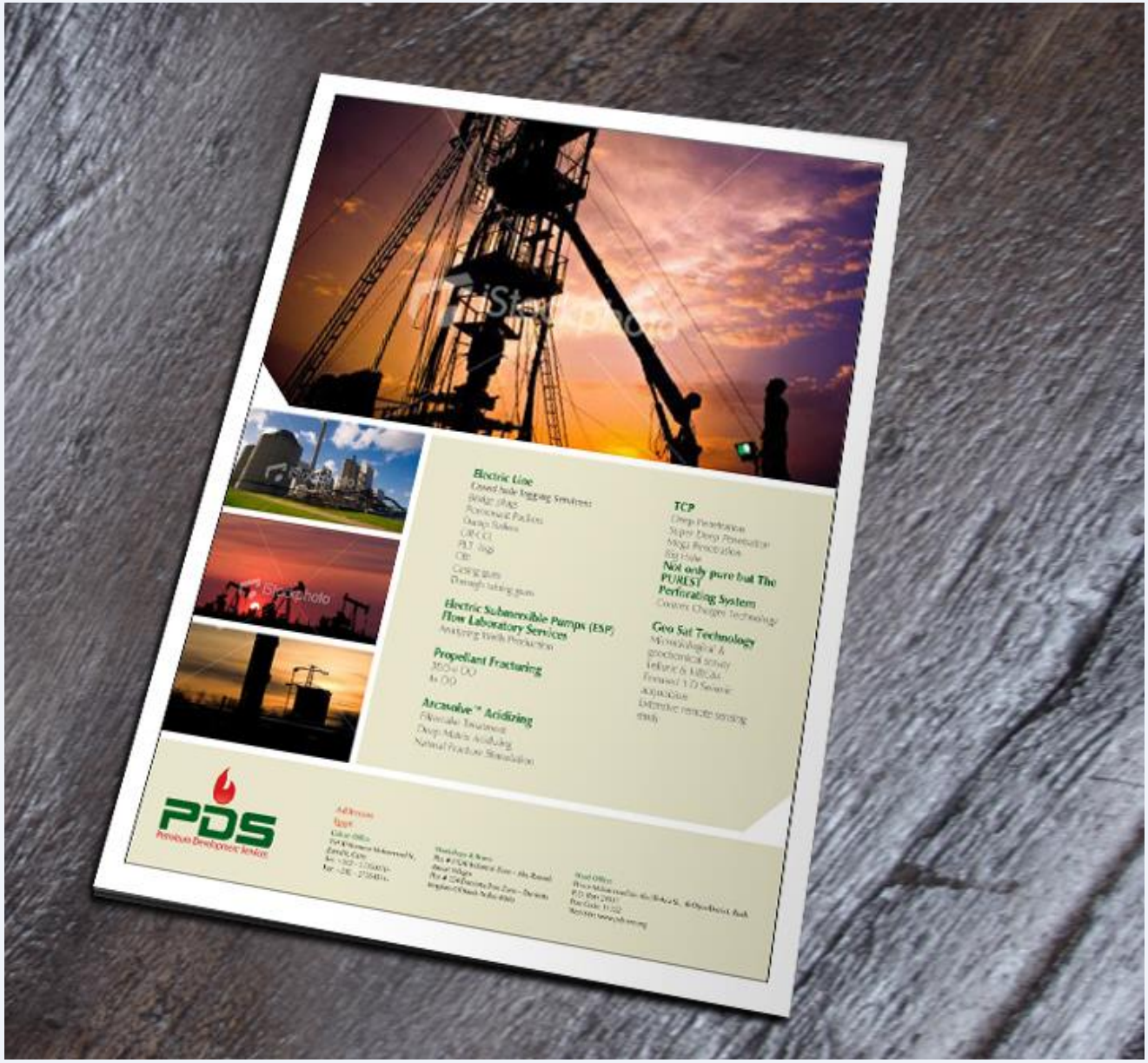
Electric Line
TCP
Not only pure but The PUREST Perforating System
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