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New Insights into Optimizing Perforation Clean Up and Enhancing Productivity with Zinc-Case Shaped Charges

IPS 16-49

POSTER PRESENTATION

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AGENDA/INTRODUCTION

- Objectives
- Perforation Flow Laboratory
- Well Description and Test Details
- Results
  - Zinc vs Steel charge performance
  - Underbalance management
  - Fluids compatibility
- Conclusions

Objectives of the Study

- In recent years, there have been concerns with zinc-case charges related to:
    - Impact on formation damage.
    - Increased detonation energy that may damage downhole equipment.
    - Formation of precipitates due to reactions with exotic wellbore fluids.

- **Objectives of the study**:
    - Utilize the perforation flow laboratory to provide a better understanding of shaped charge performance between zinc-case and steel-case charges.
    - Provide insight into selecting optimal well conditions (overbalance or underbalance?) while using zinc-case charges.
    - Investigate the compatibility of wellbore fluids with zinc-case material/debris.

Perforation Flow Laboratory

The flow laboratory provides the capabilities to:

- ✓ Study and qualify the performance of different perforating systems in formation rock at reservoir conditions.
- ✓ Study the influence of various factors on well productivity.
- ✓ Integrate this knowledge to select the optimal perforating system and clean up strategy for improved productivity.

	Section-I	Section-II	Section-II Modified	Section-IV
Target	Concrete	Analog Rock	Analog Rock	Analog Rock
Confining Pressure	Atmospheric	25000	15000	15000
Fluid	Not Applicable	Saturation fluid (OMS)	OMS/Brine	OMS/Brine
Wellbore Pressure	Not Applicable	25000	10000	10000
Pore Pressure	Not Applicable	25000	10000	10000
Temperature	Not Applicable	500F	300F	300F
Pre-shot Flow	Not Applicable	Not Applicable	Not Applicable	Applicable
Post-shot Flow	Not Applicable	Not Applicable	Not Applicable	Applicable

Well Description and Test Details

The fields are located in the Gulf of Guinea in water depths varying from 1000 to 2000m. The fields typically consist of sinuous turbidite sandstone channel systems of Turonian age.

	Actual	Analog
Formation Type	Sandstone	Buff Berea Sandstone
Reservoir Fluid Type	Oil	OMS
Water Depth (m)	1000 - 2000	-
Pore Pressure (psi)	~6300	6000
Permeability (md)	200 - 600	90-200
Porosity (%)	~20	21
Temperature (°F)	~200	200
Effective stress (psi)	~3,000	3,300
Casing Size (in.)	9.625	9.625
Borehole Size (in.)	12.25	12.25

Two charge types

- 39 gm steel case DP, HMX
- 39 gm zinc case DP, HMX

Test Matrix

1. Comparison of shaped charge performance between steel and zinc-case charges

2. Selection of optimal well conditions (underbalance/overbalance) scenarios with zinc-case shaped charges

3. Compatibility of wellbore fluids with zinc-case shaped charges

Results – Zinc Vs Steel Case Comparisons

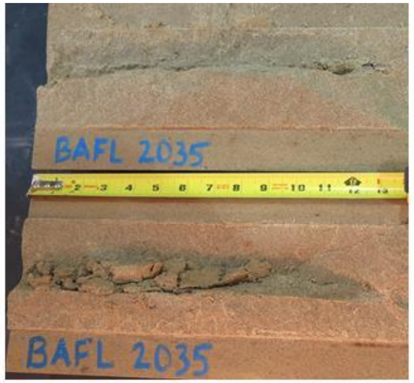
- Multiple tests conducted to obtain a fundamental understanding of performance between steel and zinc-case charges.

- Test details:
  - 500psi static underbalance
  - Maximum free gun volume to simulate dynamic underbalance

- Average depth of penetration lower with zinc-case charges.

- Productivity ratio comparable between steel and zinc-case charges.

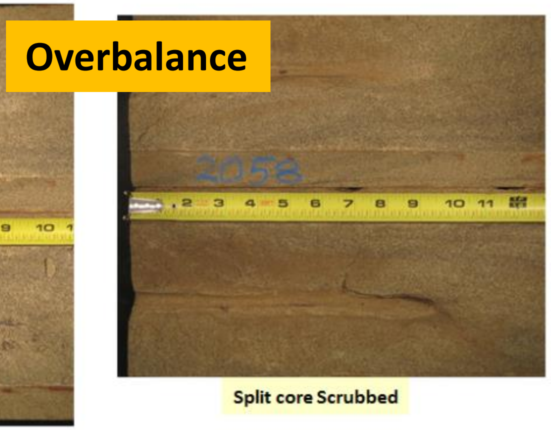
Test ID	Simulated Gun System/Charge	Penetration (in.)	Productivity Ratio
2038	Zinc case DP, HMX	11.25	1.00
2039	Zinc case DP, HMX	8.13	0.97
2035	Steel case DP, HMX	13.31	1.07
2048	Steel case DP, HMX	12.25	1.16

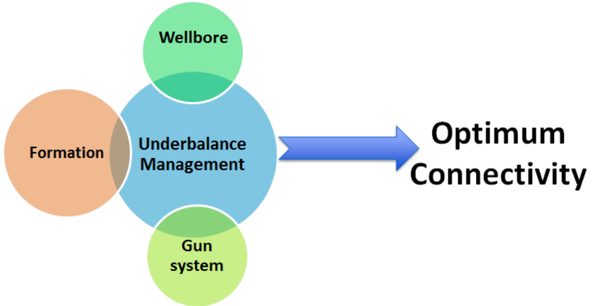


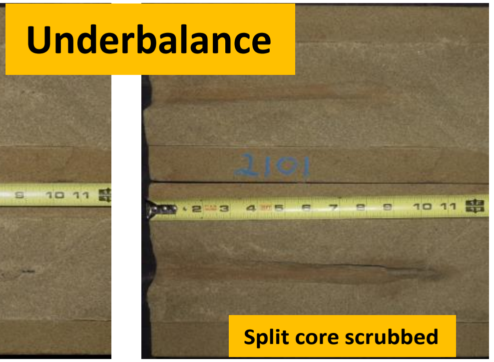
Results – Zinc-case: Underbalance or Overbalance ?

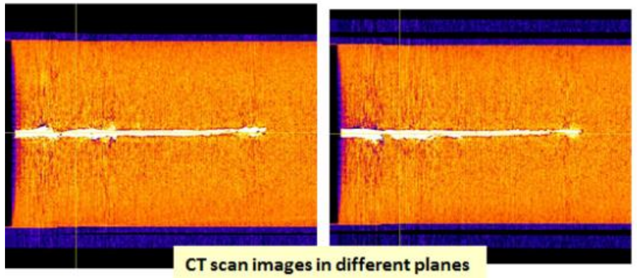
Optimizing underbalance is critical for clean-up and enhancing productivity with zinc-case charges.

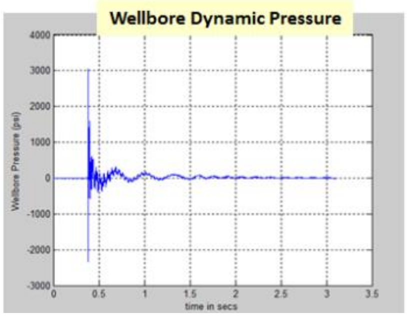
Test ID	Wellbore fluid	Charge case	Confining (psi)	Pore (psi)	Wellbore (psi)	Gun volume (cc)	Penetration (in)	PR
2058 2059	NaBr	Zinc	9300	6000	6250 (OB)	330	9.44 13.81	0.11 0.69
2094 2101	NaBr	Zinc	9300	6000	5500 (UB)	660	10.31 10.63	1.20 1.89

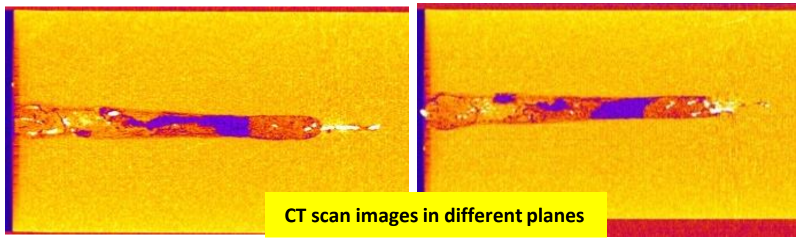


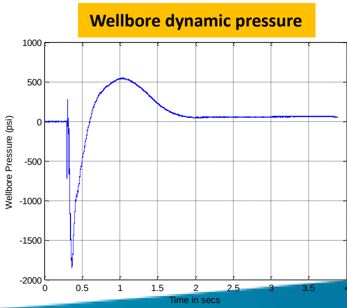








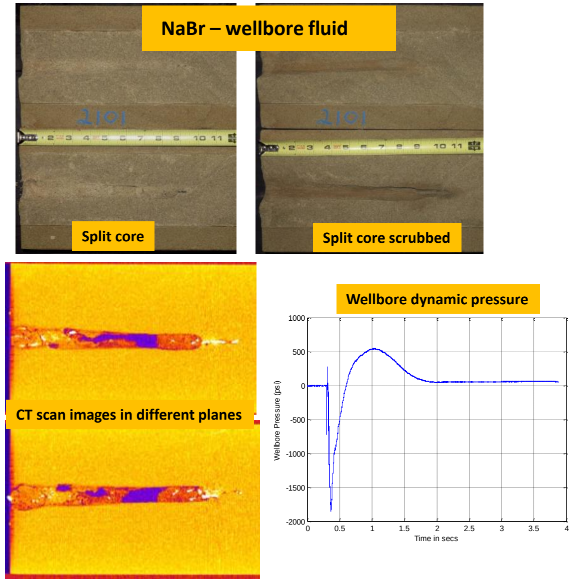


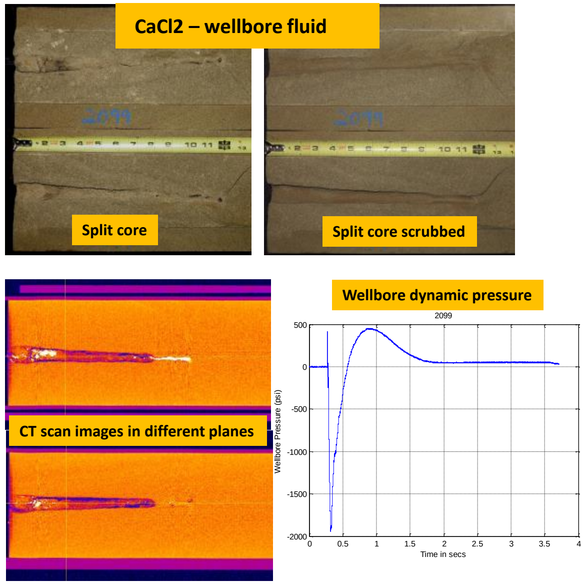


Results – Zinc-case: Fluids Compatibility

Section-IV Testing

Wellbore fluid	Charge case	Confining (psi)	Pore (psi)	Wellbore (psi)	Gun volume (cc)	Penetration (in)	PR
NaBr	Zinc	9300	6000	5500 (UB)	660	10.31 10.63	1.20 1.89
CaCl2	Zinc	9300	6000	5500 (UB)	660	10.88 12.13	1.13 1.69





Mineralogy

- Interpreted minerals and their relative abundance are shown in the following table along with interpreted sources.
- The mineralogical analysis indicated that the perforating debris was mostly composed of quartz (from the Buff Berea core) along with charge material (tungsten, lead and copper), with minor traces of precipitates (Cuprite, Tsumebite, Scheelite).

	2094	2101	2095	2099	2096	2100
	Zinc	Zinc	Zinc	Zinc	Steel	Steel
	NaBr	NaBr	$CaCl_2$	$CaCl_2$	NaBr	NaBr
Copper (Cu)	Major	minor	minor	minor	minor	minor
Lead (Pb)	minor	minor	minor	minor	minor	minor
Tungsten (W)	Major	Major	Major	Major	Major	Major
Tungstenite (WS_2)	minor to trace	nd	nd	nd	nd	nd
Zinc (Zn)	trace	nd	nd	nd	nd	nd
Scheelite $Ca(WO_4)$	minor	minor	minor	minor	minor	minor
Cuprite CuO	minor	trace	trace	trace	trace	trace
Tsumebite $CuPb_2(PO_4)(SO_4)(OH)$	minor	trace	trace	trace	trace	trace
Quartz (SiO_2) Plagioclase Feldspar ($NaAlSi_3O_8$)	Predominant component in all samples Originates from the Buff Berea Sandstone					

No compatibility issues were observed between wellbore fluids and zinc.

Conclusions

- Baseline tests conducted with steel and zinc-case charges indicated that the average depth of penetration with the steel charges was slightly higher than that of a zinc charge. However, the productivity ratio was comparable between zinc and steel-case charges.

- Parametric studies conducted under different well conditions (overbalance with standard gun volume and underbalance with maximum gun volume) clearly demonstrated that **optimizing underbalance was critical for clean-up and enhancing productivity** with zinc-case charges.

- **No compatibility issues were observed between wellbore fluids and zinc**.

- The qualitative nature of debris within the tunnel (from CT scan) and the values of measured productivity ratio between zinc-case and steel-case charges were similar.

- The data presented in this paper is based on a controlled flow laboratory environment. Further experimentation may be required to account for other operational or design factors before translating laboratory learnings into a field environment.

QUESTIONS? THANK YOU!