NORTH SCHLUMBERGER OILFIELD TECHNOLOGIES (XI'AN)CO.,LTD

Multi-pulse Hybrid Perforating Technology

— for Low Permeability and Tight Reservoirs in China

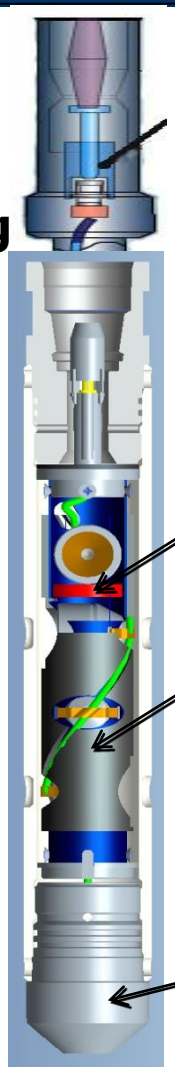
Rock Wang
General Manager - NSOTC

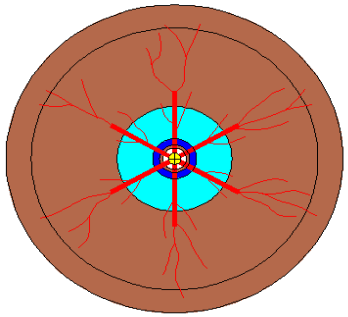
NORTH 北方斯伦贝谢 Schlumberger

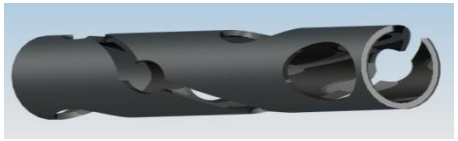
www.north-slb.com

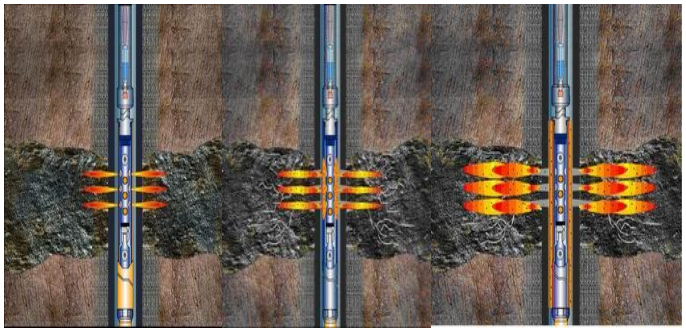
Introduction to Multi-pulse Hybrid Perforating

- **Multi-pulse Hybrid Perforating**
  - combine perforating and propellant near wellbore fracturing in single run
  - improve cleanout of formation damage
- **Multi-pulse propellant**
  - enable higher pressure pulses
  - extended pressure pulses enable more effective fracturing
- **Long interval**
  - >100m per run via TCP
  - 4m per run via Wireline









API RP 19B Style Surface Test

Case Study I: Well Cheng-XXX in Changqing Oilfield

Oilfield: Changqing Oilfield

Reservoir: oil

Formation: Yan X, sandstone

Average Porosity: 0.9~13.8%

Average permeability: 1.7～44.2mD

Completion: 5-1/2”

History: perforated by regular 4” gun, 5spf, 90deg, but with very low productivity .

Solution: Use hybrid perforating to reperforate and frack the zone.

Cheng-XXX: Basic Information

Well Name	Cheng-XXX	Geological location		Qingyang, Gansu		
Wellhead altitude (m)	1459.88	Start Date of Drilling		/	End Date of Drilling	/
Date of Completion	/	Formation		Yan X	Well depth (m)	1415.00
Distance of Drilling Platform to Wellhead (m)	4.70	Depth of Top Cement Surface (m)		1396.00	Bottom hole displacement (m)	/
Depth of Dogleg Point (m)	/	Max well deviation (^{0})		25.70	Target radius (m)	/
Testing Pressure（MPa）	/	Forecasted formation pressure (MPa）		8.0	Poisonous or harmful gases forecasted	/
Casing	Spec.	OD (mm)	Wall Thickens (mm)	Type of Steel	Depth (m)	Cementing surface depth (m)
Top casing	9”5/8	244.50	8.94	J55	226.00	
Production casing	5”1/2	139.7	7.72	J55	1415.00	43.00
Quality of Cementing	Okay quality					

Formation	Zone (m)	Thickness (m)	Logging Information						Interpretation
			Electrical resistance (Ωm)	Time delay (us/m)	Shaliness (%)	Porosity (%)	Permeability (mD)	Oil saturation (%)	
Yan 9	1359.8-1370.0	10.2	18.89	238.18	10.67	12.10	18.49	49.88	Oil bearing

Cheng-XXX：Perforating Solution

Multi-pulse Hybrid Perforating

Conveyance	Perforator model	Perforating zone (m)	Perforating gun length (m)	Gun size	Shot density (spf)	Phase	Propellant Pellet Load（g）	Modular Propellant（g）
Wireline	Hybrid Perforating	1361.0-1363.5	2.5	4″	5	90°	780	2000

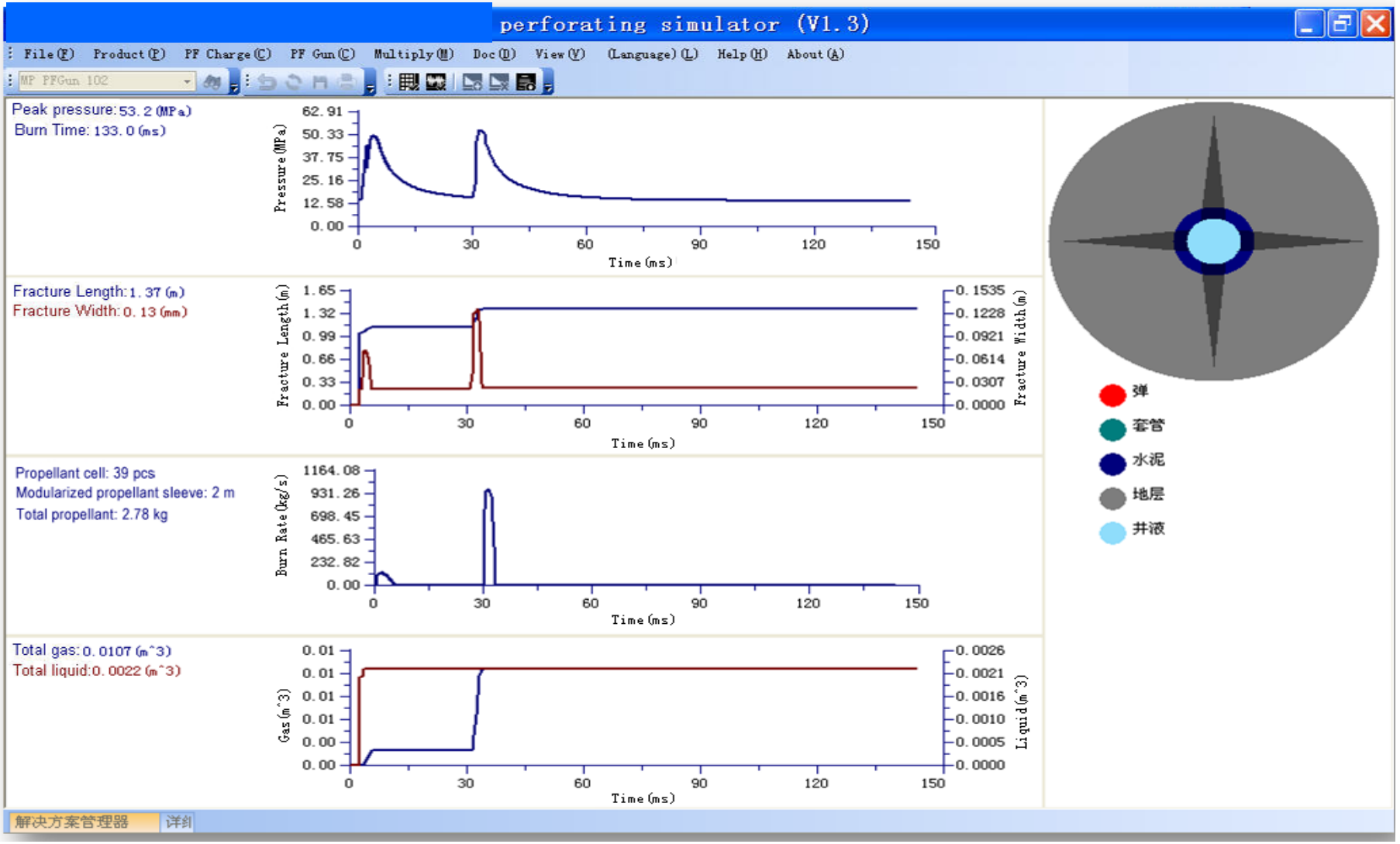
Propellant Pellet

Modular Propellant

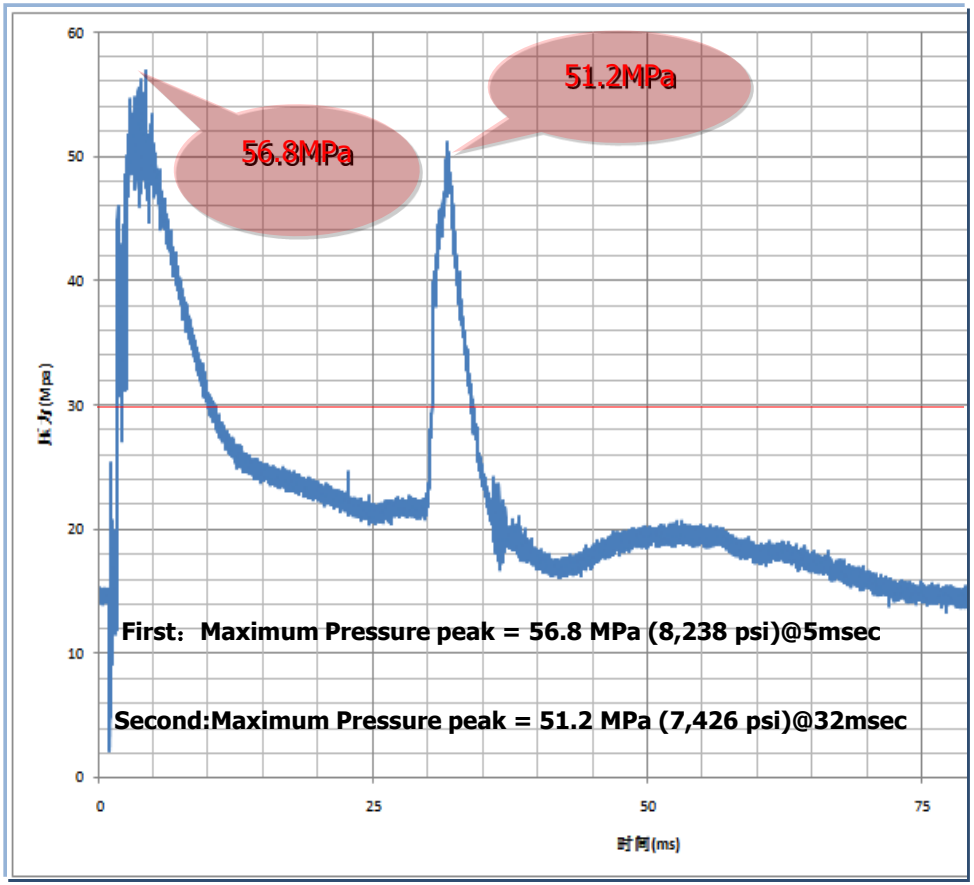
Loading Tube

Fully loaded gun

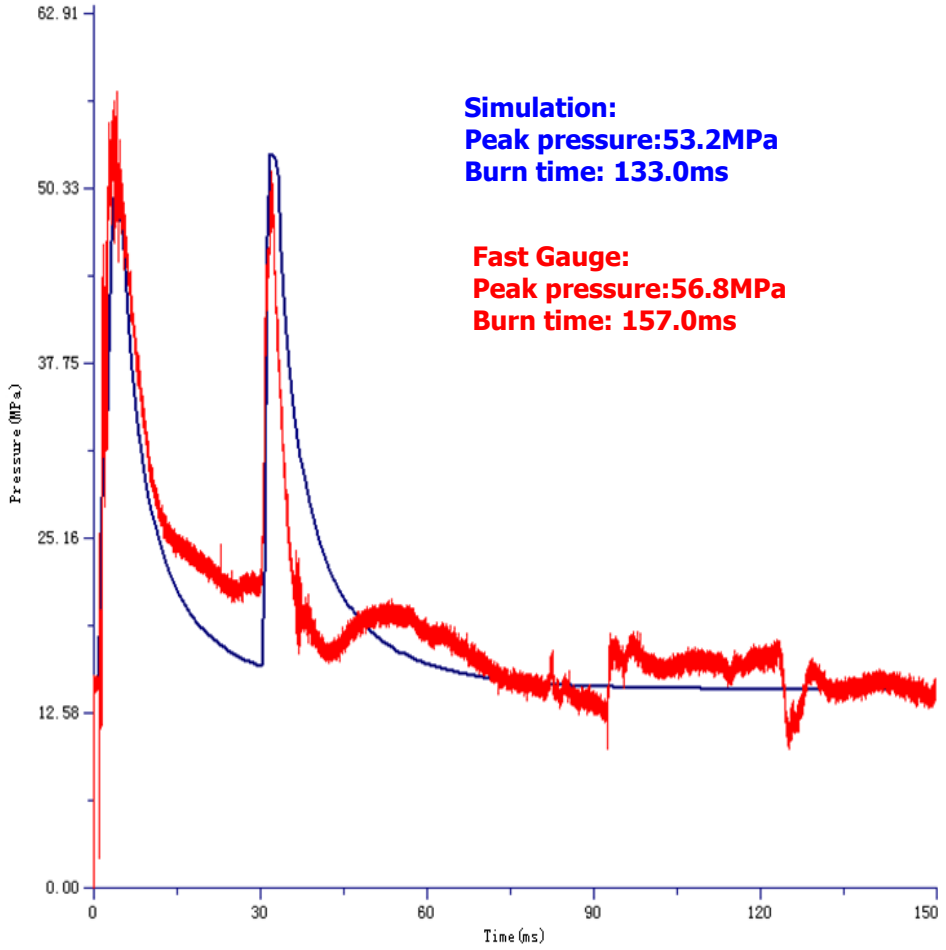
Cheng-XXX: Simulation by Simulator



Cheng-XXX： Fast Gauge Measurements

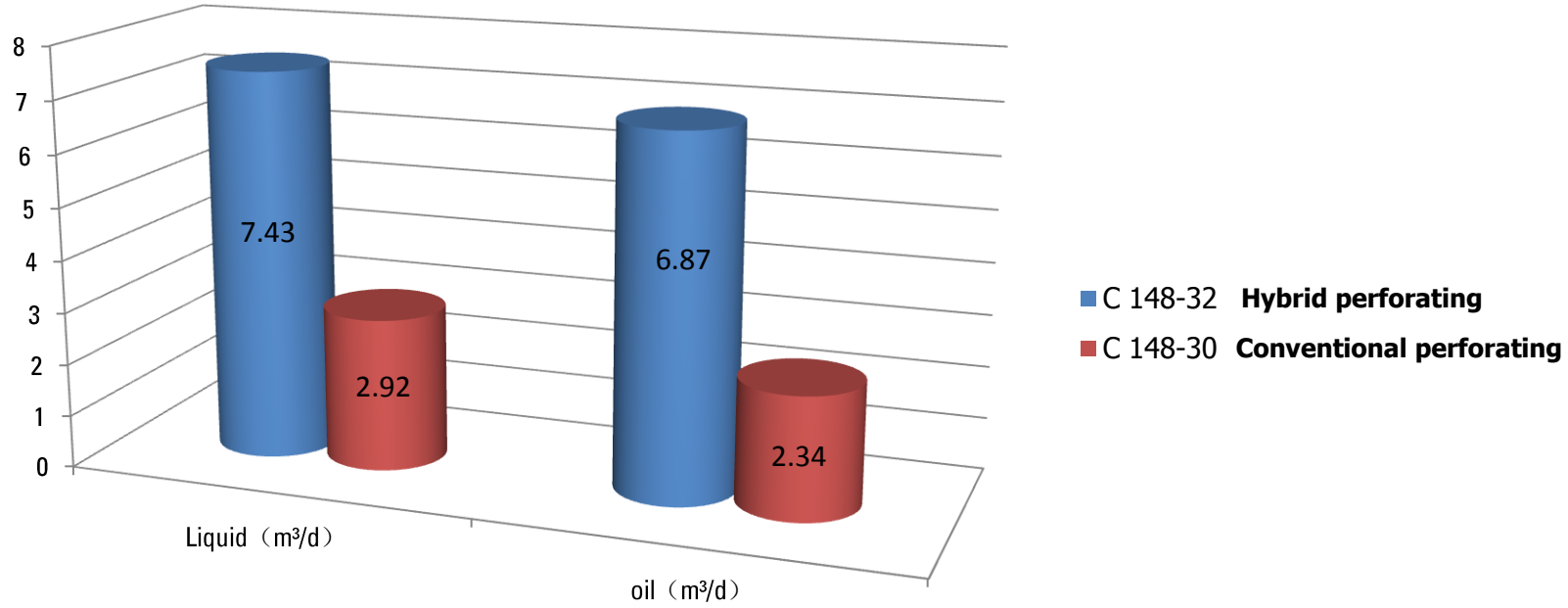


Measured by gauge



Simulation Vs Measurements

Cheng-XXX: Effectiveness Analysis



Block	Well#	Formation	Perforating zone (m)	Perforator	Productivity（m³/d）	
					Liquid	Oil
13	C148-32	Yan 9	1361.0-1363.5(2.5m)	hybrid Perforating	7.43	6.87
	C148-30		1360.0-1362.5(2.5m)	Conventional Perforating	2.92	2.34

Case Study II : Henan Oilfield

-Jianghe Block V, Henan Oilfield with low permeability (2-30mD) , 8-12% porosity

-Low productivity after conventional perforating due to the tight formation

-Multi-pulse hybrid perforating makes different

Perforator	Well	Date of perforating	Production layer	Perforating zone (m)	Permeability mD	Production m^3/d
Hybrid Perforating	ZA4016	2011.12.26	$H1III2^{1.2}3^{1-2}$	949.0-951.6	3.0	43.4
Conventional Perforator 1	A4019	2011.12.20	$H1III1.2^{1.2}3^{1}$	920.8-951.6	12.0	27.4
Conventional Perforator 2	A4016	2011.12.12	$H1III2^{1}3^{1}$	934.4-943.6	7.0	6.7

Comparison between hybrid perforating and conventional perforators

Summary

Technical features

- Perforating and fracturing at the same run with high operation efficiency
- Matured technique, safe and reliable
- Simulation before the operation to ensure no damage to wellbore and casing

Applications

- Can be applied for tight formation with low permeability
- Re-perforation for old wells to enhance productivity
- Pre-treatment for hydraulic fracturing to lower breakdown pressure

Limitations

- No longer than 4m loaded gun per run via wireline to avoid cable damage
- Cannot replace hydraulic fracturing for very low permeability formation(<1mD)