



Cairo, Egypt. November 7-8, 2022

MENAPS 2022

MIDDLE EAST AND NORTH AFRICA PERFORATING SYMPOSIUM



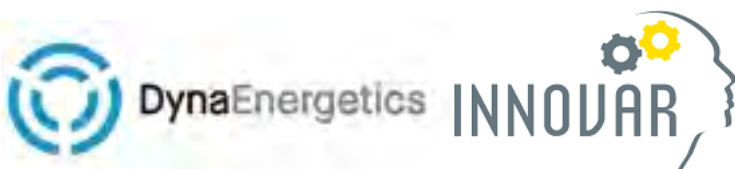
Laser Magnet for Retrieving Debris Case Study in High-Risk Wells

RAY
INTERNATIONAL
OIL & GAS

Presented By:

Maryam AL Musalami

Petroleum Development Oman

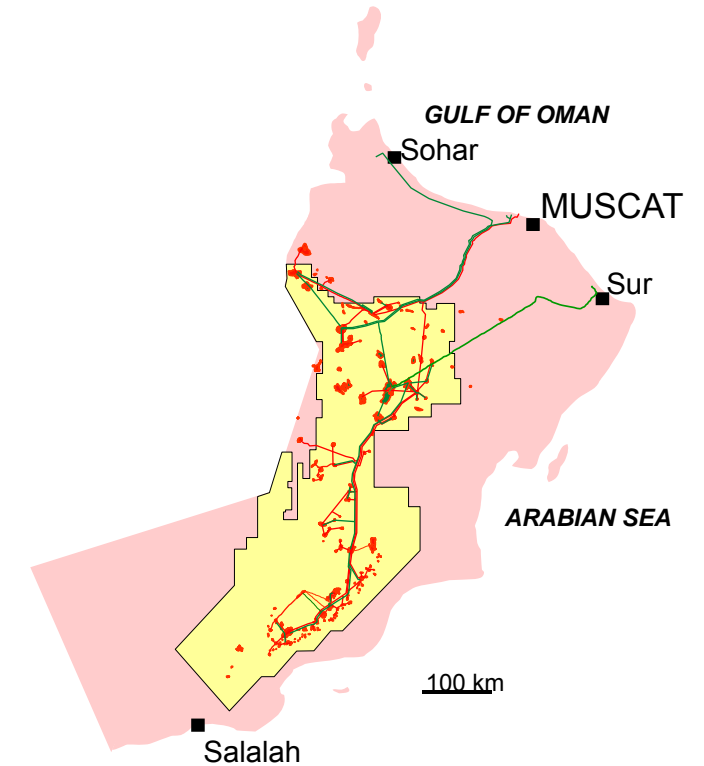


MENAPS-20-22 AUTHORS:

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- Introduction
- Completion Strategy
- Horizontal Perforation Design
- PDO Case Study
- Productivity Charts
- Case Study Journey
- Summary
- Conclusion and Way Forward

- **Petroleum Development Oman (PDO)**
 - Major exploration and production company in the Sultanate of Oman
 - It accounts for about 70% of the country's crude-oil production
 - Nearly 100% of Nation's natural-gas supply.
- **The Company is owned by the Government of Oman, a non-operating JV between**
 - 60% Government of Sultanate of Oman
 - 34% Royal Dutch Shell
 - 4% Total
 - 2% PTTEP



Yibal Khuff Project

The second largest and most technically complex project in PDO's history

1.4
Km²

Equivalent to
235 football
stadiums

20,000b
bl/d

Producing of
crude oil

5.4 MM
m³/d

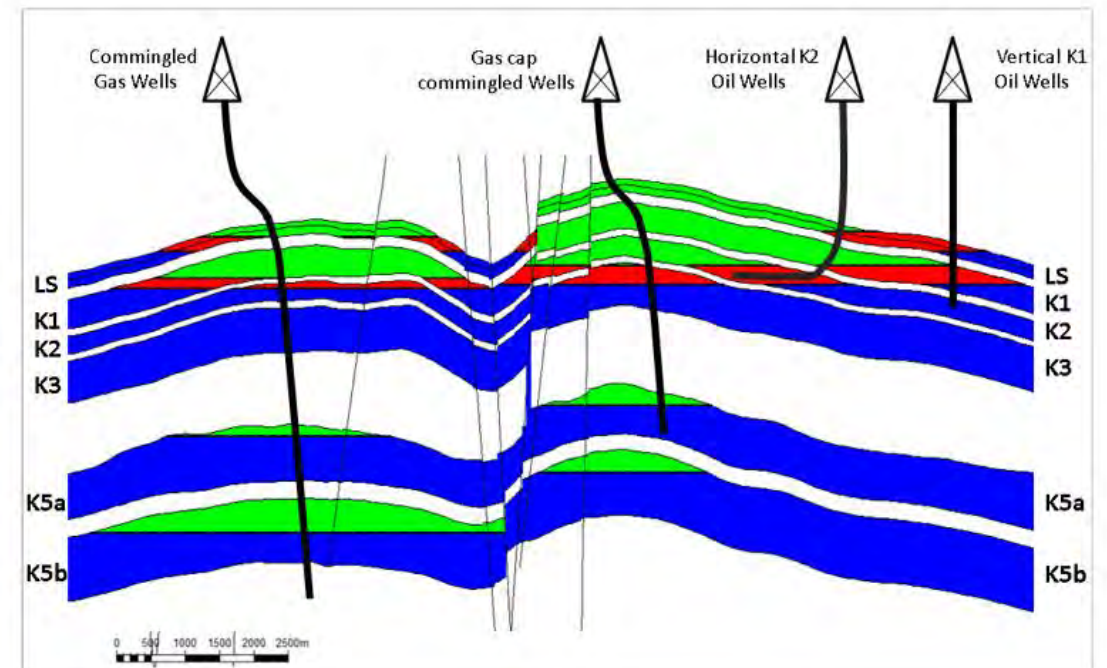
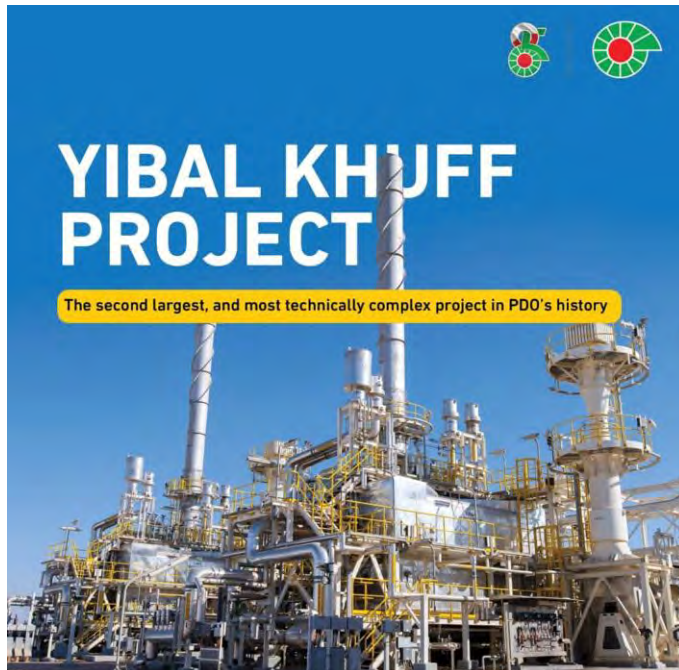
Producing of
gas

230
tons/d

Producing of
Sulphur

70%

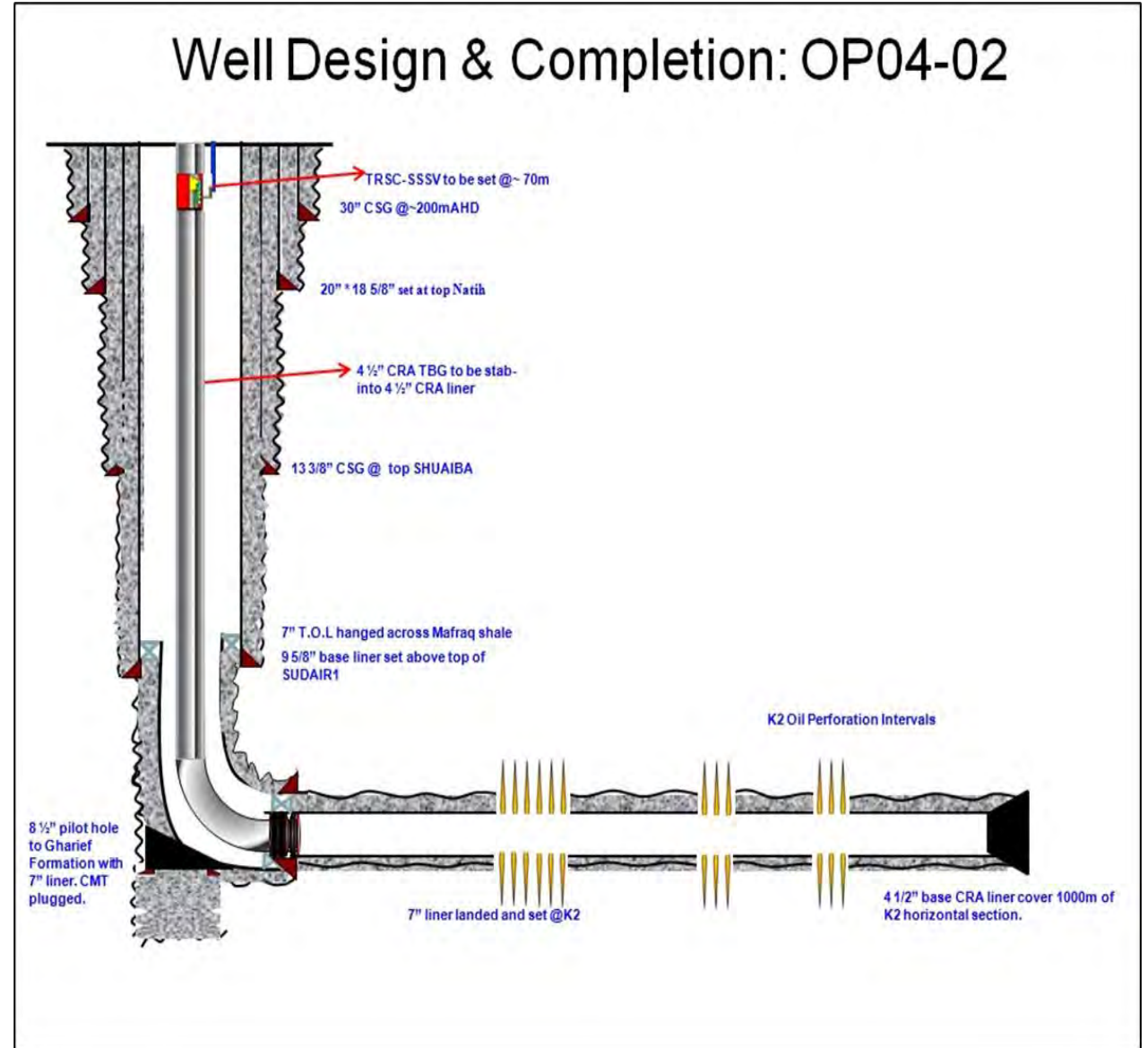
of scaffolding
scope was
allocated to
Omani
scaffolders



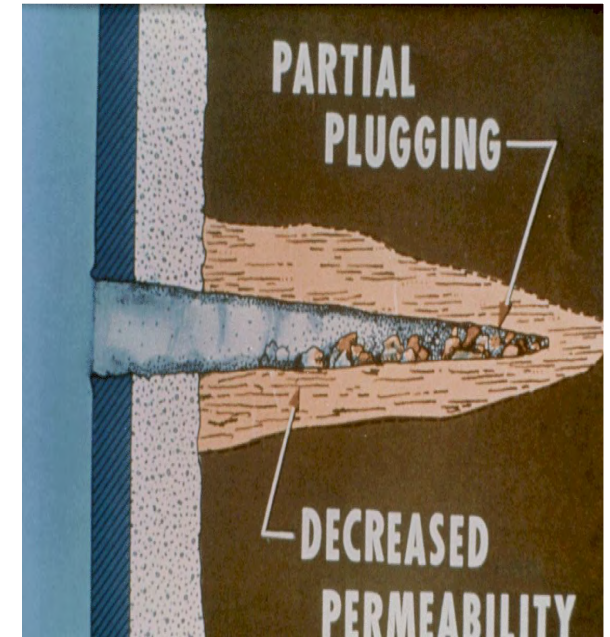
Horizontal well Perforation design

Plan Job:

- High sour well ~3.1 % ppm
- Long horizontal gun assembly ~ 1000 m (3300 ft)
- Perf interval around ~ 150 -700 m
- Gun size/type & shot density : 2.88" HSD, 6 SPF, DP3, HMX
- Multiple firing heads
- Tubing or gun swivels
- Conventional magnets
- Over balance perforation with coil tubing



1. Cleanout trip with Coil Tubing.
2. TCP Overbalance Perforation.
3. Magnet to be used along with TCP Guns.
4. Acid Stimulation after perforation.



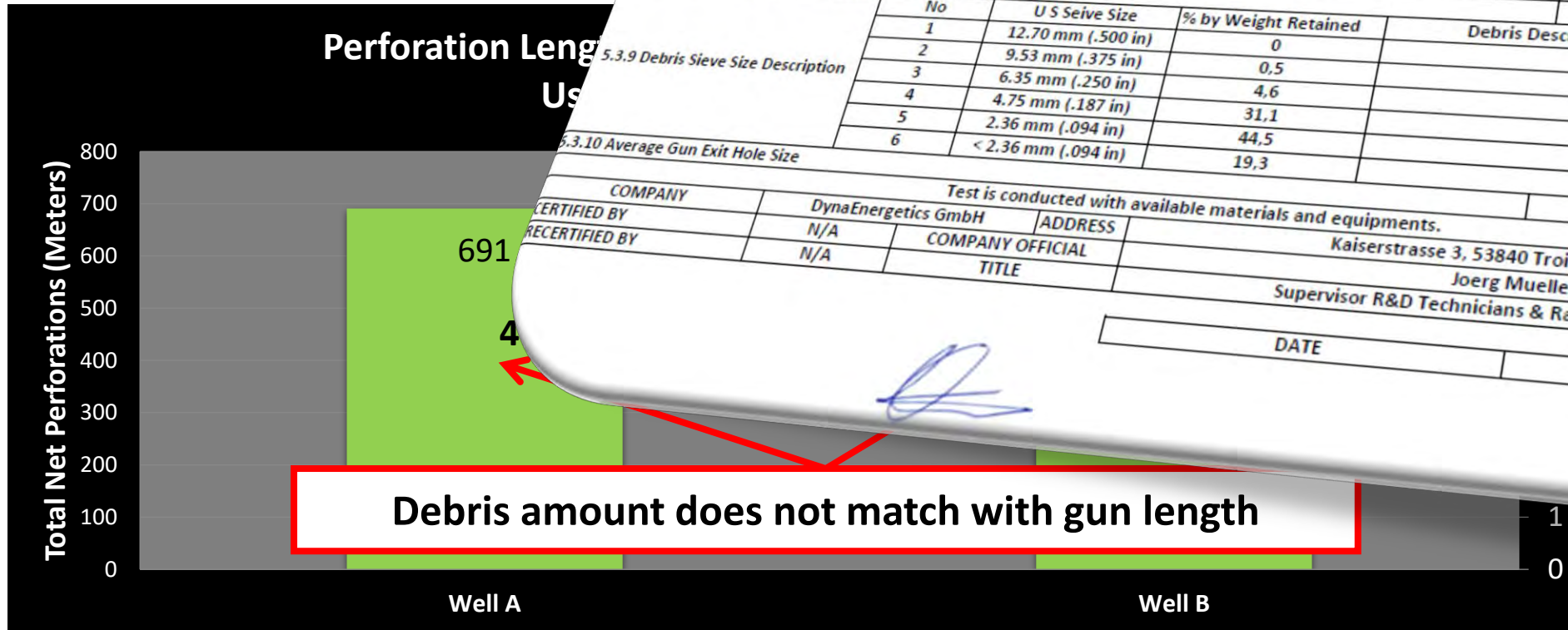
PDO Case Study – Conventional Magnets



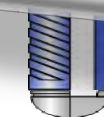
- Compared with API section 5 data.
- Magnet was not efficient.
- PDO requested RAY to find better
- This analysis resulted to come up

GUN DEBRIS DATA SHEET FOR HOLLOW CARRIER PERFORATING SYSTEMS

Hardware Description		Charge Description		Test Configuration		
Service Company	DynaEnergetics GmbH	Charge Name	DW 15g DP3 St. HMX	Casin OD	4,5	Inch
Gun OD & Trade Name, in	2,875	Charge Part No	2327049	Casing Weight per Foot	11,6	lbs
Gun Type	Carrier	Explosive Type	HMX			
Gun Assy Part No	2314724	Grams per Charge	15,5			
Shots per Foot	6	Total Charges Tested	21			
Phasing	60	Case Material	Steel			
Total Shot Positions in Gun	21	Test Date	17.08.2020			
5.2.3 Net Pre-Test Weight of Loaded Gun Assembly				29,88	kg	
5.2.5 Dry Weight of Expended Gun Assembly				29,80	kg	
5.2.7 Weight of Debris Lost per Linear Foot of Perforations at Time of Detonation				204	gm	
5.2.8 Volume of Debris Lost Per Linear Foot of Perforations at Time of Detonation				57	cc	
5.3.2 Weight of Debris Rolled from the Gun per Linear Foot of Perforations				108	gm	
5.3.4 Volume of Debris Rolled From Gun Per Linear Foot of Perforations				30,0	cc	
5.3.5 Average Weight of Gun Debris Per cc				3,6	gm/cc	
5.3.7 Total Volume of Debris Lost Per Linear Foot of Perforations				87	cc	
5.3.8 Total Weight of Debris Lost Per Linear Foot of Perforations				312	gm	
5.3.9 Debris Sieve Size Description			No	U S Sieve Size	% by Weight Retained	Debris Description Including Type of Material
			1	12.70 mm (.500 in)	0	Charge case
			2	9.53 mm (.375 in)	0,5	Charge case
			3	6.35 mm (.250 in)	4,6	Charge case
			4	4.75 mm (.187 in)	31,1	Charge case
			5	2.36 mm (.094 in)	44,5	Charge case
			6	< 2.36 mm (.094 in)	19,3	Charge case
5.3.10 Average Gun Exit Hole Size				0,31	in	
Test is conducted with available materials and equipments.						
COMPANY	DynaEnergetics GmbH	ADDRESS	Kaiserstrasse 3, 53840 Troisdorf/Germany			
CERTIFIED BY	N/A	COMPANY OFFICIAL	Joerg Mueller			
RECERTIFIED BY	N/A	TITLE	Supervisor R&D Technicians & Rapid Response Team			
			DATE	17.08.2020		



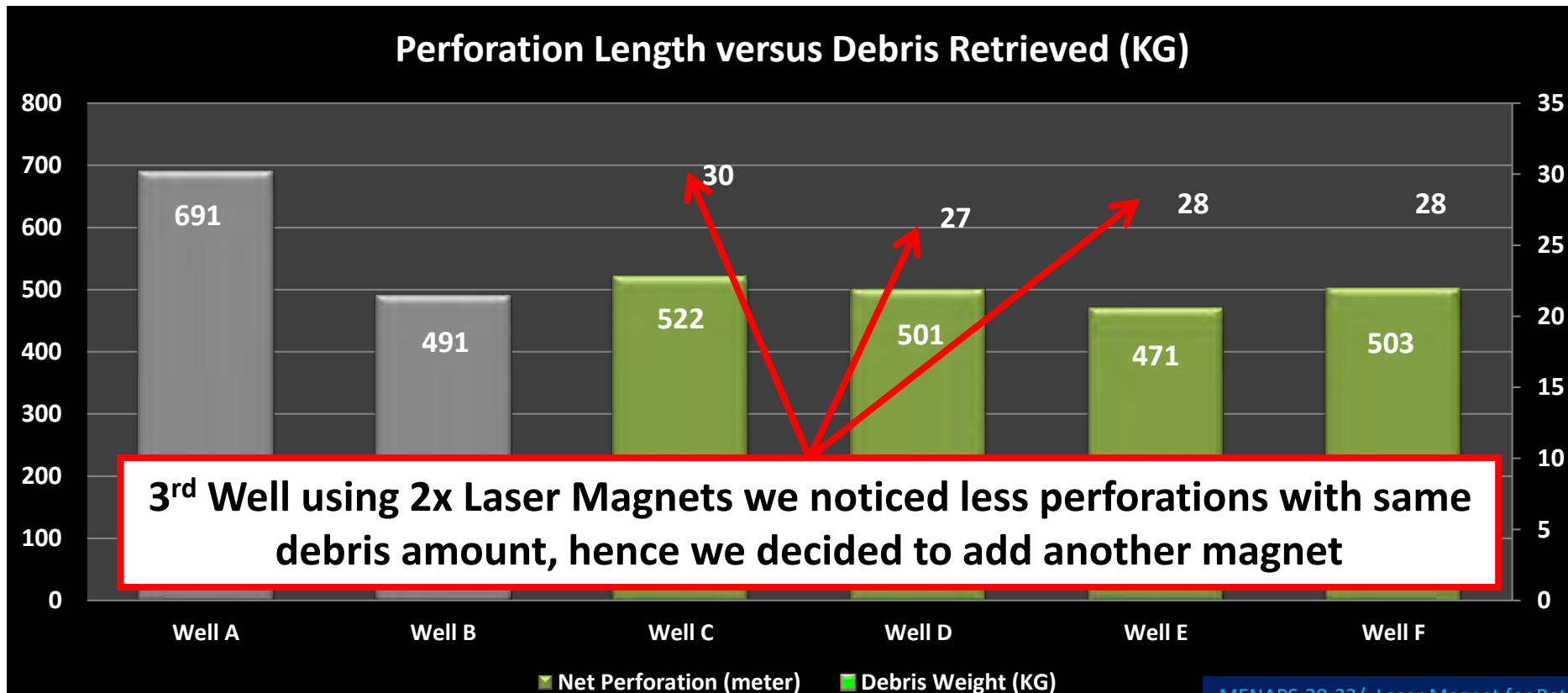
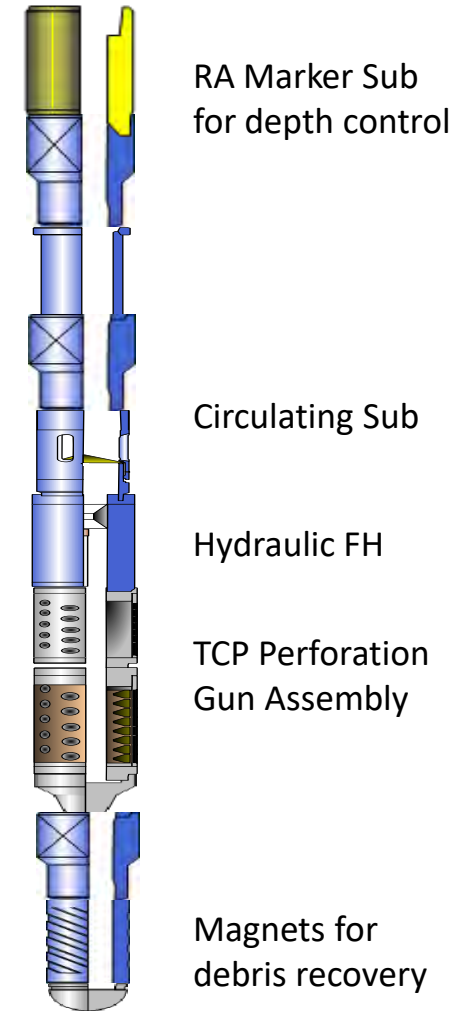
Debris amount does not match with gun length



Magnets for debris recovery

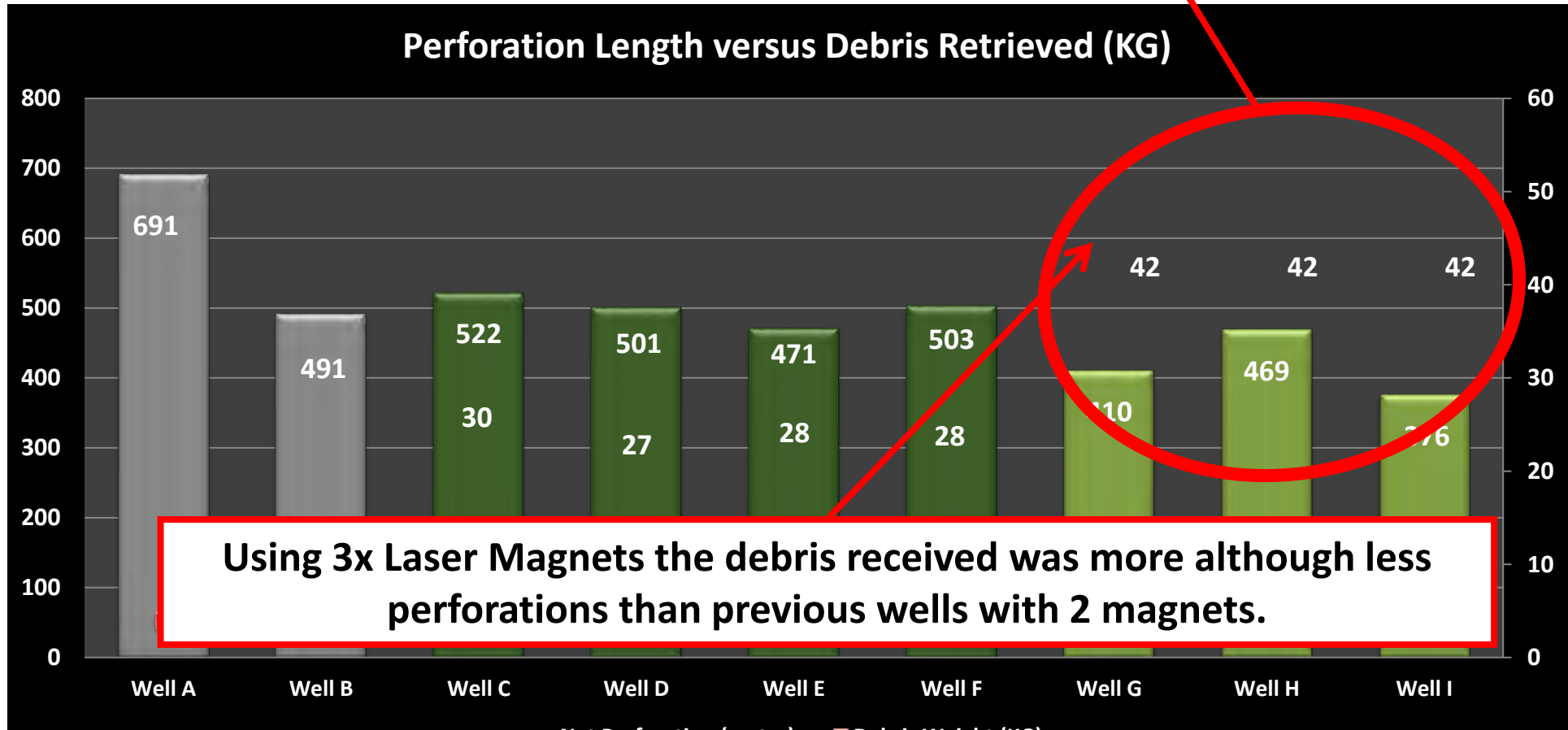
PDO Case Study – 2 Laser Magnets

- 2x laser focused magnets was run in 4 wells with 28kg average retrieved debris.
- Improved clean out versus conventional magnets was noticed.
- Different results suggests the capacity of ~14kg per magnet.
- This analysis resulted to add another magnet to the design.

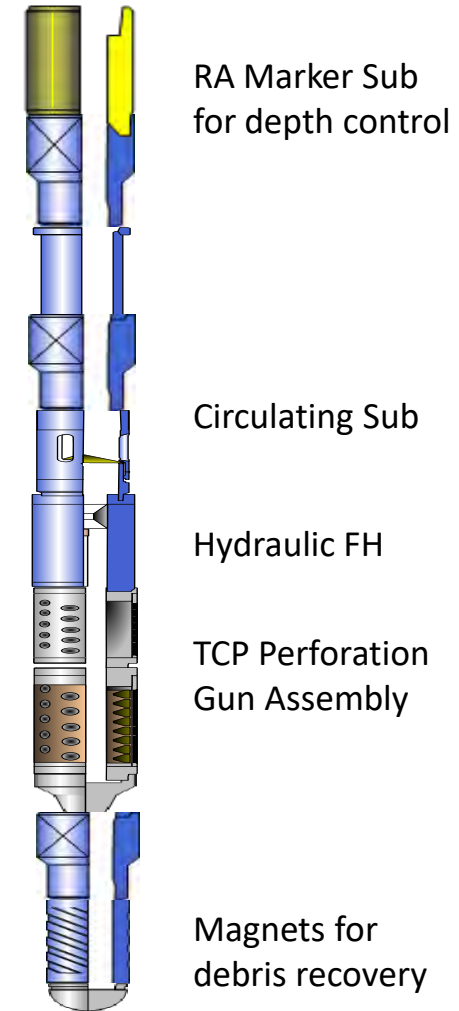


PDO Case Study – 3 Laser Magnets

- 3x laser focused magnets was run in 3 wells; 42kg retrieved debris in each well.
- This analysis resulted to add more magnets to the design.

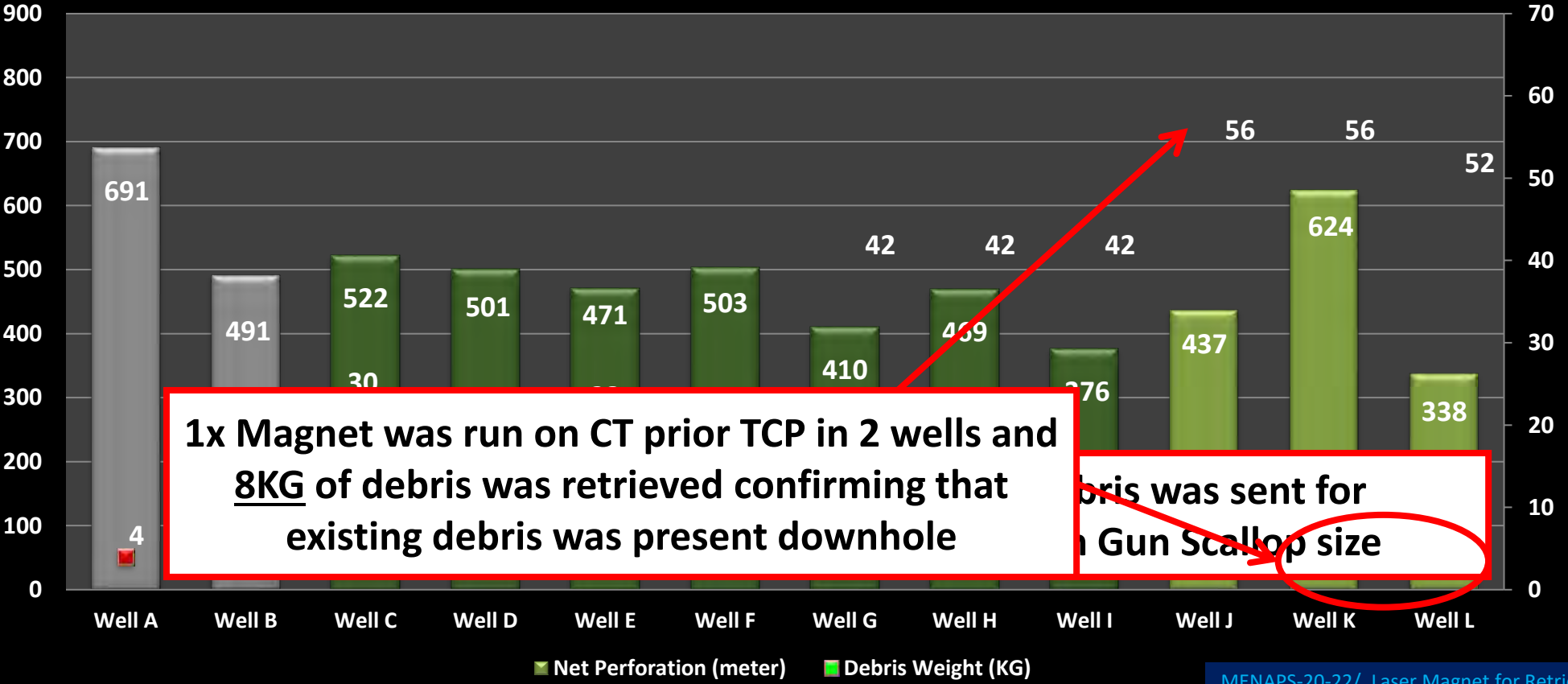


Using 3x Laser Magnets the debris received was more although less perforations than previous wells with 2 magnets.

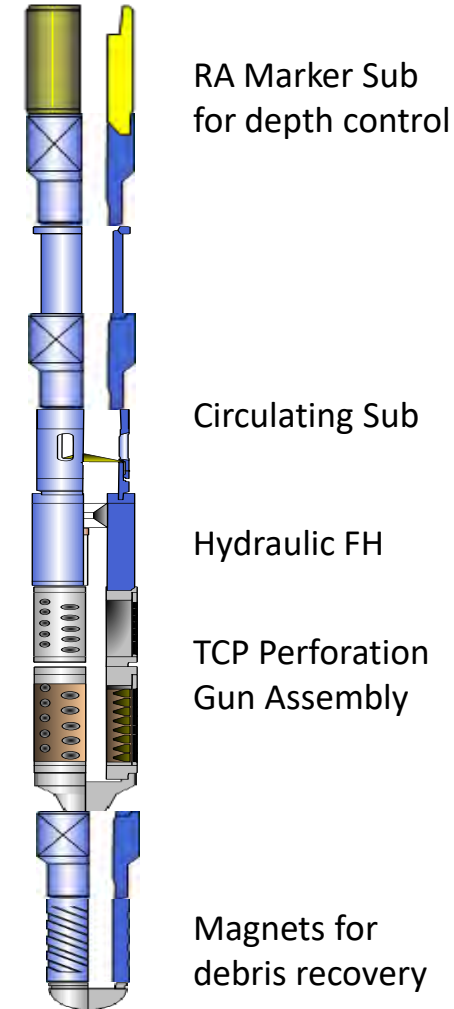


PDO Case Study – 4 Laser Magnets

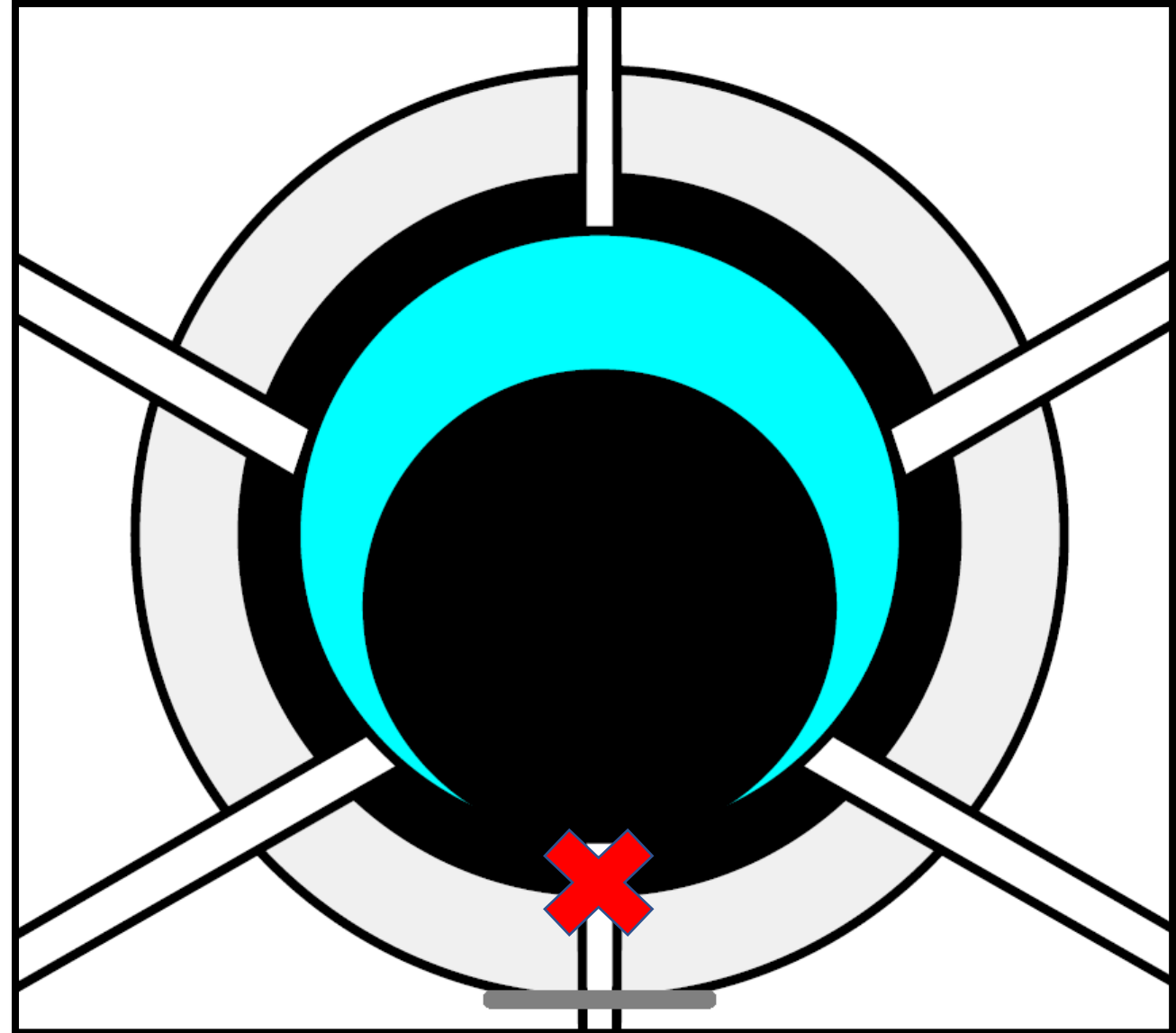
- 4x laser focused magnets was run in 3 wells with 56kg max retrieved debris.
- Some retrieved debris was not coming from the perforation gun.
- This analysis resulted to Run 1x Laser Magnet prior Perforation Job on Coil Tubing during clean out trip.



1x Magnet was run on CT prior TCP in 2 wells and 8KG of debris was retrieved confirming that existing debris was present downhole. Debris was sent for Gun Scallop size.

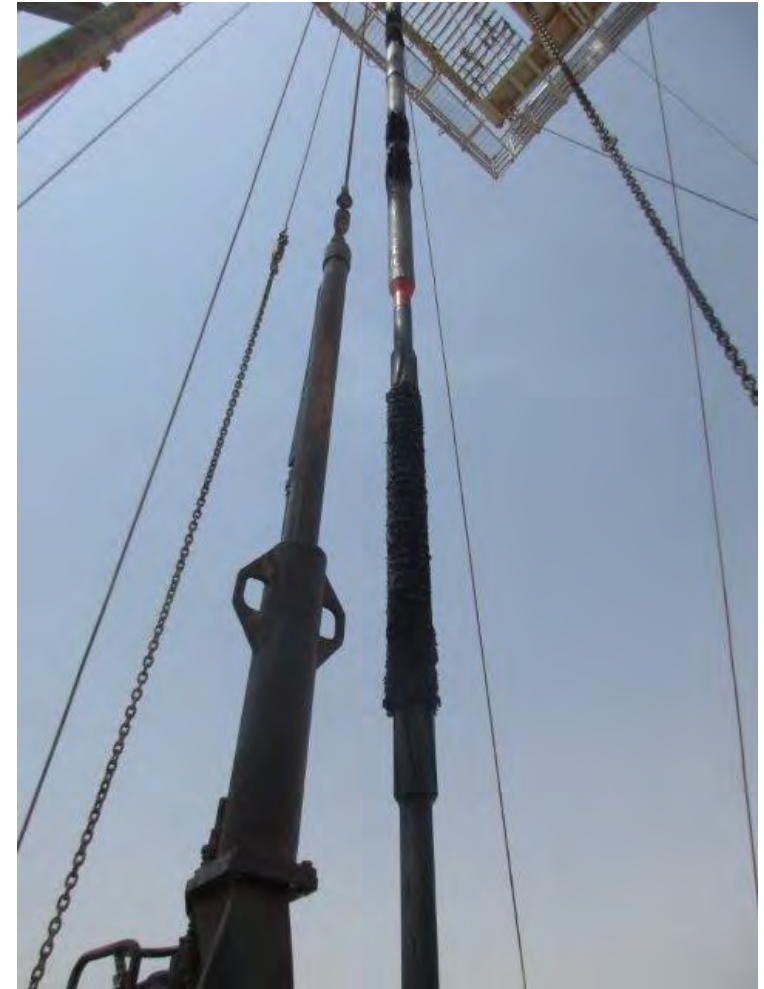


- Selected gun type is 6spf based on model for best productivity ratios.
- Downhole condition cannot be confirmed. Hence, shots facing down may get plugged with debris. (20 shots plugged in every 20ft gun)
- Productivity will reduced to match 5 SPF instead of 6 SPF.
- During gun POOH debris will plug more tunnel facing down.
- Surface facility may be effected during production at due to debris left in hole.
- Debris downhole causes limitation on future interventions.



Debris Photos from Laser Magnets

- Photos from YK Horizontal wells after POOH TCP guns with Laser Magnets



Debris Photos from Laser Magnets



- Debris collected using Laser Magnets

Well Name	Number of Magnets	Debris Retrieved (KG)	Comments
Well C	2	30	Horizontal Well
Well D	2	27	Horizontal Well
Well E	2	28	Horizontal Well
Well F	2	28	Horizontal Well
Well G	3	42	Horizontal Well
Well H	3	42	Horizontal Well
Well I	3	42	Horizontal Well
Well J	4	56	Horizontal Well
Well K	4	56	8kg in CT Run with 1 magnet
Well L	4	52	5kg in CT Run with 1 magnet
Well N	1	7	Run Magnet with Coil Tubing
Well AB	1	15	Horizontal Well
Well FE	1	5	Vertical Well (Solid Debris)



STRING MAGNETS

laser focused magnet technology
Maximum magnetic force against the pipe wall

Dimensional data		
Model	IM 19SS 10AM	IM 28L 15AM
Max OD, inch	1,9	2,75
Min ID, inch	0,5	1,0
Fish neck OD, inch	1,56	2,0
Length, mm	1757	1540
Material properties		
Body material	AISI 4140	AISI 4145
Tensile Yield strength, lbs	45 000	87 000
Torsional Yield strength, ft-lbs	510	1 470
Magnet Ribs on stabilizer	4	6
Operational data		
Flow by area, sq.in	1,5	7,1
Inside	2 7/8" 8,7#	4,5" 12,6#
Max rotation, rpm	150	150
Connection	1" AMMT	1,5" AMMT
Transport Data		
Tool weight, kg	14,5	23



Debris Retrieved from Vertical Well

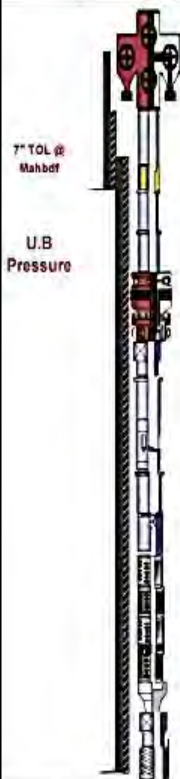
- Run Laser Magnet on Vertical Well; **retrieved 5kg** with 1 magnet - 16m net perforations

Well Name	Number of Magnets	Debris Retrieved (KG)	Comments
Well FE	1	5	1 st Vertical Well

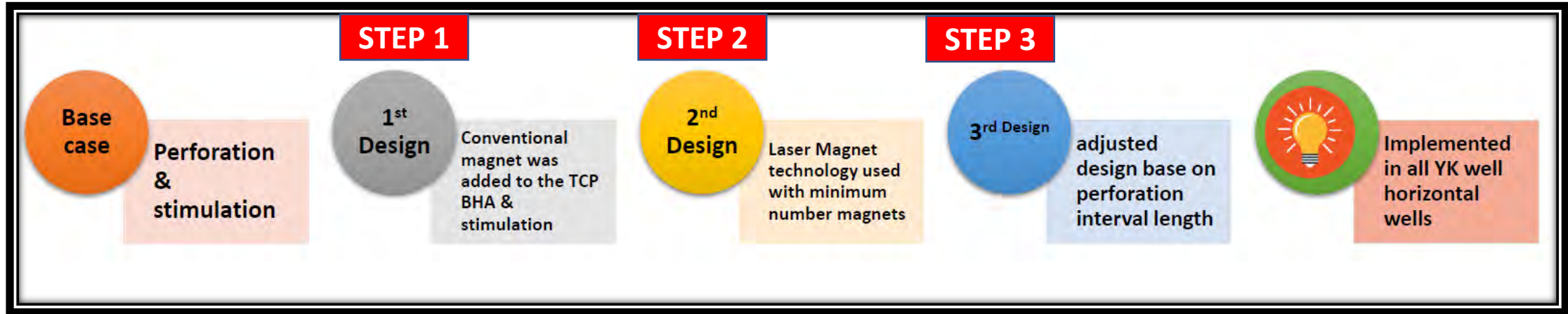


Document Number: RAY-OF-FRM-1402 (1.0)
Proposed Perf Interval: **1670 - 1678 (8m), 1600 - 1608 (8m) MAHBDF** Need to confirm the PERFORATION intervals at wellsite Gun Type: **4.5 HSD DP, 22.7 gm 12 SPF RDX**

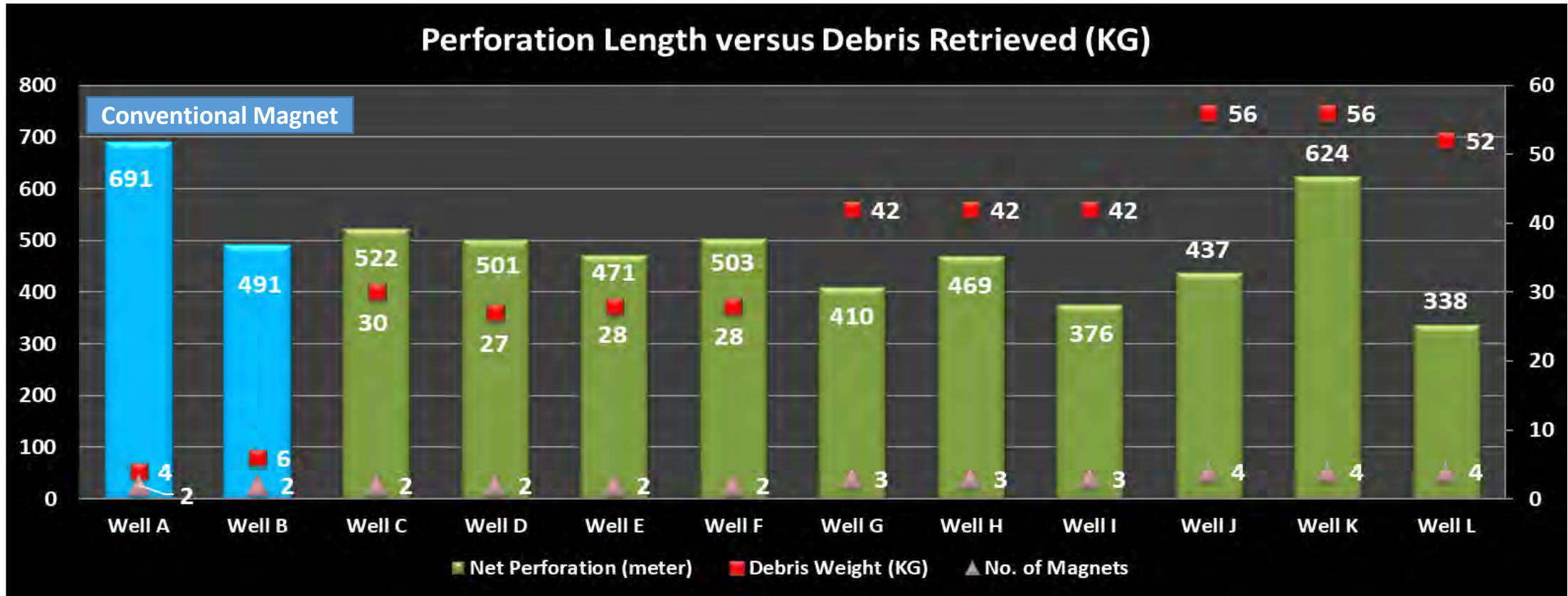
Final - TCP Under Balance (Shoot & Pull) String Diagram

Tool String	Description	Responsible Company	O.D.(")	I.D.(")	Box	Pin	Length (m)	Top Depth (m)Mahbdf	Bottom Depth(m)Mahbdf
 <p>7" TOL @ Mahbdf U.B Pressure</p>	Circulation Head	PDO	11.000	3.080			0.50	-1.80	-1.30
	3 1/2" EUE (9 3/4") TBG to surface 81 Stand & 1 joint	PDO	4.500	2.990	3.5" EUE	3.5" EUE	1512.92	-1.30	1611.62
	3 1/2" EUE RA Marker -1511.73 PIP TAG	RAY	4.500	2.990	3.5" EUE	3.5" EUE	0.15	1511.62	1611.77
	2 joints of 3 1/2" EUE tubing	PDO	4.500	2.990	3.5" EUE	3.5" EUE	18.60	1511.77	1630.37
	3 1/2" EUE PUP Joint	RAY	4.500	2.990	3.5" EUE	3.5" EUE	1.86	1630.37	1632.23
	7" Mechanical Retrievable Packer	RAY	5.970	2.440	3.5" EUE	3.5" EUE	2.97	1632.23	1635.20
	Crossover 2 7/8" EUE PIN & 3 1/2" EUE BOX	RAY	3.670	2.440	2.875" EUE	2.875" EUE	0.25	1635.20	1635.46
	1 ea 2 7/8" EUE TBG Joints	PDO	3.670	2.440	2.875" EUE	2.875" EUE	9.41	1635.46	1644.86
	2 7/8" EUE Drop bar pressure vent (BPV)	RAY	3.670	2.440	2.875" EUE	2.875" EUE	0.43	1644.86	1645.29
	2 ea 2 7/8" EUE TBG Joints	PDO	3.670	2.440	2.875" EUE	2.875" EUE	18.78	1645.29	1664.07
	Drop Bar Mechanical Firing Head (2-7/8")	RAY	3.670	****	2.75" GO	2.875" EUE	1.70	1664.07	1665.77
	4.6" Safety Spacer	RAY	4.500	****	2.375" 6 TPI	2.375" 6 TPI	4.23	1665.77	1670.00
	4.60" HSD, DP, 12 SPF, RDX	RAY	4.500	****	2.375" 6 TPI	2.375" 6 TPI	8.00	1670.00	1678.00
	4.6" Blank	RAY	4.500	****	2.375" 6 TPI	2.375" 6 TPI	22.00	1678.00	1600.00
	4.60" HSD, DP, 12 SPF, RDX	RAY	4.500	****	2.375" 6 TPI	2.375" 6 TPI	8.00	1600.00	1608.00
Blind Crossover	RAY	4.500	****	****	2.375" 6 TPI	0.27	1608.00	1608.27	
Crossover assembly	RAY	3.680	2.000	2.875" EUE	2.75" EUE	0.70	1608.27	1608.97	
Magnet tool	RAY	3.680	2.000	2.75" EUE	***	2.01	1608.97	1610.98	

Well Name	Total perforated interval/ m	Oil rate / m3/d	GOR /m3/m3	FTHP /bar	Number of Magnets	Debris Retrieved (KG)	Comments
Well A	736	24	100	22-28	2	4	Conventional Magnet
Well C	522	112	130	23	2	30	Laser Magnet
Well E	502	69	97	54.68	2	28	Laser Magnet
Well M	751	133	119	112	4	56	Laser Magnet



- PDO & RAY cooperated and ended up implementing usage of Laser focused magnet.
- Deep analysis during the journey resulted the use of 4x laser focused magnets.
- Debris examined lead to additional CT magnet run before perforation job.
- A magnet run on vertical well lead to retrieve 5kg of debris.
- Further study for Vertical Wells to be implemented as way forward.



- Laser focused technology magnets was implemented for most PDO horizontal perforations in all fields.
- Acid stimulation runs was removed from YK camping wells
- Laser magnets were run in 2 wells with CT prior RIH with TCP Guns and recovered (8kg) per well.
- Laser magnet were run in vertical wells and retrieved (5kg) of debris with short perforations.
- To correlate between perforation gun strings and required magnet joints from case history to update SOP.





Cairo, Egypt, November 7-8, 2022

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Q&A

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