Cairo. Egypt. November 7-8, 2022

MENAPS 2022

MIDDLE EAST AND NORTH AFRICA PERFORATING SYMPOSIUM

Perforation in Tight Gas reservoir using Reactive Liner Charges – Case Study

MENAPS-13-22 AUTHORS: Safouane Yagoubi, Adel Bdeir, Mowaffaq Murad “NESR”

Agenda

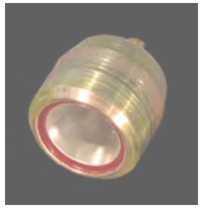
- Field history
- Specifications of Reactive liner perforators
- Conventional vs Reactive Liner Charges
- Operations in the field
- Results & Conclusions

Field history

- Tight Gas formation with compressive strength ranging between 14,000 to 19,000-psi
- High Horse-power required, to perform the Stimulation
- Long lasting clean-out operations

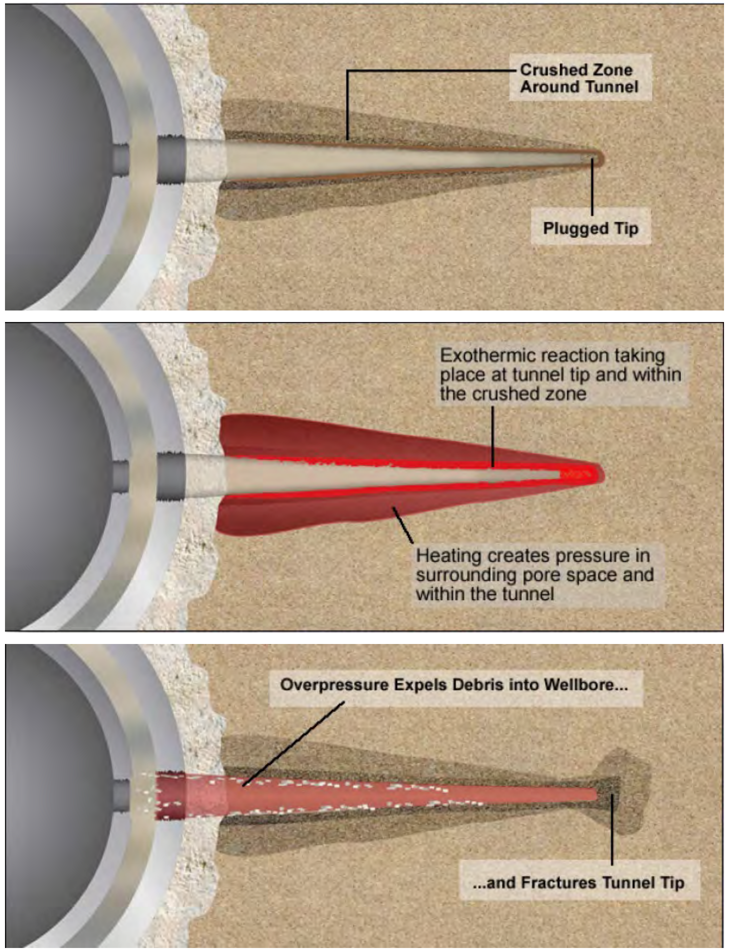
Properties of Reactive Liner Perforators 1/2

Reactive Liner Perforators

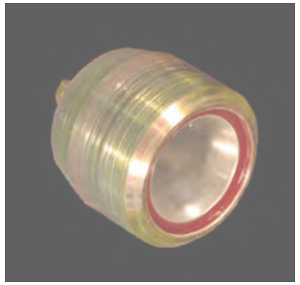


Reactive liner perforators incorporate a proprietary combination of metals into the powdered metal mixture used to form the shaped charge liner.

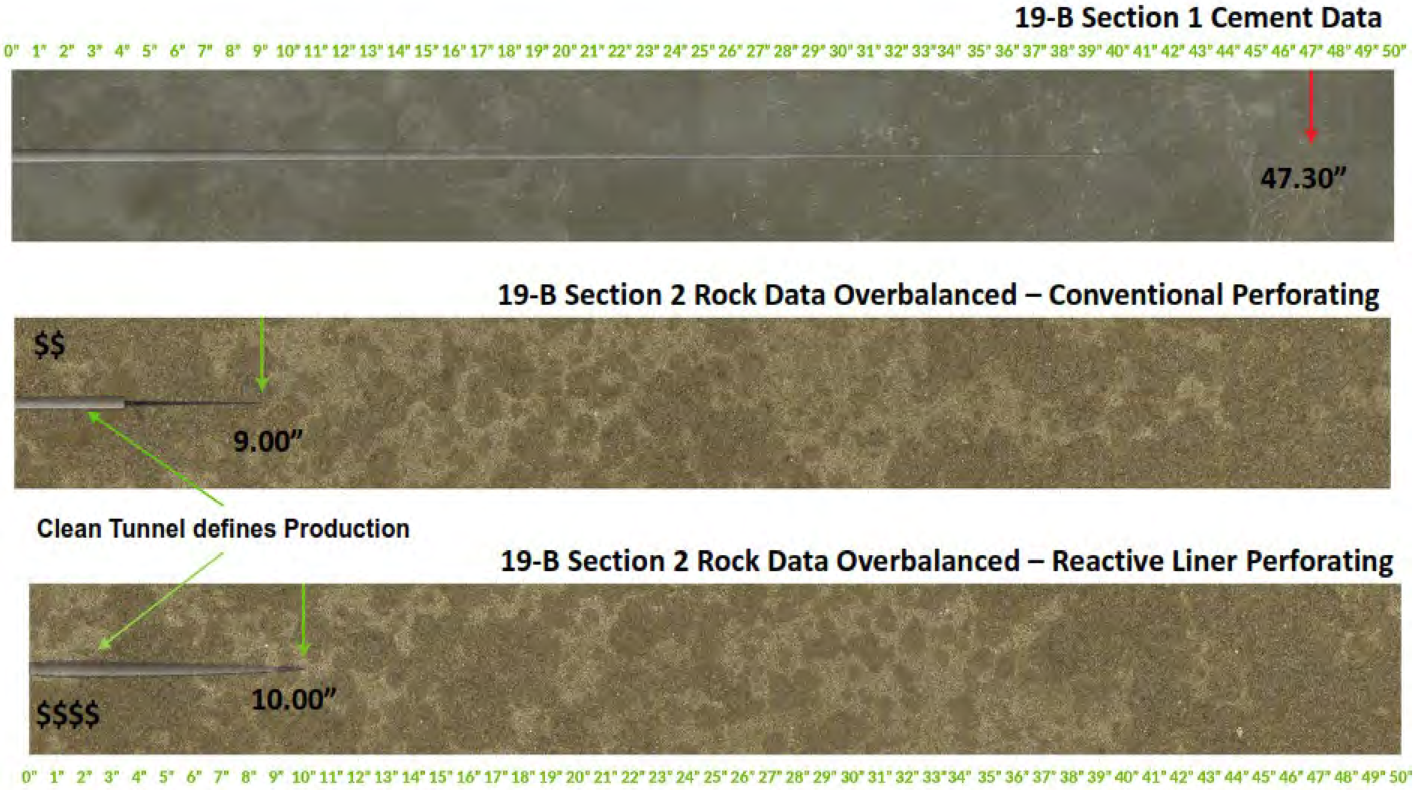
- Under the heat and pressure of detonation, these metals react to form a highly exothermic reaction. Its rate is such that most of the heat release occurs within the newly formed perforation tunnel.
- Heating of the tunnel, and of the fluid in the surrounding rock, results in a significant pressure spike of very short duration.
- Following the path of least resistance, the pressure relieves towards the wellbore, breaking up and expelling compacted fill, from within the tunnel, and damaged low-permeability rock, from the "crushed zone", along the tunnel walls.



Reactive Liner Perforators



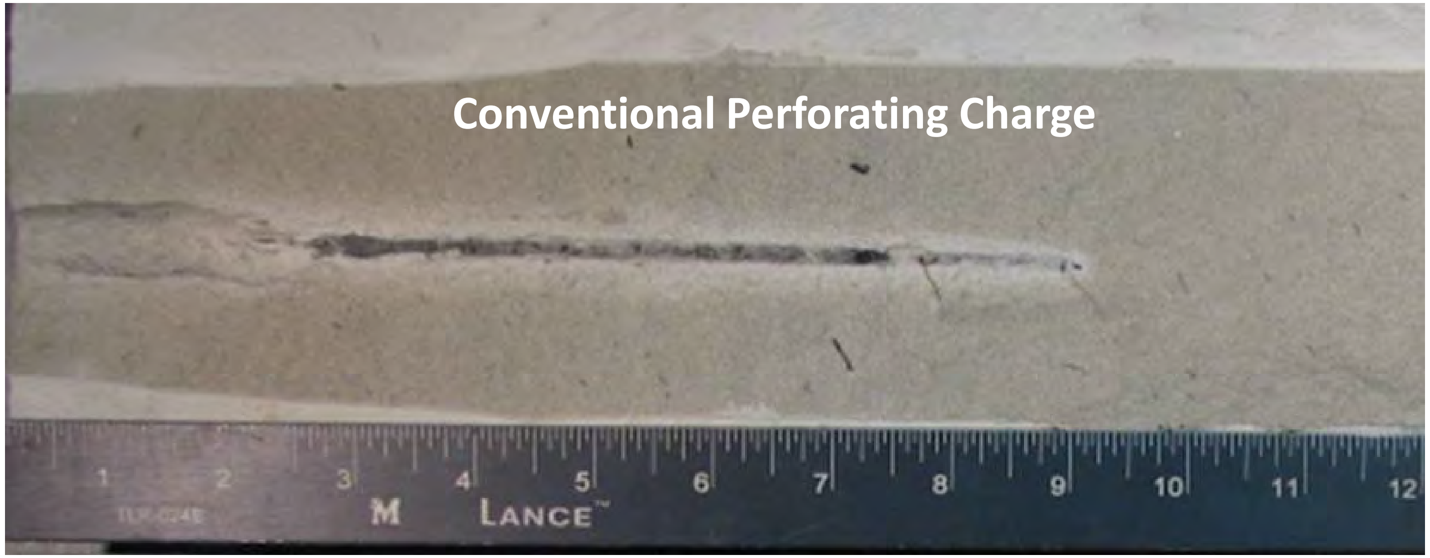
- The result is:
  - A clean tunnel with minimal obstruction to flow.
  - In sufficiently low permeability targets, the over-pressure is sustained long enough for rock failure to occur, forming small fractures at the perforation tunnel tip (where most of the reactive material is concentrated). These fractures are highly beneficial to production, injection, and fracture stimulation activities.

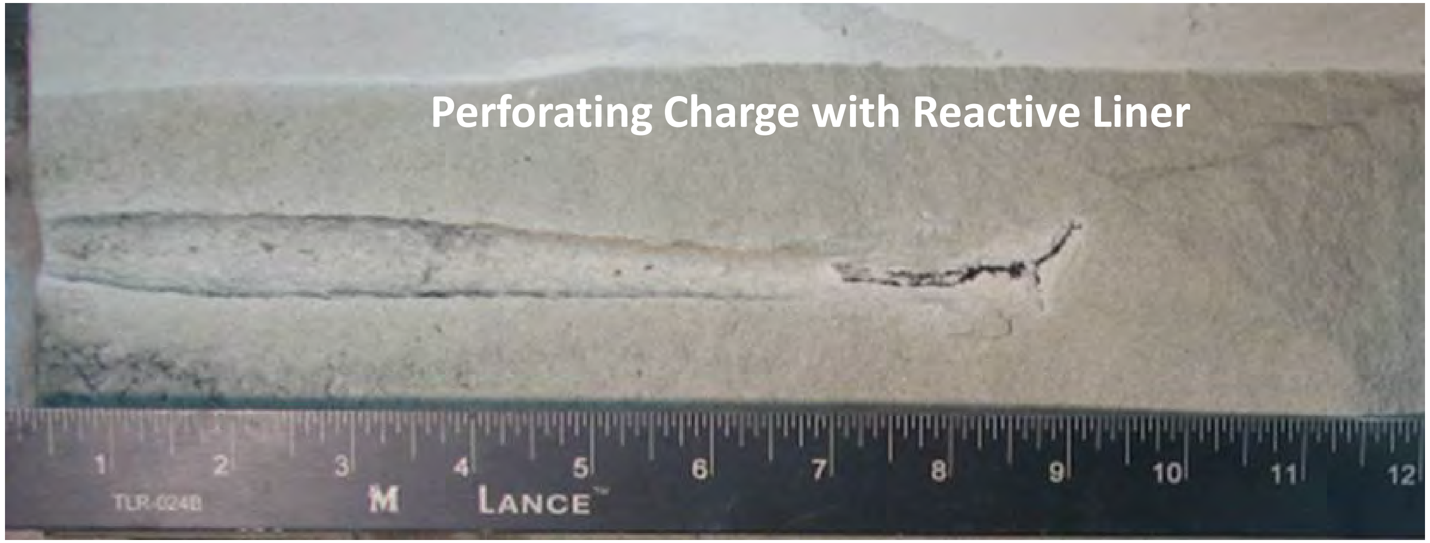


Conventional vs Reactive Liner Charges

Comparison

- Crushed zone eliminated
- Easy to flow through
- For tight reservoirs, creation of fractures at the tunnel tip





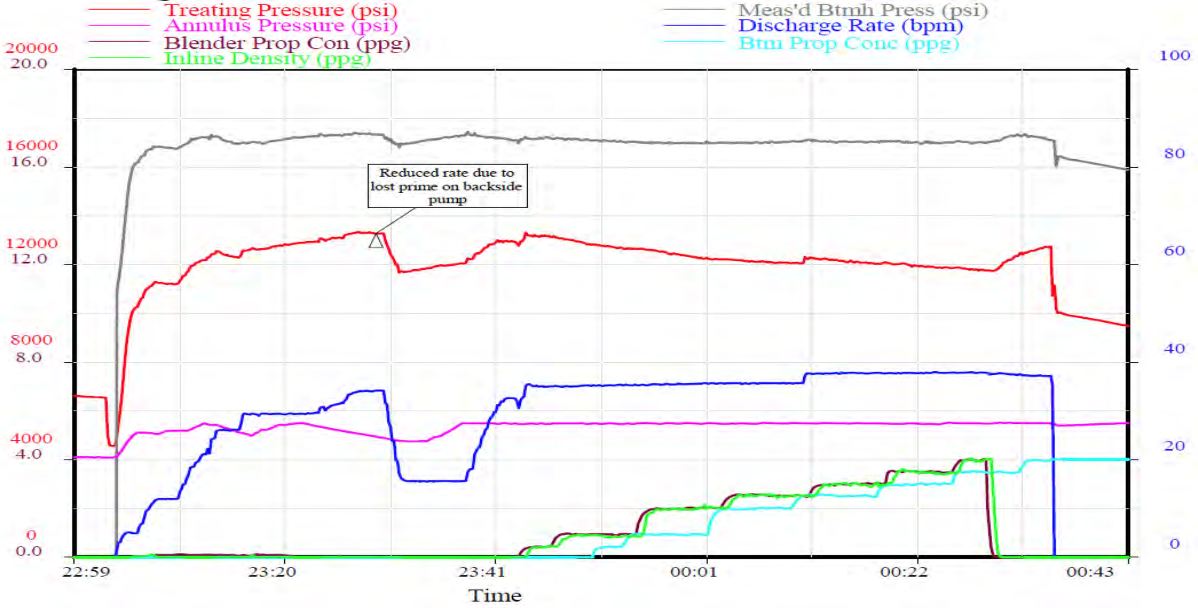
Operations in the field – Case#1

MENAPS 2022
MIDDLE EAST AND NORTH AFRICA PERFORATING SYMPOSIUM

History

- Well drilled as a development vertical well; completed as 4-1/2" monobore with Sandstone reservoir formation:
  - Reservoir Pressure around 8,500-psi
  - Formation rock compressive strength around 16,500-psi
  - Perforation using Conventional Charges
- Higher perforation friction with higher friction due to Near-Wellbore friction (**Step Down Test Analysis**).
- Harder formation break-down, as seen on the (**Main Frac Plot**).

Step Down Test Analysis

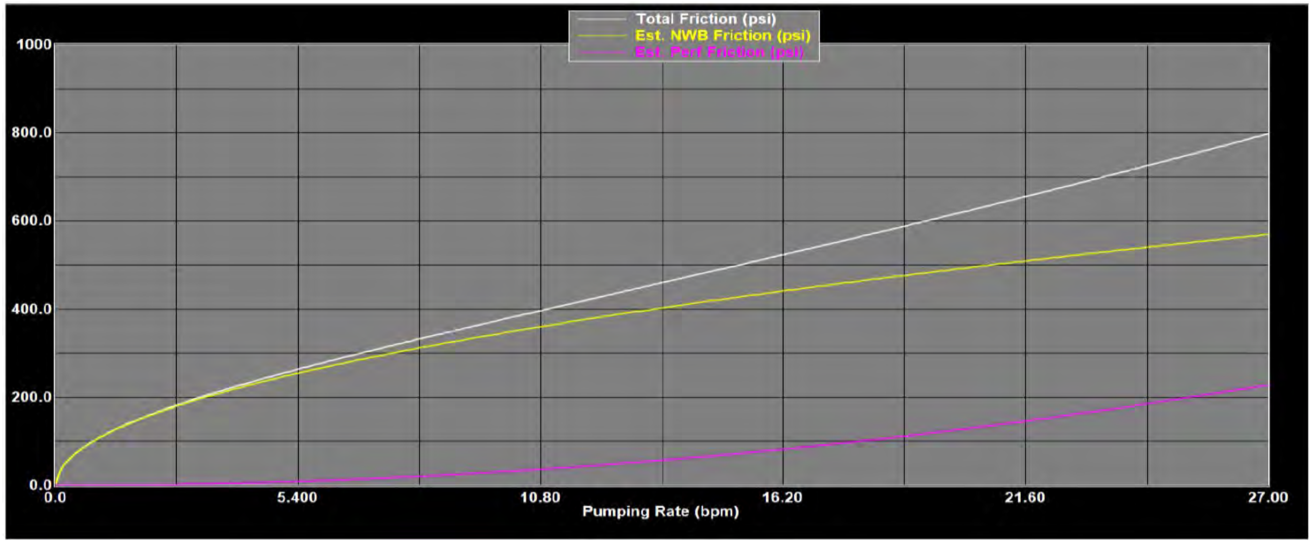


Main Frac Plot

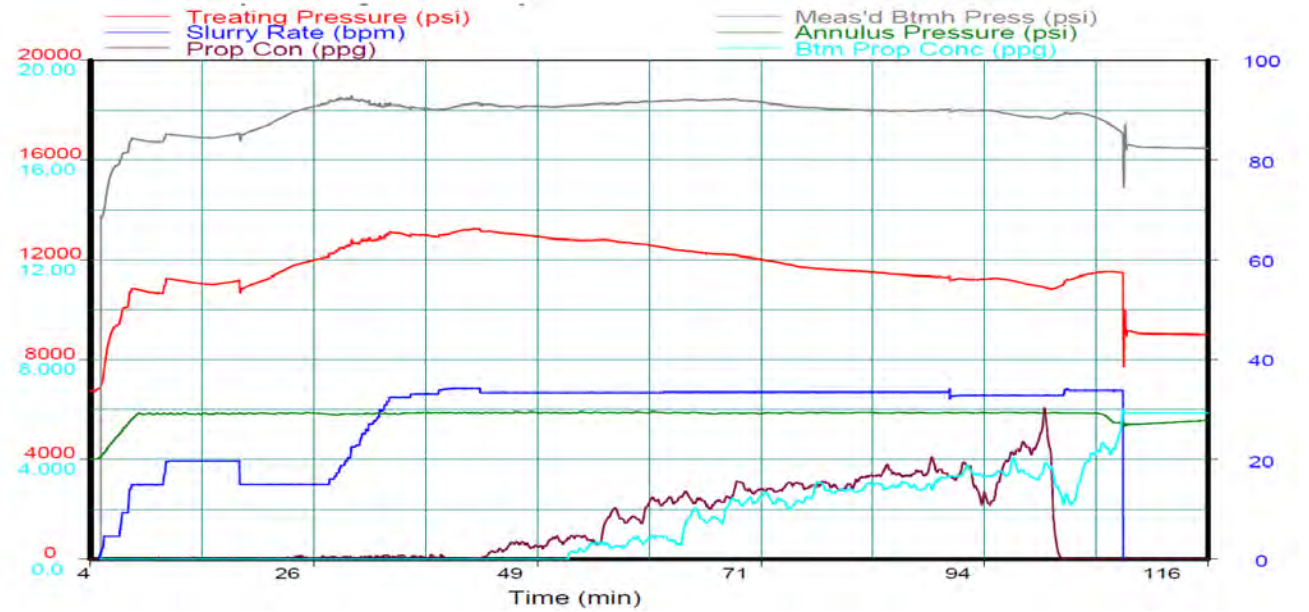
Operations in the field – Case#2

History

- Well drilled as a development vertical well; completed as 4-1/2” monobore with Sandstone reservoir formation:
  - Reservoir Pressure around 12,000-psi
  - Formation rock compressive strength around 15,900-psi
  - Perforation using Reactive Liner Charges
- Reduced perforation friction with higher friction due to Near-Wellbore friction (**Step Down Test Analysis**).
- Easier formation break-down, as seen on the (**Main Frac Plot**).



Step Down Test Analysis



Main Frac Plot

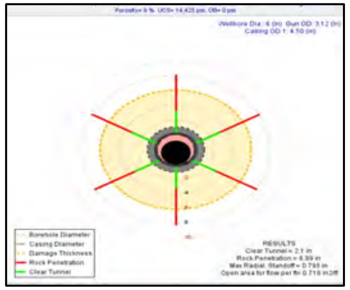
Operations in the field – Case#3

History

- Well drilled as a development vertical well; completed as 4-1/2” monobore with Sandstone reservoir formation:
  - Reservoir Pressure around 8,100-psi
  - Formation rock compressive strength around 14,000-psi
- Well, was perforated at first with conventional charges; after production, had to plug and side-track, then perforated the same reservoir with Reactive Liner charges. Below are some records:

Perforation using Conventional Charges [55-ft]

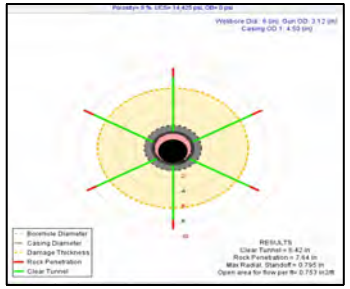
Time after Perforation	Choke [in]	Flowrate mmscf/d	FWHP [psi]	BS&W [%]
1 month	26/64	10	3,580	20
4 years	26/64	2.8	965	75



Perforation using Reactive liner charges [10-ft]

Time after Perforation	Choke [in]	Flowrate mmscf/d	FWHP [psi]	BS&W [%]
1 month	26/64	5.8	3,850	0

Faster clean-out time, as per client standard operating procedures



Results & Conclusions

Field results

- Easier formation break-down (Fracture)
- Reduced post perforation clean-out time
- Sustainable consistent flow
- Faster project execution
- Cleaner perforated tunnel, leading to improved flow performance

Support documents

References

- **SPE 122174** *Reactive Perforating: Conventional and Unconventional Applications, Learnings and Opportunities*
M.R.G. Bell, SPE, J.T. Hardesty, SPE, and N.G. Clark, SPE, GEODynamics, Inc.Bullets

- **SPE144167** *Translation of New Experimental Test Methods for the Evaluation and Design of Shaped Charge Perforators to Field Applications*
J. Hardesty, M.R.G. Bell, and N.G. Clark, GEODynamics, Inc. T. Zaleski and S. Bhakta, INGRAIN, Inc.

- **SPE-193254-MS** *Reactive Liner Perforating Technology Used to Improve Efficiency of Hydraulic Fracturing Operations*
Alvaro Javier Nunez, Mathieu Molenaar, Masoud Al-Salmi, Ibrahim Al-Farei, Hamdan Gheilani, Ernest Sayapov, and AbdulAziz Al-Shanfari, Petrolum Development Sultanate of Oman

Cairo. Egypt. November 7-8, 2022

MENAPS 2022

MIDDLE EAST AND NORTH AFRICA PERFORATING SYMPOSIUM

Q&A