Tubing Conveyed Perforating (TCP)

Presenter: Ahmed N. Al Fahdi

Supervisor: Eng. Ali Al Busaidi

Agenda

- TCP Overview
- HSE Considerations
- TCP
  - Guns & Charges
  - Firing Heads
  - Packers
  - BPV
  - RA Marker
- Case Study 1: Oriented Perforation
- Case Study 2: Water production perforation
  - Calculations (Underbalance, TCP-Correlation)

HSE considerations (1/2)

- 9 Life Saving Rules
- IHTIMAM
- **Musta'ed**

Musta'ed Worksite Activity Preparation Checklist

RAY-OG-FRM-230 (1.0)

Activity Date:	28-Sep-24	Unit (Rig/Hoist)	Rig-81
Planned Activity:	Perforation	Job Leader Name & Signature	IDRIS ALMAYHAI

No.	7 Pillars of - Musta'ed	☑	Check box (✔) Tick mark Ensure Applicable points available & validated	Remarks (if any)
1	Plan	☑ ☑ ☑ ☑ ☑ ☑ ☑	Procedure Work Instruction Risk Assessment Lift Plan PTW (Permit to Work) Third Party Checklist Well Control Barriers identified Role Verifiy Understanding	
2	Check Equipment	☑ ☑ ☑ ☑	Certification COC* & COS* Calibrated / Inspected Tests/Fit for purpose Back-up readily available	
3	Prepare Area	☑ ☑ ☐ ☐	Housekeeping Zone Management (Red Zone,No-Go) SIMOPS/Above,Below,Beside Emergency Preparedness	
4	Control Energy	☐ ☑ ☐	Isolate(Lock-out,Tag-out,Test) Line of Fire (Manage Stored Energy, Pressurized Equipment,Tension Lines, etc	
5	Communicate	☑ ☑ ☑ ☑	Toolbox TalK TRIC (Transition to work – Ask open questions) Hand Signals Signage Learning From Incidents (LFI) Focus Area -Pers□al and Well Process safety	
6	Final Checks	☑ ☑ ☑ ☑	100% ready to go Complete PTW Emergency Response/Plan in Place Walk the Line with P&ID	
7	Start Work	☑ ☑ ☑ ☑	Comply-Intervene-Respect (Golden Rules) Adhere to Life Savig Rules Well Barriers/ DROPS/Hands Off **STOP** re-assess rIsk if any changes	

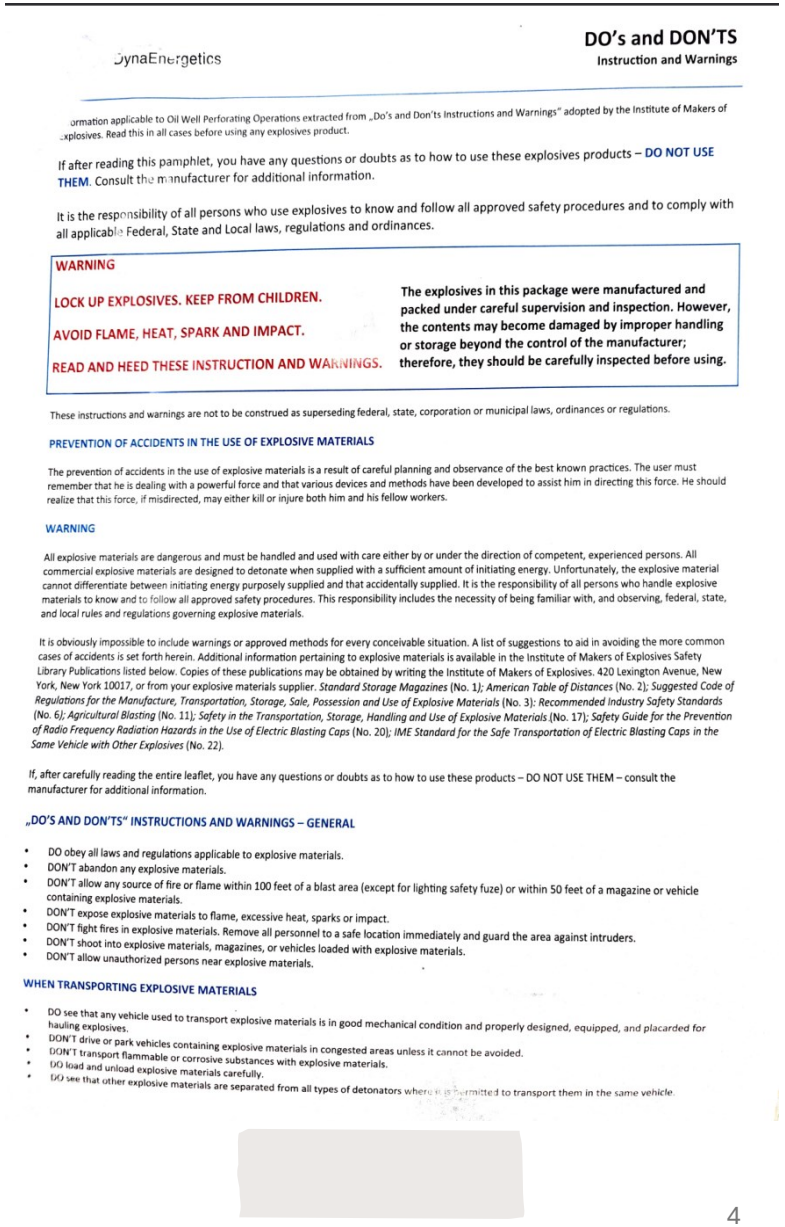
Note: COC* & COS* (Certificate of Compliance & Certificate of Service)

Starting the job is not the first step

HSE Considerations (2/2)

- When Storing in Magazine:

1. Magazines must be located in the most isolated place available.
2. They must be well ventilated, dry, reasonably cool, substantially constructed (Bullet and missile proof if needed), securely looked, weather resistant, fire resistant, theft resistant.
3. Don’t store in wet or damped areas or near excessive heat or flame sources.
4. Don’t store explosives with detonators in the same box, containers or magazines.
5. Don’t store any sparking material.
6. Don’t allow vegetation to grow within 25 feet of magazines.



DynaEnergetics

DO’s and DON’TS
Instruction and Warnings

ormation applicable to Oil Well Perforating Operations extracted from „Do’s and Don’ts Instructions and Warnings” adopted by the Institute of Makers of explosives. Read this in all cases before using any explosives product.

If after reading this pamphlet, you have any questions or doubts as to how to use these explosives products – DO NOT USE THEM. Consult the manufacturer for additional information.

It is the responsibility of all persons who use explosives to know and follow all approved safety procedures and to comply with all applicable Federal, State and Local laws, regulations and ordinances.

WARNING

LOCK UP EXPLOSIVES. KEEP FROM CHILDREN.

AVOID FLAME, HEAT, SPARK AND IMPACT.

READ AND HEED THESE INSTRUCTION AND WARNINGS.

The explosives in this package were manufactured and packed under careful supervision and inspection. However, the contents may become damaged by improper handling or storage beyond the control of the manufacturer; therefore, they should be carefully inspected before using.

These instructions and warnings are not to be construed as superseding federal, state, corporation or municipal laws, ordinances or regulations.

PREVENTION OF ACCIDENTS IN THE USE OF EXPLOSIVE MATERIALS

The prevention of accidents in the use of explosive materials is a result of careful planning and observance of the best known practices. The user must remember that he is dealing with a powerful force and that various devices and methods have been developed to assist him in directing this force. He should realize that this force, if misdirected, may either kill or injure both him and his fellow workers.

WARNING

All explosive materials are dangerous and must be handled and used with care either by or under the direction of competent, experienced persons. All commercial explosive materials are designed to detonate when supplied with a sufficient amount of initiating energy. Unfortunately, the explosive material cannot differentiate between initiating energy purposely supplied and that accidentally supplied. It is the responsibility of all persons who handle explosive materials to know and to follow all approved safety procedures. This responsibility includes the necessity of being familiar with, and observing, federal, state, and local rules and regulations governing explosive materials.

It is obviously impossible to include warnings or approved methods for every conceivable situation. A list of suggestions to aid in avoiding the more common cases of accidents is set forth herein. Additional information pertaining to explosive materials is available in the Institute of Makers of Explosives Safety Library Publications listed below. Copies of these publications may be obtained by writing the Institute of Makers of Explosives. 420 Lexington Avenue, New York, New York 10017, or from your explosive materials supplier. *Standard Storage Magazines* (No. 1); *American Table of Distances* (No. 2); *Suggested Code of Regulations for the Manufacture, Transportation, Storage, Sale, Possession and Use of Explosive Materials* (No. 3); *Recommended Industry Safety Standards* (No. 6); *Agricultural Blasting* (No. 11); *Safety in the Transportation, Storage, Handling and Use of Explosive Materials* (No. 17); *Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Electric Blasting Caps* (No. 20); *IME Standard for the Safe Transportation of Electric Blasting Caps in the Same Vehicle with Other Explosives* (No. 22).

If, after carefully reading the entire leaflet, you have any questions or doubts as to how to use these products – DO NOT USE THEM – consult the manufacturer for additional information.

„DO’S AND DON’TS” INSTRUCTIONS AND WARNINGS – GENERAL

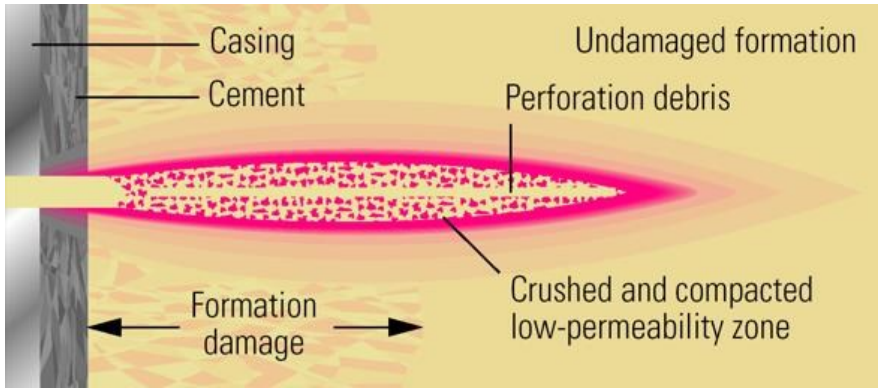
- DO obey all laws and regulations applicable to explosive materials.
- DON’T abandon any explosive materials.
- DON’T allow any source of fire or flame within 100 feet of a blast area (except for lighting safety fuze) or within 50 feet of a magazine or vehicle containing explosive materials.
- DON’T expose explosive materials to flame, excessive heat, sparks or impact.
- DON’T fight fires in explosive materials. Remove all personnel to a safe location immediately and guard the area against intruders.
- DON’T shoot into explosive materials, magazines, or vehicles loaded with explosive materials.
- DON’T allow unauthorized persons near explosive materials.

WHEN TRANSPORTING EXPLOSIVE MATERIALS

- DO see that any vehicle used to transport explosive materials is in good mechanical condition and properly designed, equipped, and placarded for hauling explosives.
- DON’T drive or park vehicles containing explosive materials in congested areas unless it cannot be avoided.
- DON’T transport flammable or corrosive substances with explosive materials.
- DO load and unload explosive materials carefully.
- DO see that other explosive materials are separated from all types of detonators where it is permitted to transport them in the same vehicle.

What is TCP?

- A perforation carried out by means of tubing instead of wireline.
- Perforation is needed to make conductive path for fluids from virgin reservoir rock to wellbore.



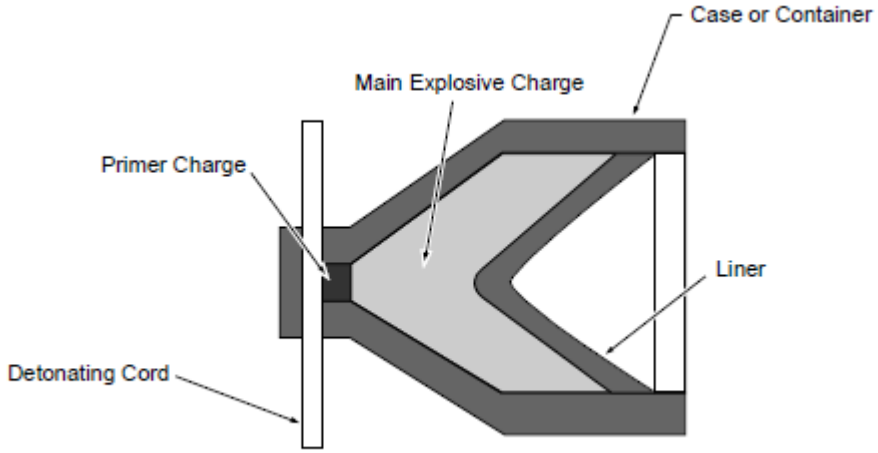
Why use TCP over Wireline?

1. For large guns, large intervals, multi-intervals, multi-zone.
   - TCP allows for the simultaneous perforation of long or widely spaced intervals in a single trip, which can significantly reduce rig time compared to multiple wireline runs.
2. For wells with high deviation angle
   - Horizontal wells
   - Wireline high key-seating risk in J-shaped tangent wells or S-shaped wells
3. Reduced Risk of Wellbore Damage
   - The ability to perform operations underbalanced which helps protect the integrity of the wellbore during perforation.
   - Underbalance perforation provides clean tunnels.

- Other Advantages of TCP
  - Extreme Overbalance perforation (Mini frac).
  - Ability to inject acid in the same run.
  - Double and Triple Casing Perforation.

Charges (1/4)

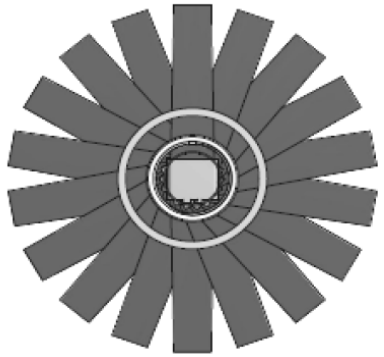
- Components
  1. Case made of Zinc or Steel
  2. Conical Liner
  3. Main explosive made of secondary high explosive
  4. Detonating Cord made of secondary high explosive



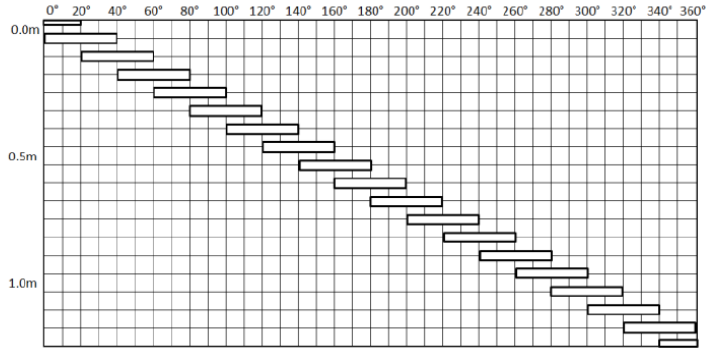
Charges (2/4)

- Types:
  1. DP
  2. GH
  3. BH
  4. DynaSlot (Cement Squeeze & Abandonment Wells)

Configuration Schematic

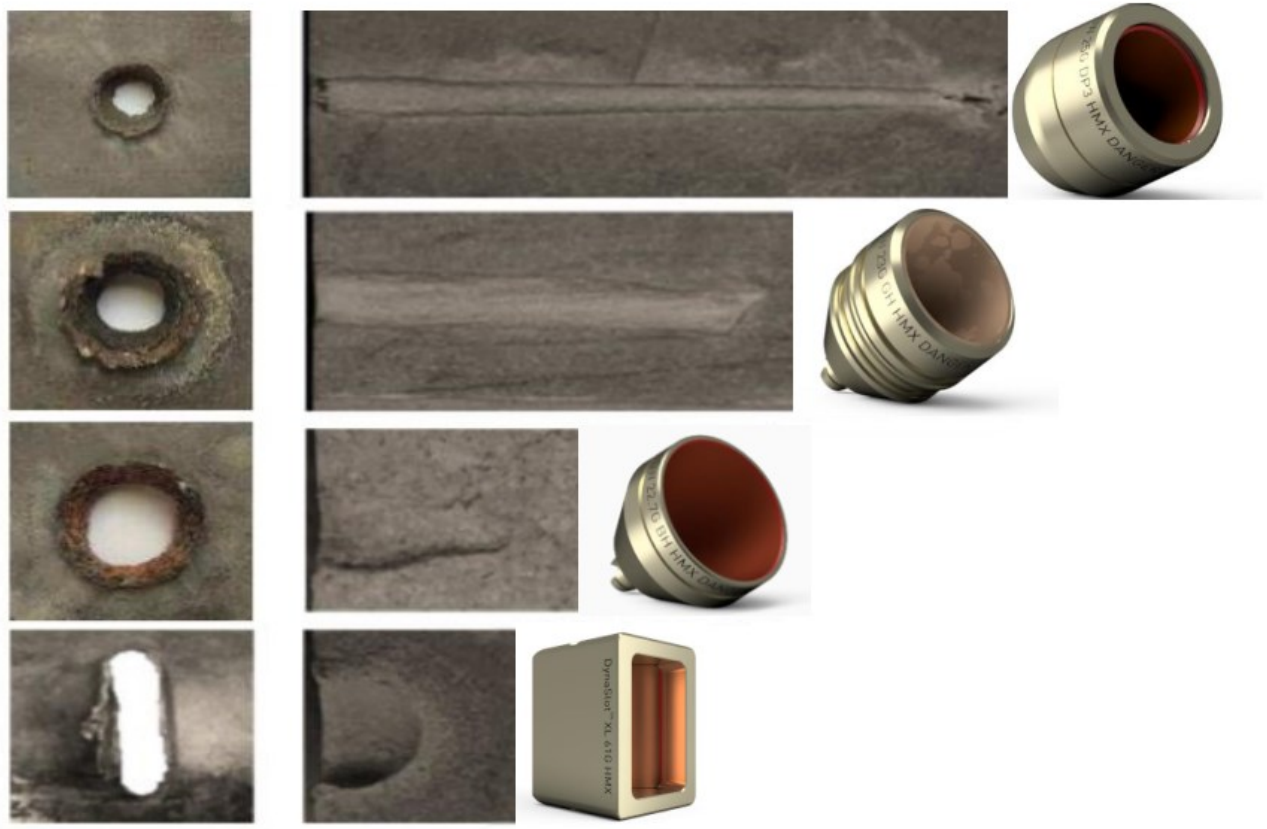


Shot Pattern



Charges (3/4)

- Deep Penetrating (DP)
- Good Hole (GH)
- Big Hole (BH)
- DynaSlot



Charges (4/4)

- Types of explosive:

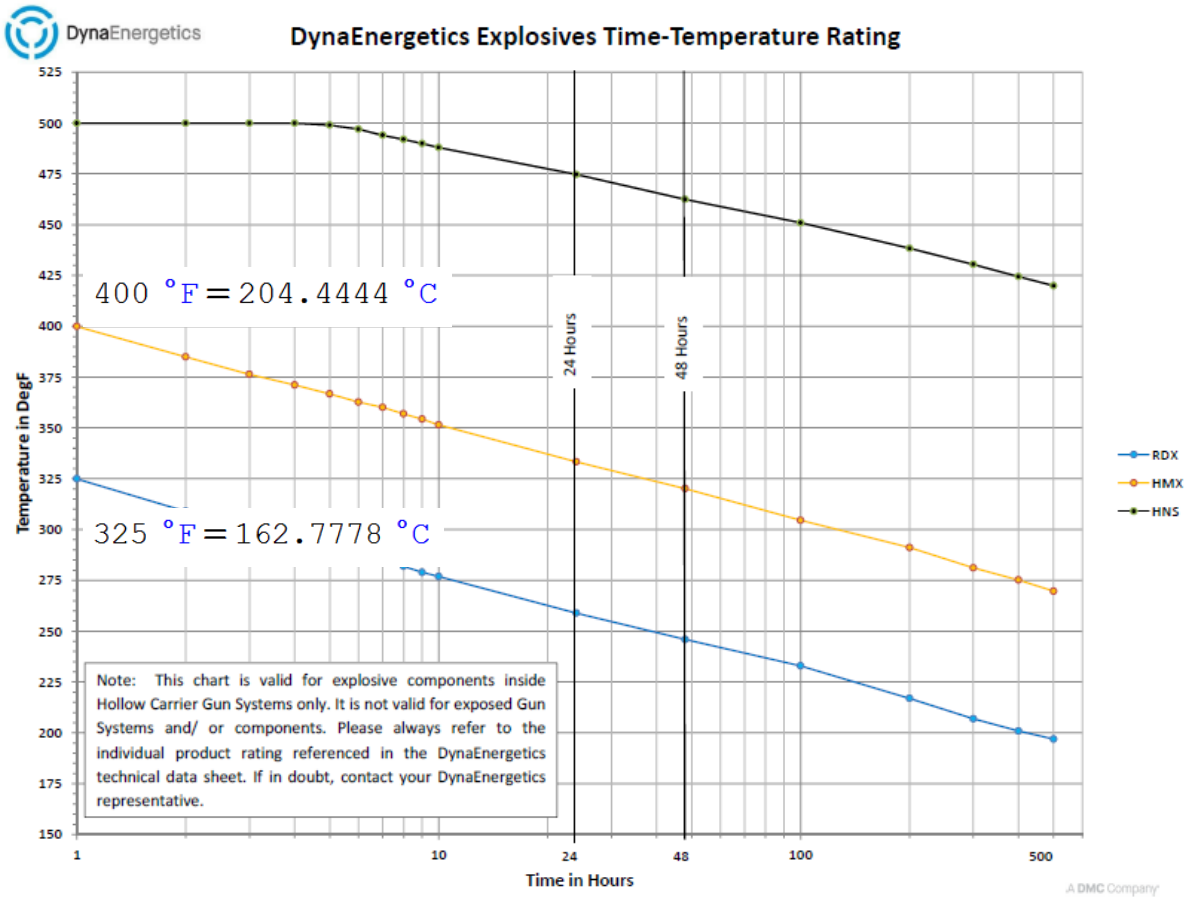
Table 1. Relative Energies of Explosives

Type	Scale	Comments
RDX	100	none
HMX	105	none
HNS	70	none
PYX	65	PYX detonating cord is not recommended for TCP as it creates a lot of interference between charges.

Blue Det. Cord

Yellow Det. Cord for high Temp.

1. Primary **Lead Azide** $Pb(N_3)_2$: Detonators & Boosters C-63
2. Secondary **RDX/HMX/HNS**: Det. Cords, charges



Guns

Shoot & Pull

Hollow Carrier Gun Systems

Strip Gun Systems

Link Gun Systems

Shoot & Drop

Fragmenting Gun Systems

Firing Head

- Contains the primary initiator explosive
- Types:
    1. Mechanical Drop Bar FH
    2. Hydraulic
    3. Auto-vent

Cont. FH (1/3): Mechanical FH

- Dropped from the surface to initial the mechanical actuation type firing head in well within “40 Deg” deviation. It has brass indent can be used to determine if the drop bar reached firing head.
- Limitations:
  1. Cannot be used for high deviation wells; there is a risk of it getting stuck.
  2. Unlike other methods, the debris can cause some issues that require fishing.

Desilting Mechanical Firing Head

Description

The **Desilting Mechanical Firing Head** is a kind of debris proof firing head is designed to fire guns in TCP. Drop bar must be required. The firing head must be used in light mud well and little deviated well.

Feature

1、Sample 、Reliable, Easy to use

2、Desilting

Product Structure

Item	P.N.	Part Name	Qty.
1	RADMF01093001	Upper Sub	1
2	RADMF01093002	Pup joint	1
3	RADMF01093100	Mechanical Firing assembly	1
4	RADMF01093004	Detonator house	1
5	RADMF01093005	Centralizer tube	2
6	RASTX01268001	Stop tube	2
7	GB/T 95 6	Washer	2
8	AS-115	O-ring φ17.12×2.62	4
9	RADMF01093003	Centralizer disk	1
10	ANSI B18.3	Set Screw 5/16-24 UNF x 0.75	3
11	RADMF01093006	Guide rod	1
12	RGCMX01288001	Coupling	1
13	RADMF02093001	lower stacking adapter	1
14	AS-224	O-ring φ44.04×3.53	2
15	RADMF02093002	Lower sub	1

Technical Parameters

Part Number		RADMF02093000
O.D. (mm)		93
Total Length (mm)		1689.6
Connection	Upper Thread	2-7/8EUE BOX
	Bottom Thread	2 3/4-6ACME BOX
Temperature Rating (℃)		200℃
Pressure Rating (MPa)		70MPa
Type of Detonator		DYNA

1

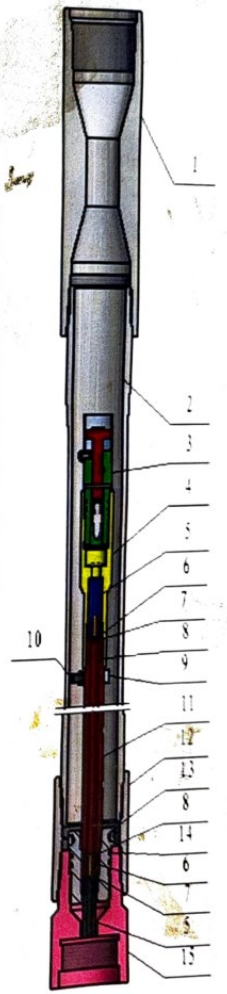
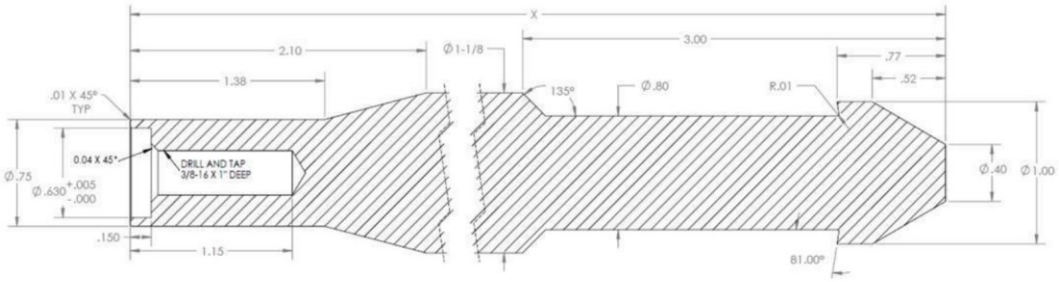


Figure1

Cont. FH (1/3): Mechanical FH: Drop Bar

- Dimensions:
  - Fishing neck (O.D) = 20.3mm or 0.800”
  - Length = 1830 mm or 6.0 ft
  - Weight = 8.9 kg
  - Dimensions = 1830mm x 28.57mm



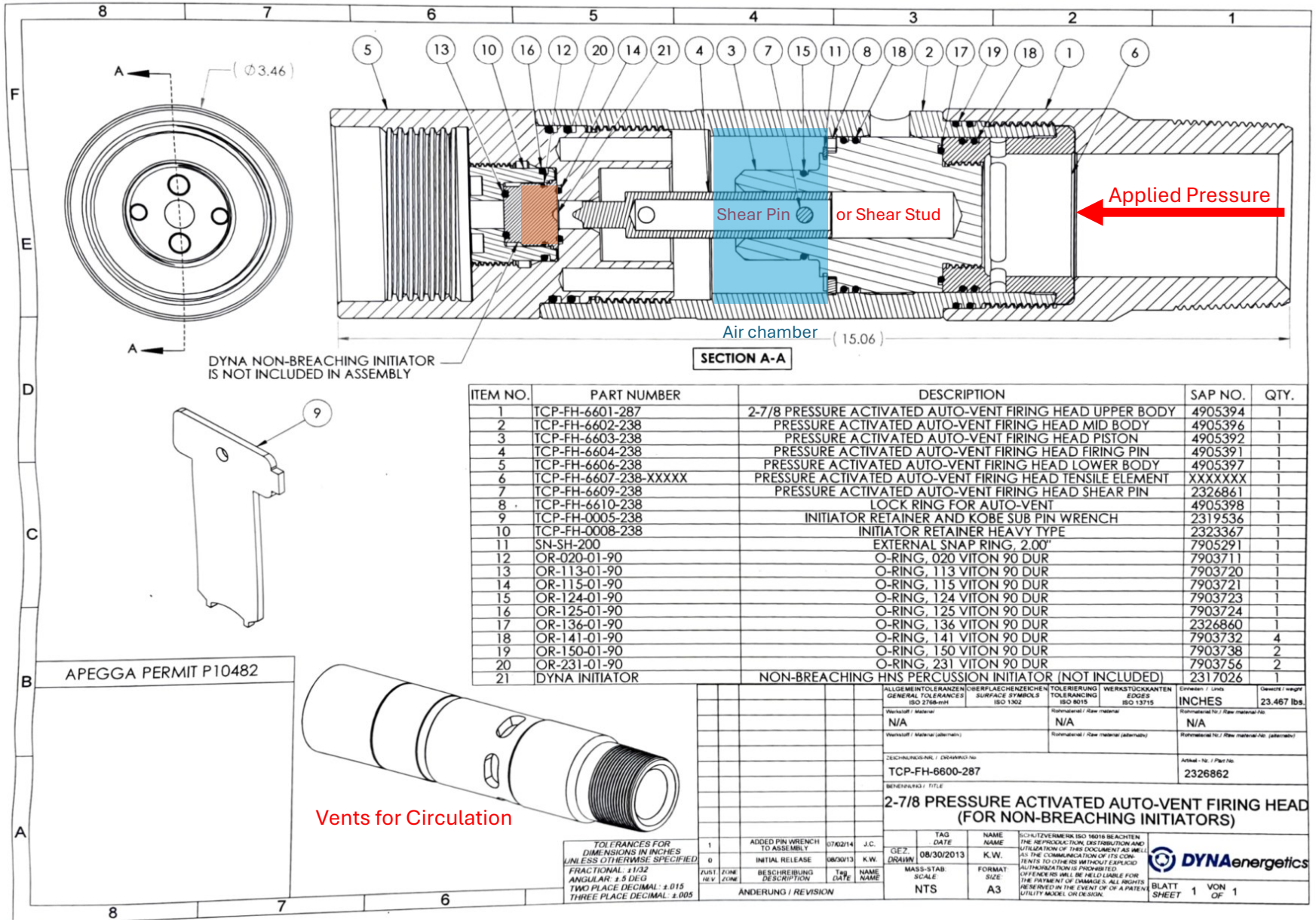
- Recommendations
  1. Change brass indicator after each run
  2. Don’t use for more than 40 Deg deviation. [As per Dyna manual]

Cont. FH (1/3): Mechanical FH: Drop Bar

- Has brass tag to show the impact with firing head.
- The dimensions of DB are import for fishing.

Cont. FH (2/3): Auto-vent FH

- Activated using absolute pressure .
  - Absolute pressure = Hydrostatic pressure + Applied pressure (pumps)
  - $\pm 5\%$
- Commonly used for multi-zone/ multi-interval perforation along with Mechanical FH and time delay fuses.
- Commonly used for high deviation wells
- Works better with debris, as the applied pressure can be beneficial for cleaning up the debris via direct and/or reverse circulation.
- Shear pin/ shear stud is calculated by engineer depending on required pressure, the pumps available at the Rig/Hoist



ITEM NO.	PART NUMBER	DESCRIPTION	SAP NO.	QTY.
1	TCP-FH-6601-287	2-7/8 PRESSURE ACTIVATED AUTO-VENT FIRING HEAD UPPER BODY	4905394	1
2	TCP-FH-6602-238	PRESSURE ACTIVATED AUTO-VENT FIRING HEAD MID BODY	4905396	1
3	TCP-FH-6603-238	PRESSURE ACTIVATED AUTO-VENT FIRING HEAD PISTON	4905392	1
4	TCP-FH-6604-238	PRESSURE ACTIVATED AUTO-VENT FIRING HEAD FIRING PIN	4905391	1
5	TCP-FH-6606-238	PRESSURE ACTIVATED AUTO-VENT FIRING HEAD LOWER BODY	4905397	1
6	TCP-FH-6607-238-XXXXX	PRESSURE ACTIVATED AUTO-VENT FIRING HEAD TENSILE ELEMENT	XXXXXXX	1
7	TCP-FH-6609-238	PRESSURE ACTIVATED AUTO-VENT FIRING HEAD SHEAR PIN	2326861	1
8	TCP-FH-6610-238	LOCK RING FOR AUTO-VENT	4905398	1
9	TCP-FH-0005-238	INITIATOR RETAINER AND KOBE SUB PIN WRENCH	2319536	1
10	TCP-FH-0008-238	INITIATOR RETAINER HEAVY TYPE	2323367	1
11	SN-SH-200	EXTERNAL SNAP RING, 2.00"	7905291	1
12	OR-020-01-90	O-RING, 020 VITON 90 DUR	7903711	1
13	OR-113-01-90	O-RING, 113 VITON 90 DUR	7903720	1
14	OR-115-01-90	O-RING, 115 VITON 90 DUR	7903721	1
15	OR-124-01-90	O-RING, 124 VITON 90 DUR	7903723	1
16	OR-125-01-90	O-RING, 125 VITON 90 DUR	7903724	1
17	OR-136-01-90	O-RING, 136 VITON 90 DUR	2326860	1
18	OR-141-01-90	O-RING, 141 VITON 90 DUR	7903732	4
19	OR-150-01-90	O-RING, 150 VITON 90 DUR	7903738	2
20	OR-231-01-90	O-RING, 231 VITON 90 DUR	7903756	2
21	DYNA INITIATOR	NON-BREACHING HNS PERCUSSION INITIATOR (NOT INCLUDED)	2317026	1

TOLERANCES FOR DIMENSIONS IN INCHES UNLESS OTHERWISE SPECIFIED
FRACTIONAL: ±1/32
ANGULAR: ±.5 DEG
TWO PLACE DECIMAL: ±.015
THREE PLACE DECIMAL: ±.005

REV.	ZONE	BESCHREIBUNG / DESCRIPTION	DATE	NAME
1		ADDED PIN WRENCH TO ASSEMBLY	07/02/14	J.C.
0		INITIAL RELEASE	08/30/13	K.W.

ANDERUNG / REVISION

ALLGEMEINTOLERANZEN GENERAL TOLERANCES ISO 2768-mH | OBERFLAECHENZEICHEN SURFACE SYMBOLS ISO 1302 | TOLERIERUNG TOLERANCING ISO 8015 | WERKSTUECKKANTEN EDGES ISO 13715

Einheiten / Units: INCHES | Gewicht / weight: 23.467 lbs.

Werkstoff / Material: N/A | Rohmaterial / Raw material: N/A | Rohmaterial No. / Raw material No.: N/A

ZEICHNUNGS-NR. / DRAWING No.: TCP-FH-6600-287 | Artikel - Nr. / Part No.: 2326862

BENENNUNG / TITLE:
2-7/8 PRESSURE ACTIVATED AUTO-VENT FIRING HEAD
(FOR NON-BREACHING INITIATORS)

	TAG DATE	NAME NAME
GEZ. DRAWN	08/30/2013	K.W.

MASS-STAB: SCALE: NTS | FORMAT SIZE: A3

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DYNAenergetics

BLATT / SHEET 1 VON / OF 1

Cont. FH (3/3): Hydraulic

- Same working principle as Auto-vent FH
- It requires ported sub (flow Sub) for circulation.
- Required pressure depends on:
  1. Temperature
  2. Mud weight
  3. True Vertical Depth (TVD)

Packers: Overview [As Per RAY-OG-PKR (3.0)]

- What?
  - Retrievable **Map**/Anton/RTTS/**CREST III** Packers: are types of downhole isolation tools which will be unset and retrieved from the wellbore after use.
- Why?
  - Used to isolate the annulus from the production tubing, allowing a controlled production, injection or treatment, incorporating a mean of securing the Packer against the casing or liner wall, such as a slips arrangement, and a means of creating a reliable hydraulic seal to isolate the annulus, typically by means of an expandable elastomeric element.

Packers: Example of CREST III

Packers: Map Schematics

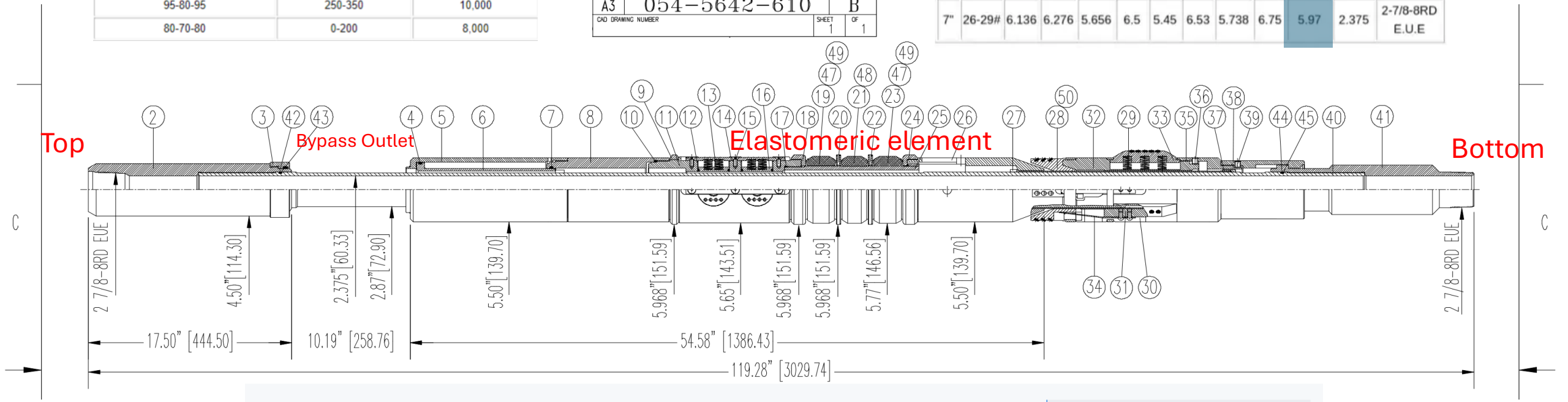
SET-DOWN WEIGHT TABLE - JS®-2A PACKERS Minimum Set Down Weight (in lbs.) Required To Pack-Off Packing Elements Systems		
Packing Element System Hardness	Temp. Limits (Deg F)	Packer Size
		7 & 7-5/8
90-70-90	0-275 133.33 C	9,000
95-80-95	250-350	10,000
80-70-80	0-200	8,000

MAP OIL TOOLS
NEW LBERIA, LA USA

PACKER,JS-2A,7"26-29#,P110,2 7/8"EU 8RD
2.375" ID,W/CARBIDE SLIPS

SIZE	PART NUMBER	REVISION
A3	054-5642-610	B
CAD DRAWING NUMBER	SHEET 1	OF 1

Specifications												
Casing		Setting Range		Absolute Travel Limits						Packer max. O.D	Packer Bore	Thread Box Up Pin Down
				Button Slips		Slips		Drag Block				
OD	WT (T&C)	Min ID	Max ID	Min OD.	Max OD.	Min OD.	Max OD	Min OD.	Max OD.			
7"	26-29#	6.136	6.276	5.656	6.5	5.45	6.53	5.738	6.75	5.97	2.375	2-7/8-8RD E.U.E



$Packer_{MaxOD} := 5.97\ inch$	5.97 inch
$Casing_{OD} := 7\ inch$	7 inch
$Clearance := Casing_{OD} - Packer_{MaxOD}$	1.03 inch

Packers: Setting-up The Map Packer

1. Pick up on tubing (String in tension position)
2. Rotate **¼ turn** to the RIGHT slack off on the tubing, set down weight on packer. This sets the slips, closes the bypass & compresses the packing elements.

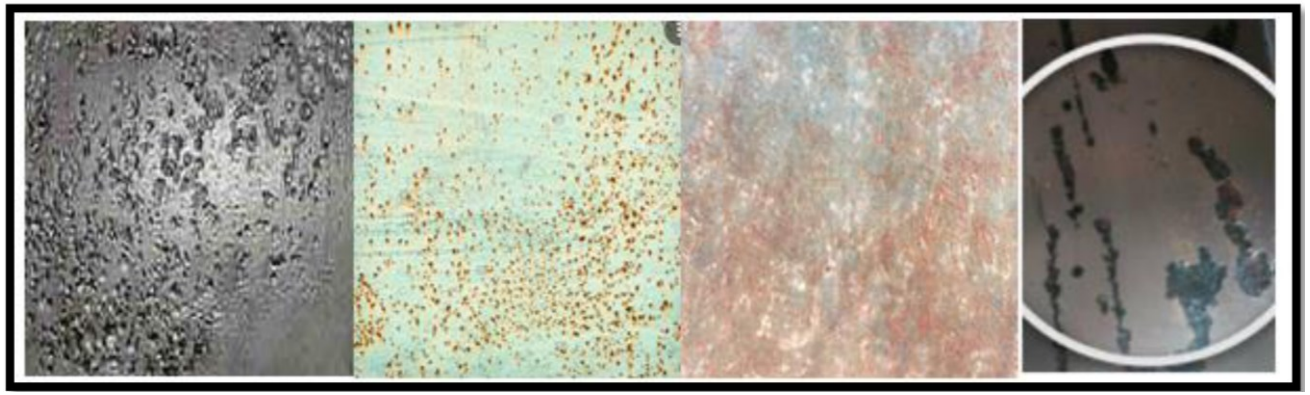
$5000 \text{ lbs} \rightarrow \text{kg}$	2267.962 kg
`# Weight Per 1"`	
$Weight := 2000 \text{ lbs}$	2000 lbs
`# Weight Per 7"`	
$Weight \cdot 7 \rightarrow \text{kg}$	6350.293 kg

Packers: Unsetting The Map Packer

1. Make sure all pressure is bled off from the annulus before unsetting Packer
2. Pick up to strings full up weight slowly. This will open packer bypass, and pressure will equalize across annulus and tubing. Then continue pickup and go for packer release. Packer should take around 5k lbs – 10k lbs weight extra while un-setting.
3. Once Packer has been unset, lower string 10 ft to ensure it is in safety position.
4. Continue operations as usual.

Packers: Corrosion & Counter-measures

- Pitting Corrosion is localized form of corrosion by which cavities or “holes” are produced in the material, most cases of pitting are believed to be caused by local cathodic sites in an otherwise normal surface. Apart from the localized loss of thickness, corrosion pits can also be harmful by acting as stress risers.




CRACK

BPV (Bar Pressure Vent)

- Why?
  - The BPV helps to control and vent excess pressure that may build up in the wellbore during perforation. This is essential for maintaining the desired underbalance condition, which is crucial for effective perforation and minimizing formation damage.
- How?
  1. It is operated by dropping a bar to break the impact pin;
  2. when the pins broken, tubing pressure forces the sleeve upward against the air chamber to open the production vents.
  3. The piston is held up in its place by a snap ring allowing the fluid circulation.

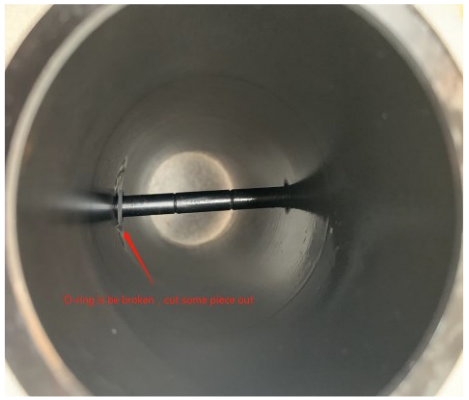
Cont.

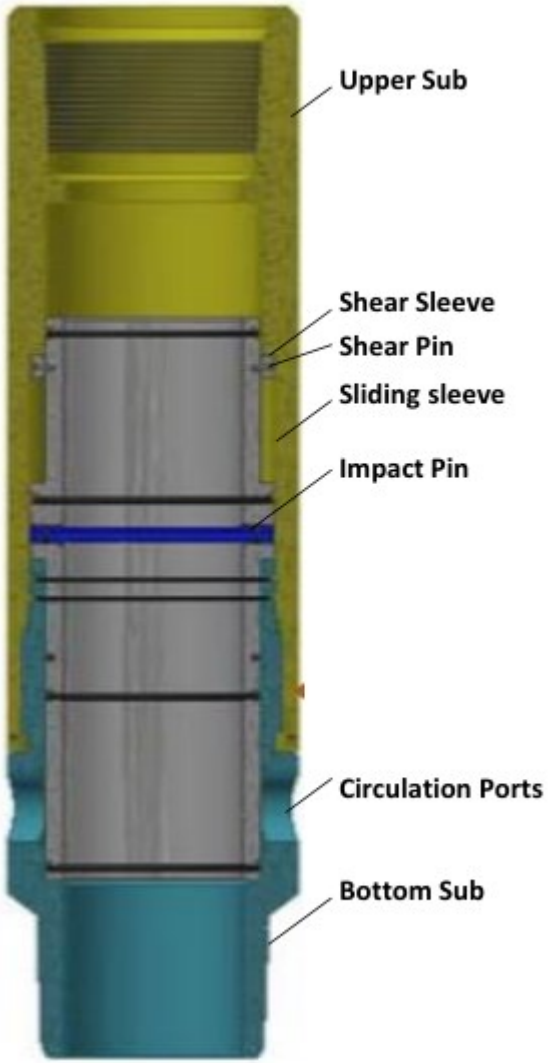
- Other remarks
  - The BPV may be opened prior to firing the guns to achieve a packer test or it may be opened simultaneously with the guns firing to achieve a differential in wells with existing perforations.
  - The DBPV is opened by 500 psi or more pressure in the tubing, applied or hydrostatic. The sliding sleeve is isolated from the tubing pressure by a break plug.
  - To break the impact pin, the minimum tool OD (Drop Bar or another tool) is 1.25 in.
  - NOTE: 500 psi minimum actuating pressure must be tubing pressure, not differential pressure, do not confuse the two.

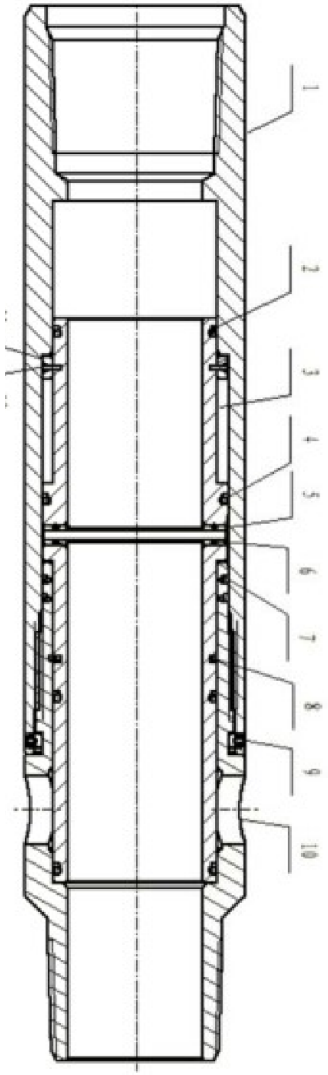
500 psi → kPa	3447.379 kPa
1.25 inch → mm	31.75 mm

Cont. BPV

- Parts (LTR):
  1. Shear Sleeve
  2. Bottom Sub
  3. Upper Sub







Item	Part Name	P.N.	Qty
	RCDBV01288000	RCDBV01288000	
1	Upper Sub	RCDBV01288001	1
2	O-ring φ66.27×3.53	AS-231	3
3	Sliding sleeve	RCDBV01288002	1
4	O-ring φ75.79×3.53	AS-234	1
5	Impact Pin	RCDBV01288003	1
6	O-ring φ6.07×1.78	AS-010	2
7	O-ring φ75.87×2.62	AS-151	2
8	Grip Ring	RCDBV01288004	1
9	Set Screw 1/4-20UNCx0.25	ANSI B18.3 1/4-20UNCx0.25	2
10	Bottom Sub	RCDBV01288005	1
11	Shear sleeve	RCDBV01288006	1
12	Shear pin	RAPFH01080107	4

Cont. BPV Location

- The Drop bar Pressure Vent Sub is normally run between the firing head and the packer in a TCP string.
- If a gun drop sub is used, the Drop Bar Pressure Vent Sub is normally run below the gun drop sub.
- It is recommended that the Drop Bar Pressure Vent Sub be placed at least 30 ft above the firing head and at least 30 ft below the gun drop sub or packer.
- This spacing allows the drop bar to regain momentum after breaking the impact pin.

Radioactive Marker (MA Marker)

- Used to determine accurately the exact location of TCP string, and how much adjustment is needed to reach the target depth.
- Uses Cobalt isotope 60
- Wireline/Slikline lowers GR CCL/ Memory GR CCL tool to locate the “Pip Tag”.
- Sizes:
  - $2\,^{7}/_{8}$
  - $2\,^{1}/_{2}$

Case Studies: Oriented Perforation

MM-1382

Overview

- Objective:
  - The job aims to do a perforation in a well where a Fiber Optics Cable exists. It’s used to gather live data about well.
- Well No. & Rig/Hoist No.:
  - MM-1382
  - HFBU-04
- Date:
  - 10/Aug/2024
- Outcome:
  - Failure

Technical Details: Header

RAY INTERNATIONAL OIL & GAS	Client	PDO	Job Reference	TCP-24-08-16	Date	10-Aug-24
	Field	MARMUL	Total Depth (Mahbdf)	985.00	Run No.	1
	Well	MM-1382	Hold Up Depth (Mahbdf)	970.00	Top (Mahbdf)	Bottom (Mahbdf)
	Rig	HFBU-04	Casing Details	9 5/8", 36#, K55	Surface	984.56
	Formation Zones		Liner Details	7", 23#, K55	Surface	972.00
	Mud Weight (kPa/m)	10.1 Brine	Annulus Hydrostatic at Packer (kPa)	8481	BHT (Deg C)	55 ºC
	Cushion Weight (kPa/m)	10 FW	Cushion Hydrostatic at Firing Head (kPa)	8539	U.B Pressure (kPa)	N/A
Unit TCP	Max. Inclination (°)	V	Formation Pressure at Top Zone (kPa)	7096	Existing Perfs (Y/N)	NO

Proposed Perf Interval: Need to confirm the PERFORATION intervals at wellsite

Measured Above Hole, Below Drill Floor [Meters]

856.5-879.9 (23.4 m) , 888.2-919.2 (31 m) , 922.2-953.1 (30.9 m) Mahbdf

Gun Type:

4.50" HSD, 12 SPF, 22.7g DP RDX
(Loaded @ 8 SPF)

New Well

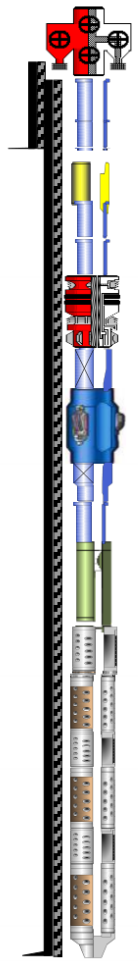
TCP Over Balance (Shoot & Pull) String Diagram with UBHO & Gyro for Gun Orientation

Since it's overbalance, the Packer is used only as a centralizer

(Universal Bottom Hole Orientation Sub)
Real North as Ref.

Technical Details: Proposed String Diagram

16 Guns

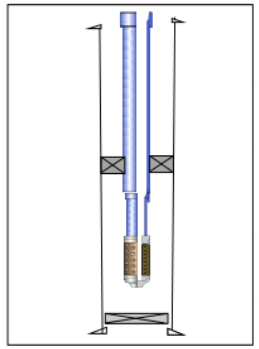


Tool String	Description	Responsible Company	O.D.(")	I.D.(")	Box.	Pin.	Length. (m)	Top Depth. (m)Mahbdf	Bottom Depth(m)Mahbdf
	Circulation Head	Client/Rig	11.000				0.50	-1.50	-1.00
	3 1/2" EUE (9.3#) TBG to surface	Client/Rig	4.500	2.990	3.500" EUE	3.500" EUE	820.00	-1.00	819.00
	3 1/2" EUE RA Marker (SN-24) PIP TAG.	RAY	4.500	2.990	3.5" EUE	3.5" EUE	0.34	819.00	819.34
	2 ea 3 1/2" EUE TBG Joints	Client/Rig	4.500	2.990	3.5" EUE	3.5" EUE	18.56	819.34	837.90
	1 ea 3 1/2" EUE Pup Joint	Client/Rig	4.500	2.990	3.5" EUE	3.5" EUE	1.77	837.90	839.67
	7" Mechanical Retrievable Packer	Client/Rig	5.800	2.440	3.5" EUE	3.5" EUE	2.97	839.67	842.64
	X-O 3 1/2" IF" EUE (P) * 3 1/2" EUE (B)	Client/Rig	4.000	2.440	3.5" EUE	3.500" IF	0.61	842.64	843.25
	UBHO Assembly (Universal Bottom Hole Orientation) Sub	VOS	4.750	1.732	3.500" IF	3.500" IF	0.76	843.25	844.01
	X-O 2 7/8" EUE (P) * 3 1/2" IF (B)	Client/Rig	4.000	2.440	3.500" IF	2.875" EUE	0.29	844.01	844.30
	1EA joint 2-7/8" EUE	Client/Rig	3.670	2.440	2.875"EUE	2.875"EUE	9.63	844.30	853.93
	Hydraulic Firign Head with Auto-Vent (SN-7) (circulating ports will activate after firing)	RAY	3.670	****	2.875"EUE	2.75" 6 TPI	0.47	853.93	854.40
	4.5" Safety Spacer	RAY	4.500	****	3.9375" 6 TPI	2.75" 6 TPI	2.10	854.40	856.50
	4.50" HSD, DP, RDX, 12 SPF (Loaded @ 8 SPF)	RAY	4.500	****	3.9375" 6 TPI	3.9375" 6 TPI	23.40	856.50	879.90
	4.5" Blank Spacer	RAY	4.500	****	3.9375" 6 TPI	3.9375" 6 TPI	8.30	879.90	888.20
	4.50" HSD, DP, RDX, 12 SPF (Loaded @ 8 SPF)	RAY	4.500	****	3.9375" 6 TPI	3.9375" 6 TPI	31.00	888.20	919.20
	4.5" Blank Spacer	RAY	4.500	****	3.9375" 6 TPI	3.9375" 6 TPI	3.00	919.20	922.20
	4.50" HSD, DP, RDX, 12 SPF (Loaded @ 8 SPF)	RAY	4.500	****	3.9375" 6 TPI	3.9375" 6 TPI	30.90	922.20	953.10
	Bottom Plug	RAY	4.500	****	****	3.9375" 6 TPI	0.27	953.10	953.37

Technical Details: Footer

Other Information:

- If Acoustic Device is used ensure all engines are shut down to reduce noise.
- Guns will be set on depth based on GR CCL results
- Gun Reference Mark "Gun Line" will be in the middle of total perforation angle.
- 180º Blank section to be placed opposite Fiber Optic Cable using UBHO Sub
- Gyro will depend on Real North as reference

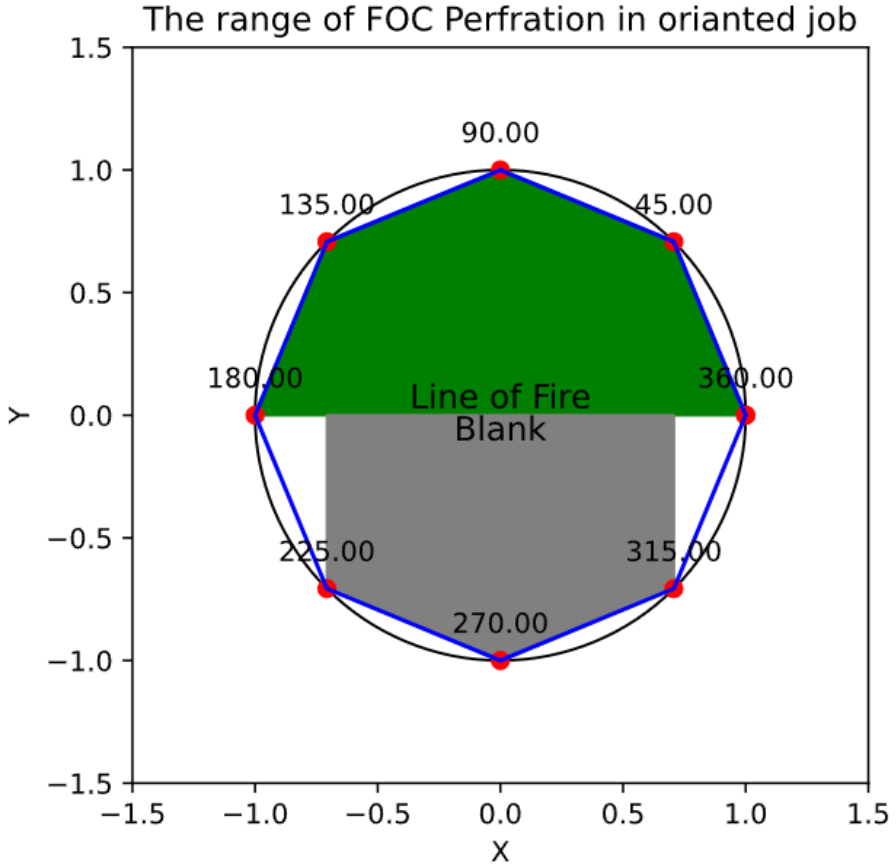


Top Shot to RA Marker:	37.30	meters
RA Marker Depth:	819.20	meters
Customer Representative:		
RAY Engineers:	FAROUK	
RAY FSM:	Ali	

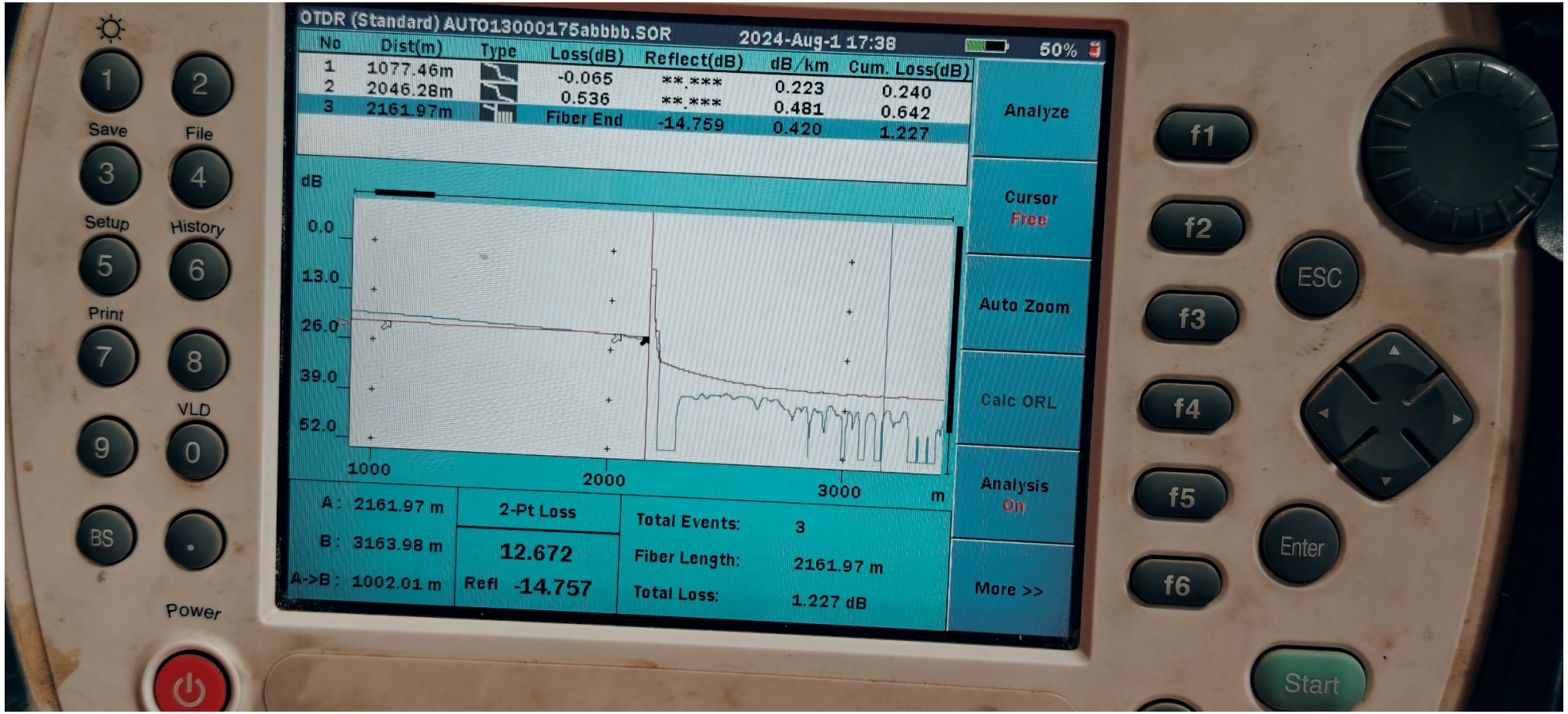
Using Wireline/Slickline

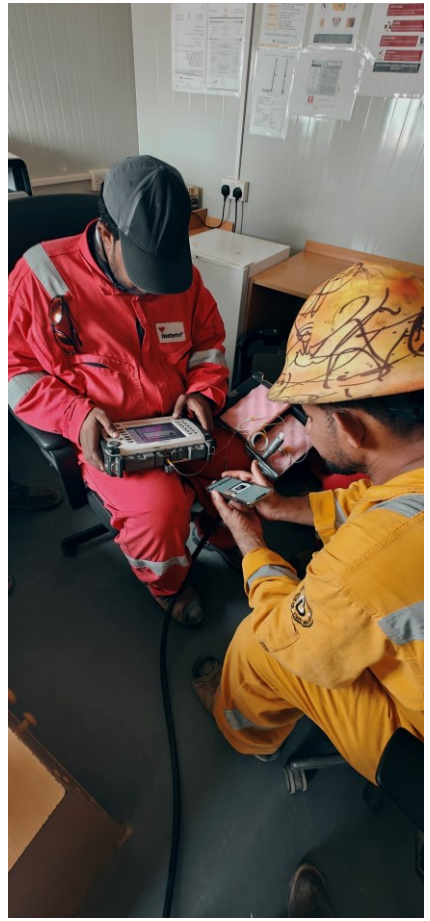

BLANK


LOAD


The range of FOC Perfration in oriented job
90.00
135.00
45.00
180.00
360.00
Line of Fire
Blank
225.00
315.00
270.00
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
Y
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
X

Verification





What went wrong?

- Unsuitable screw size.
- Longer screw, which is designed for 5” tandem subs, used instead shorter screw.

Another Oriented Perforation failure

Misfire resulted in partial detonation of charges due to missing O-rings in the adjustable tandem subs. Visual check of subs will not show the problem unless you open the tandem subs.

Case Study 2: Well Water Production Perforation

MARMUL NW-50

Overview

- Objective:
  - Perforating water production well.
- Well No. & Rig/Hoist No.:
  - MARMUL NW-50
  - Rig-81
- Date:
  - 19-Oct-2024
- Outcome:
  - Success

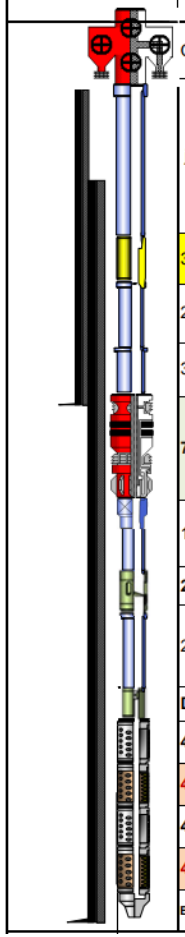
Technical Details: Header

Document Number: RAY-OF-FRM-1402 (2.0)

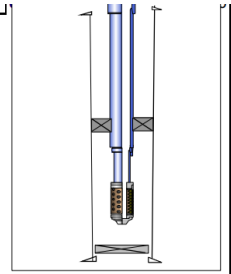
RAY INTERNATIONAL OIL & GAS		Client		PDO	Job Reference	TCP-24-09-40		Date	19-Oct-24
		Field		MARMUL	Total Depth (Mahbdf)	1011.00		Run No.	1
		Well		MARMUL NW-50	Hold Up Depth (Mahbdf)	1011.00		Top (Mahbdf)	Bottom (Mahbdf)
		Rig		Rig-81	Casing Details	9.5/8", 40#, K-55		Surface	n/a
		Formation Zones		HSAK1	Liner Details	7", 29#, K-40		Surface	1011.00
		Mud Weight (kPa/m)		10.1 WSW	Annulus Hydrostatic at Packer (kPa)		8474	BHT (Deg C)	55° Deg C
		Cushion Weight (kPa/m)		10.1 WSW	Cushion Hydrostatic at Firing Head (kPa)		8000	U.B Pressure (kPa)	2000
Unit	TCP	Max. Deviation (°)	0 ° Deg	Max 1.48 ° Deg	Formation Pressure at Top Zone (kPa)		10000	Existing Perfs (Y/N)	No
0					Gun Type:				
874-902.3 (28.3) , 907.2-1007 (99.8) Mahbdf					4.50" HSD,22.7 g, 12 SPF, DP RDX				

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

Technical Details: Proposed String Diagram

Tool String	Description	Responsible Company	O.D.(")	I.D.(")	Box.	Pin.	Length. (m)	Top Depth. (m) Mahbdf	Bottom Depth(m)Mahbdf
	Circulation Head	PDO	11.000	0.000	0	0	0.00	-2.80	-2.30
	joints 3 1/2" EUE (9.3#) TBG to surface	PDO	3.500	2.990	3.5" EUE	3.5" EUE	817.84	-2.30	815.54
	3 1/2" EUE RA Marker PIP TAG AT SN (25) 815.74 M	RAY	3.500	2.990	3.5" EUE	3.5" EUE	0.34	815.54	815.88
	2 ea 3 1/2" EUE TBG Joints	PDO	3.500	2.990	3.5" EUE	3.5" EUE	18.67	815.88	834.55
	3 1/2" EUE PUP Joint.	RAY	3.500	2.990	3.5" EUE	3.5" EUE	1.48	834.55	836.03
	7" Mechanical Retrievable Packer SN (11)	RAY	5.970	2.250	3.5" EUE	3.5" EUE	2.97	836.03	839.00
	1 ea 2 7/8" EUE TBG Joints	PDO	3.670	2.440	2.875" EUE	2.875" EUE	9.42	839.00	848.42
	2 7/8" EUE BPV (Bar-drop Production Valve) SN (23)	RAY	3.670	2.440	2.875" EUE	2.875" EUE	0.43	848.42	848.85
	2 ea 2 7/8" EUE TBG Joints	PDO	3.670	2.440	2.875" EUE	2.875" EUE	19.02	848.85	867.87
	Drop Bar Firing Head (2-7/8") with Pup joint	RAY	3.670	****	1.57" No-Go	2.875"EUE	1.70	867.87	869.57
	4.5" Safety Spacer	RAY	4.500	****	2.375" 6 TPI	2.375" 6 TPI	4.43	869.57	874.00
	4.50" HSD, DP, RDX, 12 SPF	RAY	4.500	****	2.375" 6 TPI	2.375" 6 TPI	28.30	874.00	902.30
	4.5" Blank Spacer	RAY	4.500	****	2.375" 6 TPI	2.375" 6 TPI	4.90	902.30	907.20
	4.50" HSD, DP, RDX, 12 SPF	RAY	4.500	****	2.375" 6 TPI	2.375" 6 TPI	99.80	907.20	1007.00
	Bottom Plug	RAY	4.500	****	****	2.375" 6 TPI	0.27	1007.00	1007.27

Technical Details: Footer

Other Informaion: - Ensure to fill with FRESH WATER above the Firing Head. - If Acoustic Device is used ensure all engines are shut down to reduce noise		**Top Shot to RA Marker:**	58.26 meters
		RA Marker Depth:	815.74 meters
		Customer Represntative:	SAID
		RAY TCP Engineers:	IDRIS ALMAYHAI
		RAY Field Service Manager (FSM):	ALI ALMAKHMARI

Underbalance Calculations (1/2)

# Given Info	
$FormationPressure := 10000\ \text{kPa}$	$10\ \text{MPa}$
$RequiredUnderbalance := 2000\ \text{kPa}$	$2\ \text{MPa}$
# Calculation	
$RequiredTubingHydrostatic := FormationPressure - RequiredUnderbalance \rightarrow \text{kPa}$	$8000\ \text{kPa}$
$TubingCushion := \frac{10.1\ \text{kPa}}{\text{m}}$	$\frac{10.1\ \text{kPa}}{\text{m}}$
$Filled_{tubing} := \frac{RequiredTubingHydrostatic}{TubingCushion}$	$792.079\ \text{m}$

Underbalance Calculations (2/2)

RAY INTERNATIONAL OIL & GAS

RAY-OG-FRM-1428 (2.0)

Underbalance Worksheet

Well:	MARMUL NW-50
Date :	28-Sep-24

Rig / Hoist:	Rig-81

Dry Pipe = Cushion Hydrostatic - Under balance Required / Fluid Wt.

Fill Below

TVD AT Firing Head	869.57	Meters	2853	Ft		
FORMATION PRESSURE	10000	kPa	1450	PSI		
Annulus Fluid Wt.	10.1	kPa /Meter	8.6	PPG		
Tubing Cushion Wt.	10.1	kPa /Meter	8.6	PPG		
Underbalance Required	2000	kPa	290	PSI		
Tubing Cushion Pressure	8000	Kpa	1160	PSI		
Differential Pressure(Ported Sub)	782.657	kPA	114	PSI		
Differential Pressure(Non-Ported Sub)	8000	kPA	1160	PSI		

Under Balance :-

Hydrostatic at Top Shot =	869.57	TVD at Firing Head	x	10.1	Fluid Wt =	8782.657	Kpa
Required Tubing Cushion Hydrostatic =	10000	Formation Pressure	−	2000	Underbalance	8000	Kpa
Need to Fill Tubing =	792	Mts		81 Joints			
Dry Pipe =	77	Mts					

Gun Loading Sheet (1/2)

18-Full Loaded Guns

GUN LOADING SHEET

Client	PDO	Well	Marmul NW-50	LOADED BY	Said Al Jamoodi	GUN SIZE	4-1/2"12SPF , DP 22.7g
Country	OMAN	TICKET NO		VERIFIED BY	Tarik Al Kalbani	EXP. TYPE	22.7g DP RDX
Block		RIG	Rig-81	APPROVED BY	Ali Al Makhmari	FORM #	RAY-OG-FRM-1405
Field	Marmul	Run	1	Date	28-Sep-2024	Engineer	Ali

PERF INTERVAL:874-902.3 (28.3) , 907.2-1007 (99.8) Mahbdf

GUN NO: 1 — Full loaded

SPF	12
Gun Length (m)	6
Length (m)	6.39

1000.61
1001 — 0.39
1007 — 0.27
1007.27

* The Loading details is ordered vertically according to gun image

Loaded	Bottom (m)	Top (m)	Length (m)
Loaded	1007	1001	6

TOTAL SHOTS.	235
DET.CORD. (m)	8
BOOSTERS.	2

GUN NO: 2 — Full loaded

SPF	12
Gun Length (m)	6
Length (m)	6.39

994.22
994.61 — 0.39
1000.61

* The Loading details is ordered vertically according to gun image

Loaded	Bottom (m)	Top (m)	Length (m)
Loaded	1000.61	994.61	6

TOTAL SHOTS.	235
DET.CORD. (m)	8
BOOSTERS.	2

GUN NO: 3 — Full loaded

SPF	12
Gun Length (m)	6
Length (m)	6.39

987.83
988.22 — 0.39
994.22

* The Loading details is ordered vertically according to gun image

Loaded	Bottom (m)	Top (m)	Length (m)
Loaded	994.22	988.22	6

TOTAL SHOTS.	235
DET.CORD. (m)	8
BOOSTERS.	2

GUN NO: 4 — Full loaded

SPF	12
Gun Length (m)	6
Length (m)	6.39

981.44
981.83 — 0.39
987.83

* The Loading details is ordered vertically according to gun image

Loaded	Bottom (m)	Top (m)	Length (m)
Loaded	987.83	981.83	6

TOTAL SHOTS.	235
DET.CORD. (m)	8
BOOSTERS.	2

GUN NO: 5 — Full loaded

SPF	12
Gun Length (m)	6
Length (m)	6.39

975.05
975.44 — 0.39
981.44

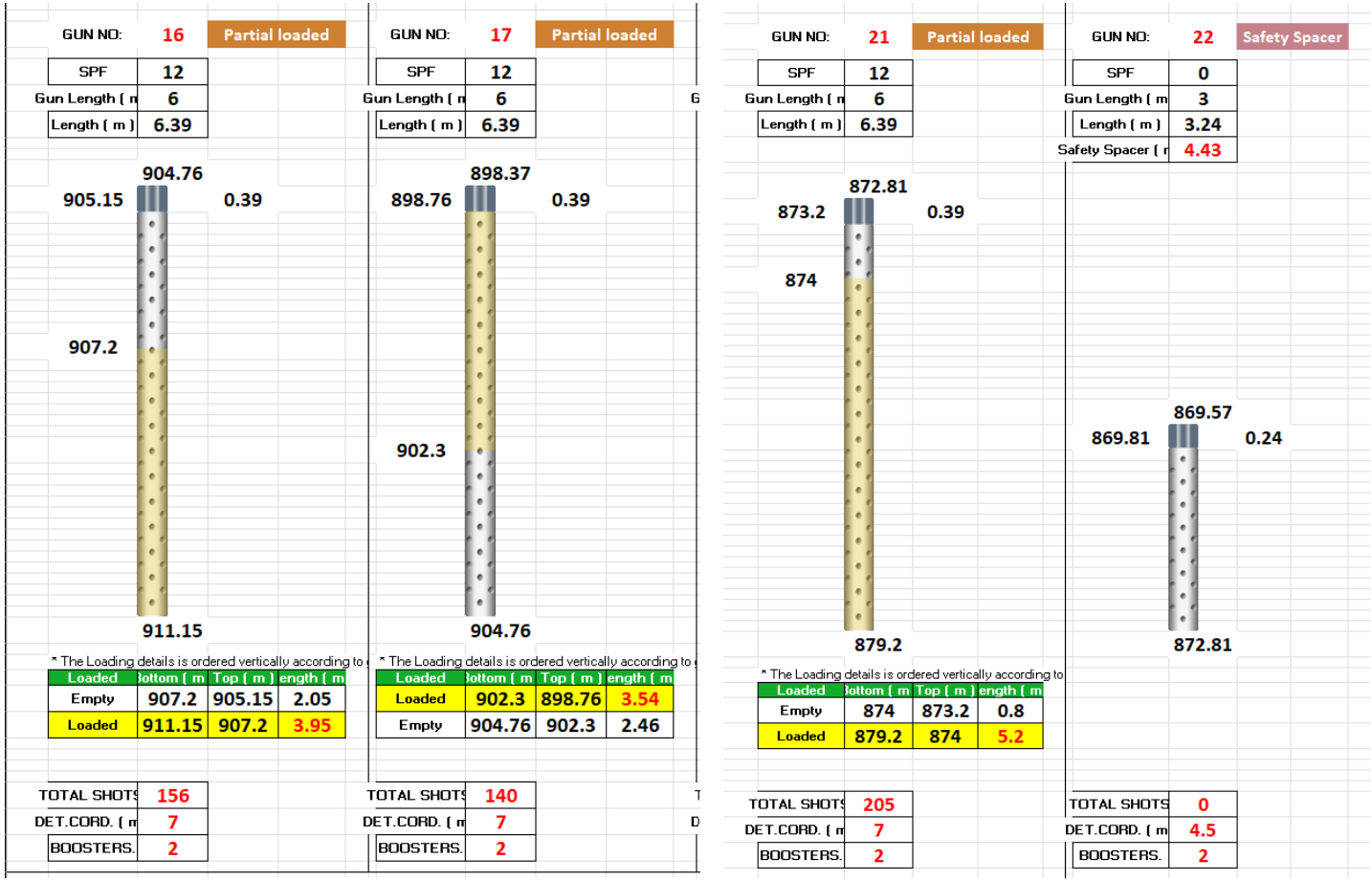
* The Loading details is ordered vertically according to gun image

Loaded	Bottom (m)	Top (m)	Length (m)
Loaded	981.44	975.44	6

TOTAL SHOTS.	235
DET.CORD. (m)	8
BOOSTERS.	2

Gun Loading Sheet (2/2)

3-Partial Loaded Guns & One Safety spacer



Depth Correlation

Go up by 1.5m

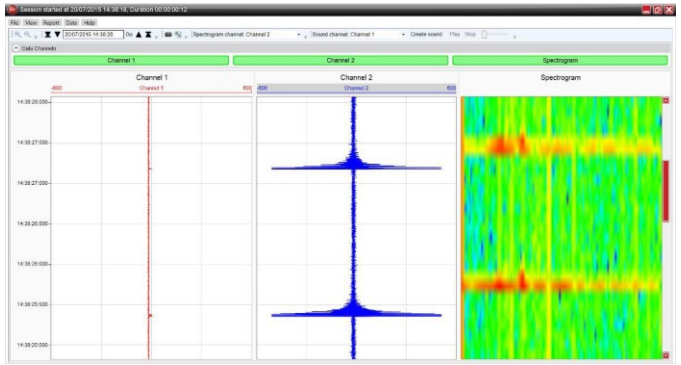
Depth Correlation - TCP Space Out Calculations (S & P)

RAY-OG-FRM 1425 (3.0)

Client:	**PDO**	**Job No.**	**TCP-24-09-40**
Rig:	**Rig-81**	**Date**	**30-Sep-24**
Well No:	**MARMUL NW-50**	**Field**	**MARMUL**
Before Spacout			
WL found RA Marker Sub at		**817.24**	Meter
RA Marker Should be at		**815.74**	Meter
Top Shot To RA Marker		**58.26**	**Meter**
Top Shop Should be at (as per TCP Intervals)		**847.00**	**Meter**
Current top Shot Depth (Before Spacout)		**848.5**	**Meter**
Difference		**1.50**	**Meter Deeper**
Current Stick up		**0.80**	Meter
Stick Up After Adding Difference		**2.3**	**Meter**
Spacout Calculations			
Length of Joint Removed		**0**	**Meter**
Length of Joint Added		**0**	**Meter**
Final Recommended Stick Up		**2.30**	Meter
Actual Stick Up		**2.3**	**Meter**
Final Top Shot depth - After Spacout (As per TCP interval)		**847.00**	Meter

Verification

- Using specialized device to confirm there has been firing.
- It uses acoustic receivers to confirm firing; however, it can’t tell you if the firing is full or partial.



Job Log

JOB LOG

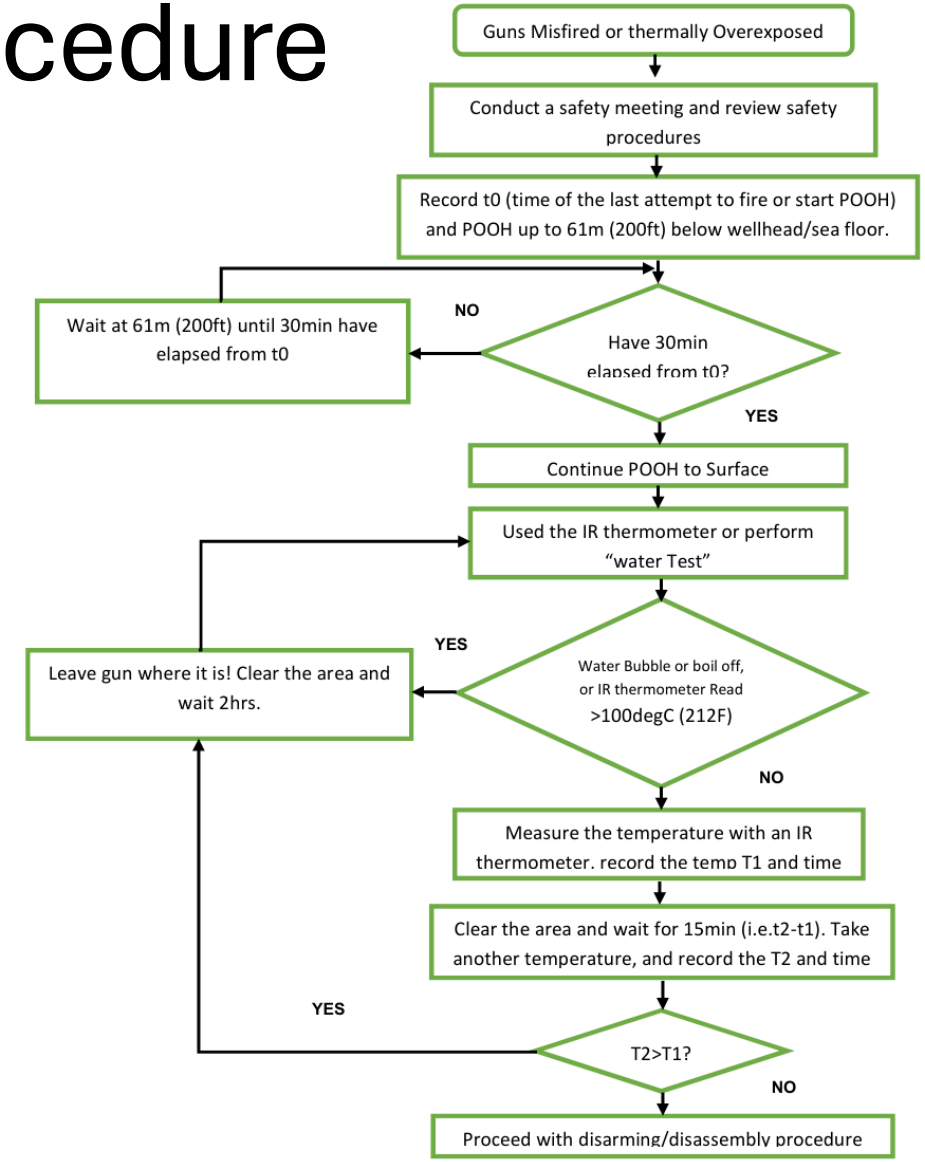
Client:	**PDO**	**SAP P.O.Number:**	
Well Name / Field	**MARMUL NW-50**	**Job Number:**	**TCP-24-09-40**
Well Location:	**MARMUL**	**Date:**	**28-Sep-24**
Rig:	**Rig-81**	**Job Discription:**	**TCP Shoot & Pull Underbalance**

Date	Time	Event
28-Sep-24	16:00	TCP Crew and Guns arrived to the wellsite.
29-Sep-24	6:00	PJSM held in the rig floor priorr picking up the guns.
	6:10	Start Picking up & RIH 4 1/2" HSD 12 SPF guns.
	9:45	Make up 2 7/8" EUE Drop Bar-Mechanical Firing Head.
	9:50	Pick up and RIH 2 joint of 2 7/8" EUE Tubing, and fill up with 10.1 KPA/M water.
	9:55	Make up 2 7/8" EUE Drop Bar Pressure Vent (BPV_Circulating).
	10:00	Pick up and RIH 1 joints of 2 7/8" EUE tubing and fill up with 10.1 KPA/M water.
	10:15	Pick up & RIH Packer assembly (7" Retreivable Packer, & 3 1/2" EUE Pup-Joint).
	10:25	Pick up and RIH 2 joints of 3 1/2" EUE, tubing and fill up with 10.1 KPA/M water.
	10:30	Make up 3 1/2" EUE RA-Marker.
	10:45	Start Picking up & RIH 3 1/2" EUE tubing.
	14:00	Completed RIH initial stick up 0.80 m.
	14:30	Rig up RAY wire line to correlate RA-Marker Depth.
	14:45	RAY wire line Start RIH.
	15:30	RAY wire line correlated RA-Marker Depth at 817.24 M.deeper 1.5 M, it should be at (815.74M).
	16:00	PDO office approved the correlation result & RAY wire line Start POOH.
	16:15	RAY Wire line Rig Down.
	16:30	make up safety vale & Final Stick up 2.3 m.
	16:35	Set Packer, and apply 8 ton slack off (String weight 35 ton).
	16:45	Close BOP and apply 5000 KPA to test Packer Integrity.
	17:00	PJSM Held before Drop the bar to fire the gun.
	17:05	Drop the detonating bar, and within 1.5 min, strong shock obseved in the string.
	17:15	Bleed off casing and pick up TCP String to unset the Packer.
	17:30	Revers out oil & Gas observed at surface.
	17:45	Flow check for 15 min, losses recorded.
	19:45	Start POOH & lay down .
30-Sep-24	9:40	Disconnect & Lay Down 3 1/2" EUE RA-Marker.
	10:00	POOH & lay down 2 joint of 3 1/2" EUE tubing.
	10:10	Disconnect & Lay down Packer assembly, (7" Retreivable Packer & 3 1/2" EUE pup-joint).
	10:15	POOH and lay down 1 joints of 2 7/8" EUE tubing.
	10:25	Disconnected & Lay down 2 7/8" Bar Pressure Vent (BPV_Circulating tool).
	10:35	POOH and lay down 2 joints of 2 7/8" EUE tubing & remove the detonating bar.
	10:55	Disconnected and lay down Drop Bar-Mechanical Firing Head.
	2:15	POOH Guns completed & confrimed all Guns Fired.
30-Sep-24	2.45	TCP Crew and Equipment left the wellsite.

Client Representative: **SAID** **RAY Representative:** **IDRIS ALMAYHAI**

Backup Slides

Misfire Procedure

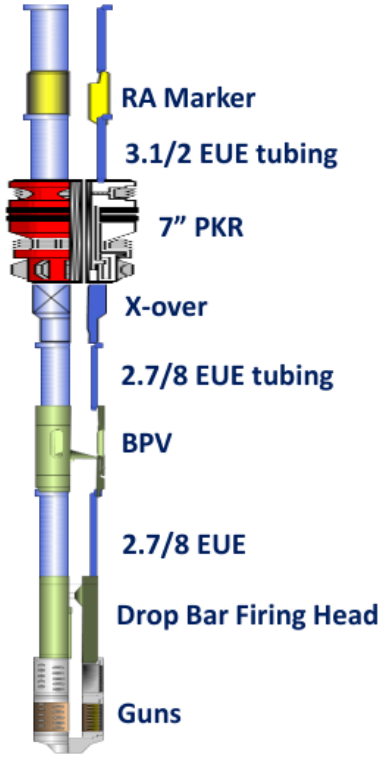


Packers: Map: Setting-up the Packer

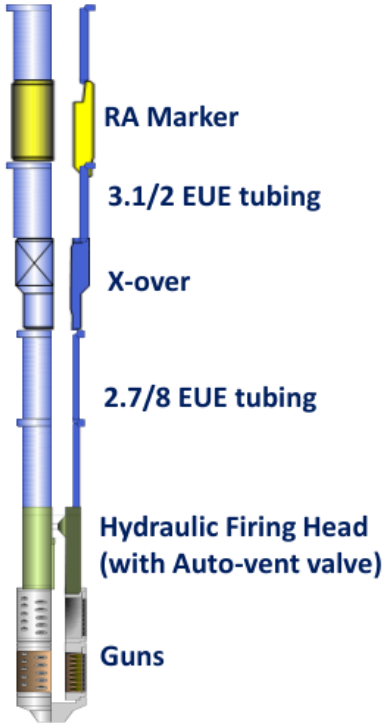
- Mark string at Gun on Depth (GOD) position. Measures 0.35m from GOD to below of the string and put 2nd mark.
- RIH string to maximum distance at rig floor and pick up string back to the 2nd mark.
- Rotate string to the RIGHT turn (clockwise) – approx. 1 turn per 1000m depth. Hold the torque and wait for 1 minute (to allow the torque to be transmitted to the bottom).
- Lower string until down weight starts to decrease. When packer starts to set, release the torque and continue to slack off required weight onto tool as per reference technical manual for each packer size **– approx. 2000 lbs per 1" packer sizes**.
- Close BOP and perform casing pressure test. Note: if any leak observed, increasing weight on packer **5 klbs** and repeat pressure test. If leak is still observed change the setting depth and repeat pressure test.

Techniques of perforation

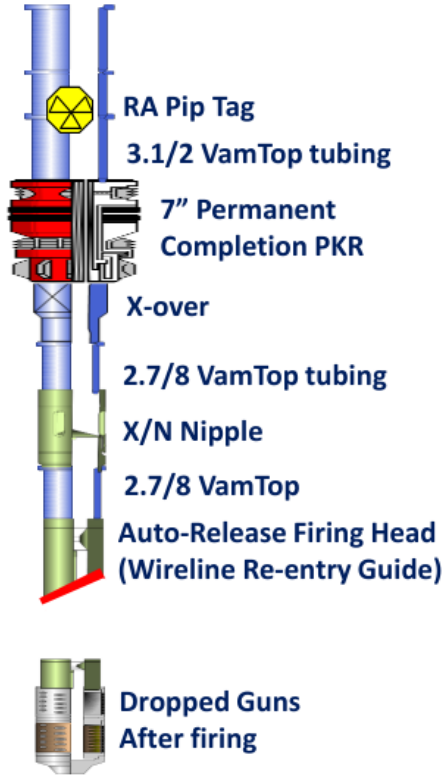
Underbalance TCP String using Drop Bar Firing Head:



Overbalance TCP String using Hydraulic Firing Head:



TCP Shoot and Drop String Auto-Release Firing Head:



42

Acid wash or Stimulation with TCP string

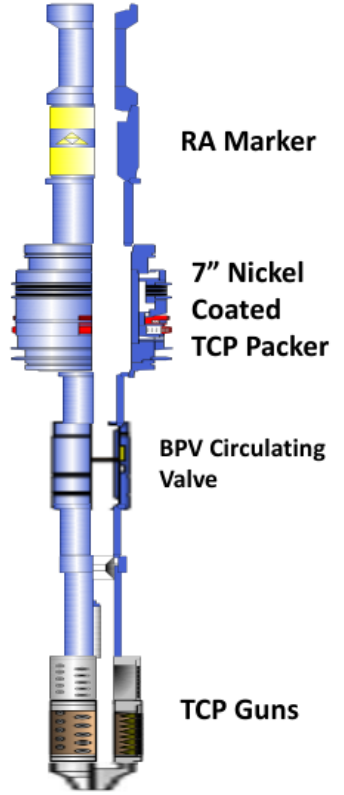
Acid wash or Stimulation with TCP string

- In a single run and after firing the guns, TCP string is moved down placing the circulating valve across the perforation zone. Tubing volume is displaced with Acid and packer is set then acid pumping activity into the perforated zone is obtained.

- The technique should consider HSE mitigation of acid handling and suitable packers and/or other tools for acid handling is required (Nickel Coated).

Benefits:

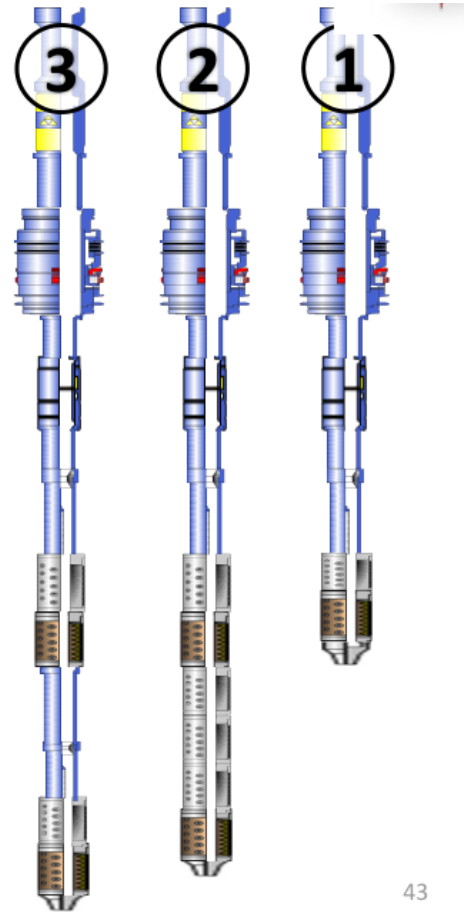
- Save rig time/cost
- Enhance production as result of acid cleanout



Multi-zone Perforation

Multi-zone Perforation

1. Several TCP runs to achieve desired SUB pressures utilizing one mechanical firing head on each run.
2. One TCP run utilizing long gun spacers in between the zones; SUB is also achieved.
3. One TCP run utilizing one mechanical and one/two absolute pressure firing head; SUB is achieved for only the top zone.

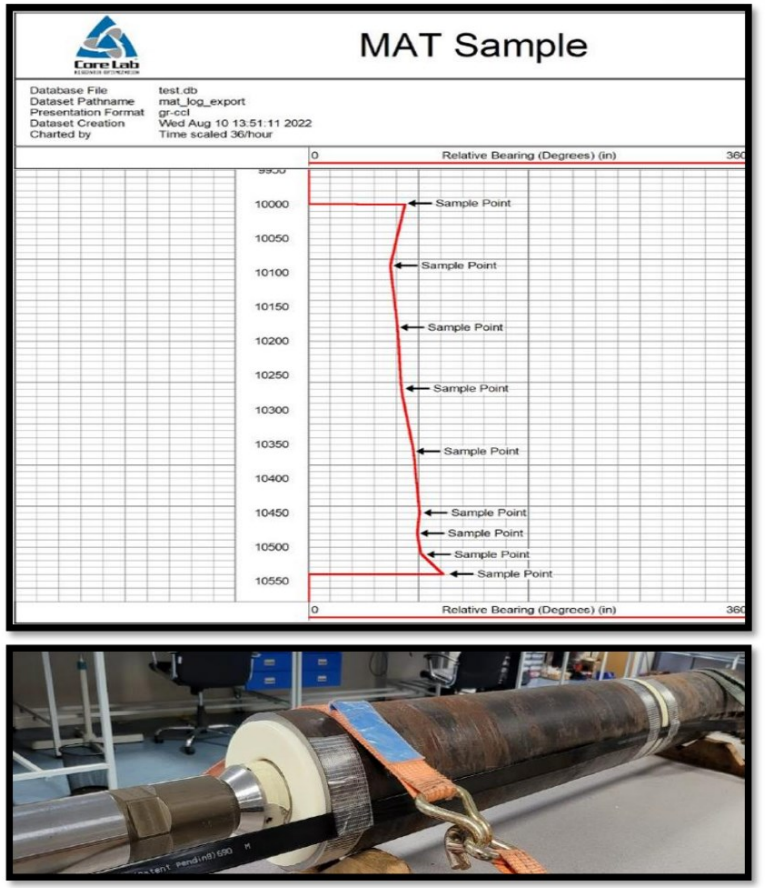


43

ROPS-Gyro

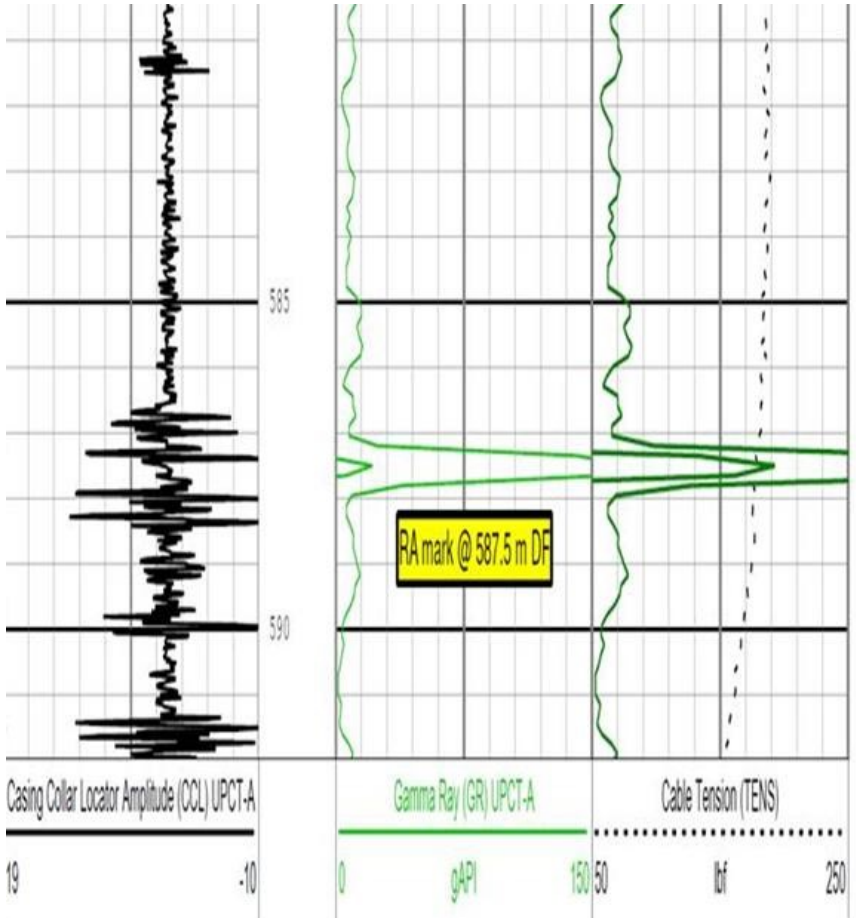
Ray Oriented Perforation System (ROPS):

- Eliminating extra runs with ability to increase shot density with improved detection accuracy of +/- 7.5 degrees. (36 samples per revolution.)
- Ability to detected FOC with well deviations < 5 degrees by implementing Gyro in the string while perforation.
- Process verifies the actual relative bearing or magnetic north offset corresponds to exact value required.
- Ability to provide FOC position while RIH at given depths (36 samples per revolution in about one minute).



UBHO Sub

CCL Correlation Log



Ready Box

Casing Sizes

Casing Size (OD in)	Coupling Size (OD in)	Common Bit Sizes (in)
4 1/2	5.0	6, 6 1/8, 6 1/4
5	5.563	6 1/2, 6 3/4
5 1/2	6.05	7 7/8, 8 3/8
6 5/8	7.39	7 7/8, 8 3/8, 8 1/2
7	7.656	8 5/8, 8 3/4, 9 1/2
8 5/8	9.625	11, 12 1/4
9 5/8	11.75	12 1/4
10 3/4	11.75	15
13 3/8	14.375	17 1/2, 17
18 5/8	19.625	22
20	21.0	24,26
24	25.25 &, 25.5	28