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Benefits of Downhole Real-time Flow-off Annular Pressure Data

Case Study of an HP Well with MPD in the Niger Delta

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Agenda - Downhole Flow-off Annular Pressure Data

Technology Introduction

- Proven Applications
- PWD Hardware
- Data Compression

Case Study Application

- Connection Monitoring during Managed Pressure Drilling for Shell in the Niger Delta



Downhole Flow-off Annular Pressure Measurements

The downhole “flow-off” environment typically occurs during:

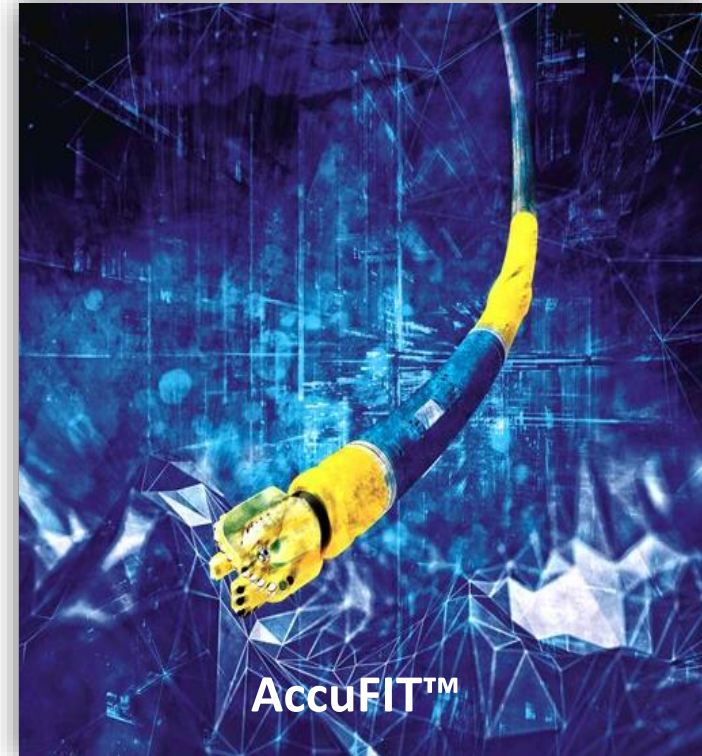
- Connections
- Leak-off Tests (LOT) and Formation Integrity Tests (FIT)

The Annular Pressure-While-Drilling (PWD) instrumentation records downhole pressure data during these flow-off events:

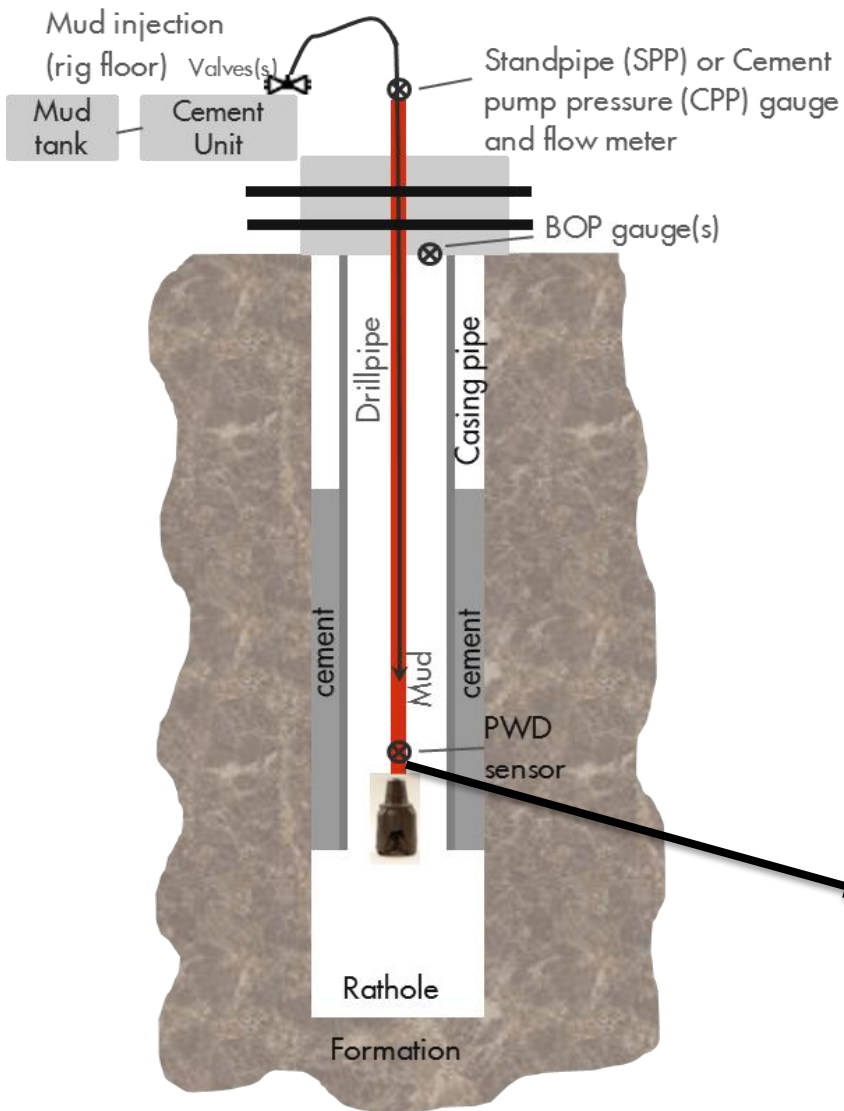
- Historically, **only** the “**Min**” and “**Max**” pressure value was transmitted to surface when normal circulation resumed
- Updated technology now supports time-efficient transmission of the entire pressure vs. time profile for enhanced interpretation of downhole conditions immediately after the “flow-off” condition

Proven Applications for Flow-Off Annular Pressure Profiles

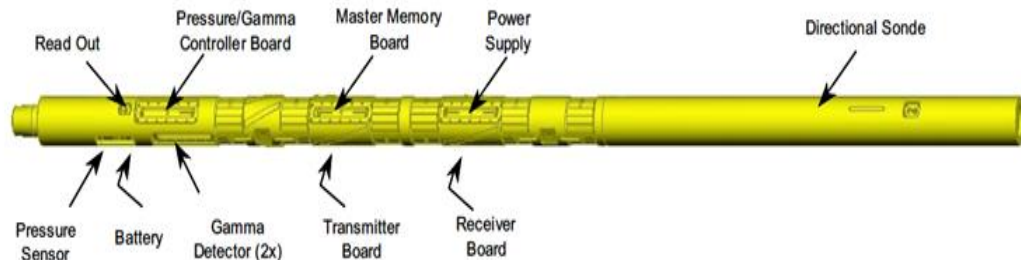
- Leak-off Tests/Formation Integrity Tests
- Connection Monitoring/Fingerprinting
 - Flow Check (Wellbore Breathing)
- Trip Speed Optimization
- Managed Pressure Drilling (calibrate/verify)
- Any flow-off event (casing test, short trip)



Downhole Annular PWD Sensor Technology – LOT Example

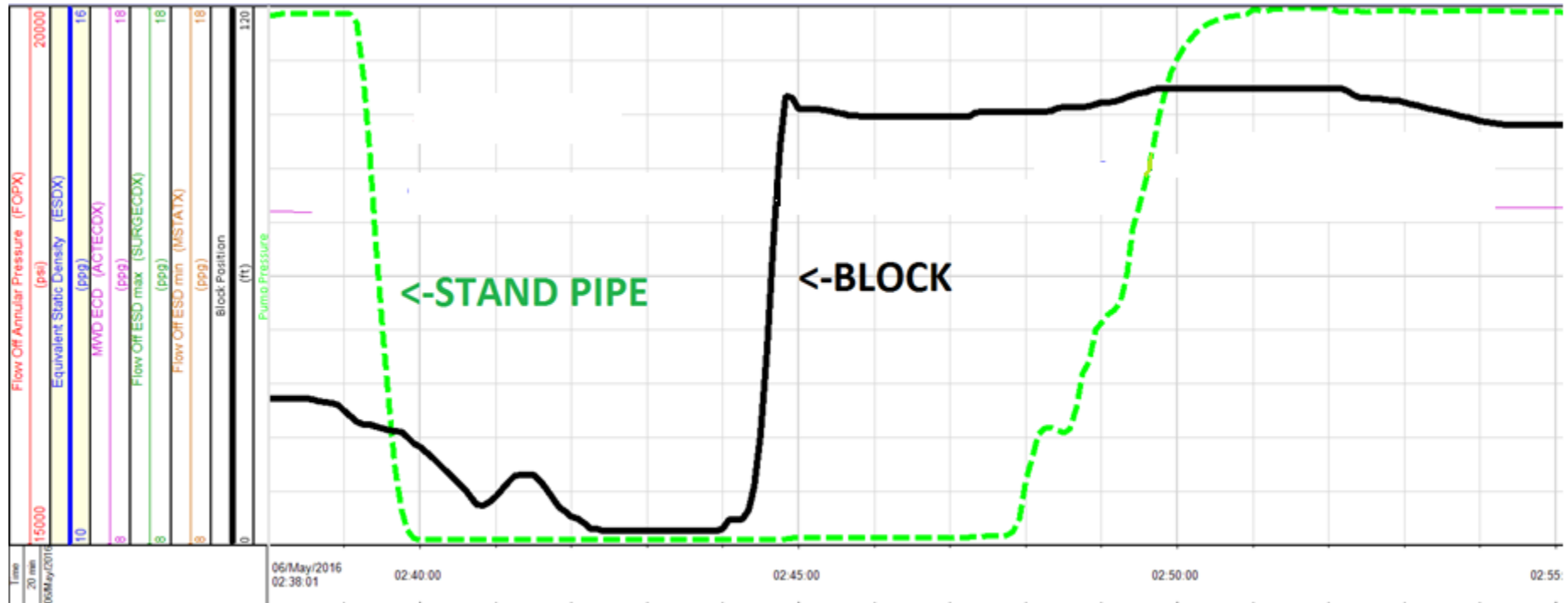


Pressure Gamma board:



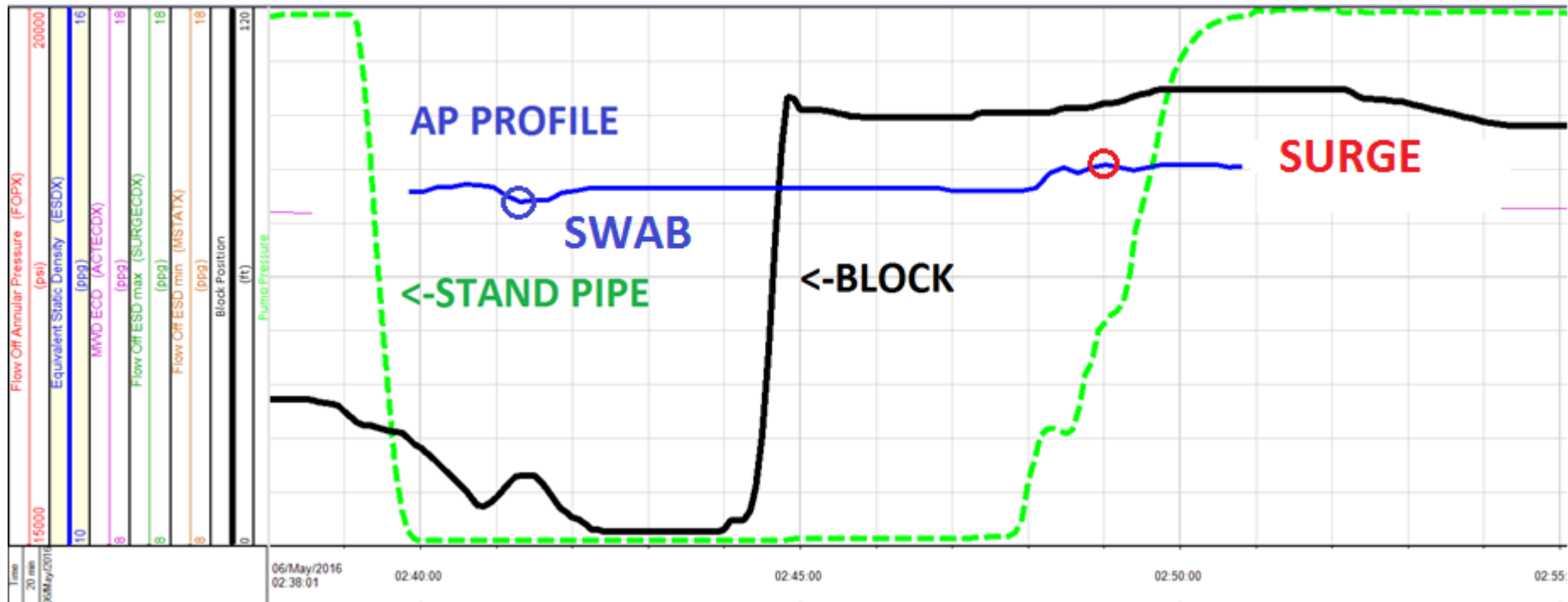
Downhole annular pressure + (bore or temperature) is recorded to memory every 2 seconds using battery power

Flow-off Event – During a Connection (10 minute interval)



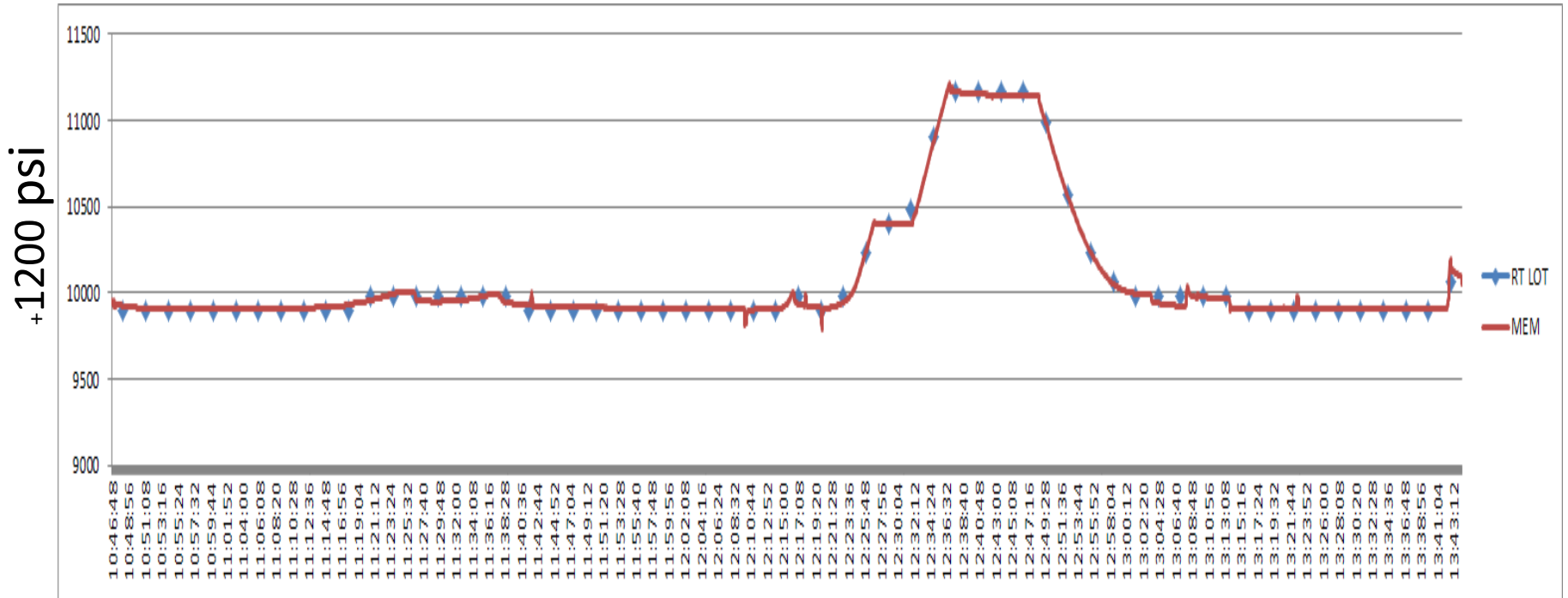
Annular Pressure is being recorded to PWD memory during this event. Without a PWD measurement, ESD is unknown during this event.

Flow-off Event – Connection Swab/Surge ESD vs. AP Profile



- Within 1-2 minutes after normal flow resumes, 60 data points have been transmitted to provide the full **Annular Pressure (AP) Profile**.
- Note that historically, **ONLY** the Min (Swab) and Max (Surge) value would be transmitted to surface, not the full time-based AP profile

Advanced Downhole Data Compression Algorithms



Advanced data compression algorithms are used downhole due to limited mud-pulse bandwidth

- Above example illustrates 3 hours of recorded **real-time** and **memory** data from a LOT
- Once flow resumes, the overall **60 data point pressure-time profile** is transmitted within 1-2 minutes
- Auto-Zoom is available via downlink(s) for **higher resolution data** over intervals of interest
- 2 second flow-off annular pressure + (bore pressure or temperature) data is available

Shell Niger Delta - Case Study Overview

- Drill a deep, **deviated HP** well in a challenging environment - 6" hole in TD section.
- 1 ppg separation between fracture (18.7 ppg) and pore pressure (17.7 ppg) gradients.
- Drill the well with a **Managed Pressure Drilling (MPD) system** in a predefined number of runs and obtain all LWD data in real-time.
- Acquire the actual bottom-hole static pressure profile during connections with **MPD system** and evaluate the **flow-off pressure profile** in real-time.
- Determine necessary mud weight for well control purposes during **MPD operation** (*using LWD formation pressure tests*).



Shell Niger Delta - MPD Connection #11 Statistics

1.11 CONNECTION # 11

Connection 11					
DEPTH - 15,393 FT MD		TVD - 15,050ft		CSG DEPTH - 14,518 ft	
DATE		DECEMBER 16th		CSG TVD - 14,192 ft	
START TIME	13:20	END TIME	14:00	TOTAL TIME	40 mins
ECD BF. CONN.		18.16 ppg		ECD After Conn.	
				18.16 ppg	
SET POINT	18.0 ppg / 0.94 psi/ft @ bit depth		ESD MIN	17.79 ppg / 0.93 psi/ft	
SBP	820 psi		ESD MAX	18.33 ppg / 0.95 psi/ft	
FLOW IN	438 gpm (TOTAL)		FLOW OUT	438 gpm (TOTAL)	

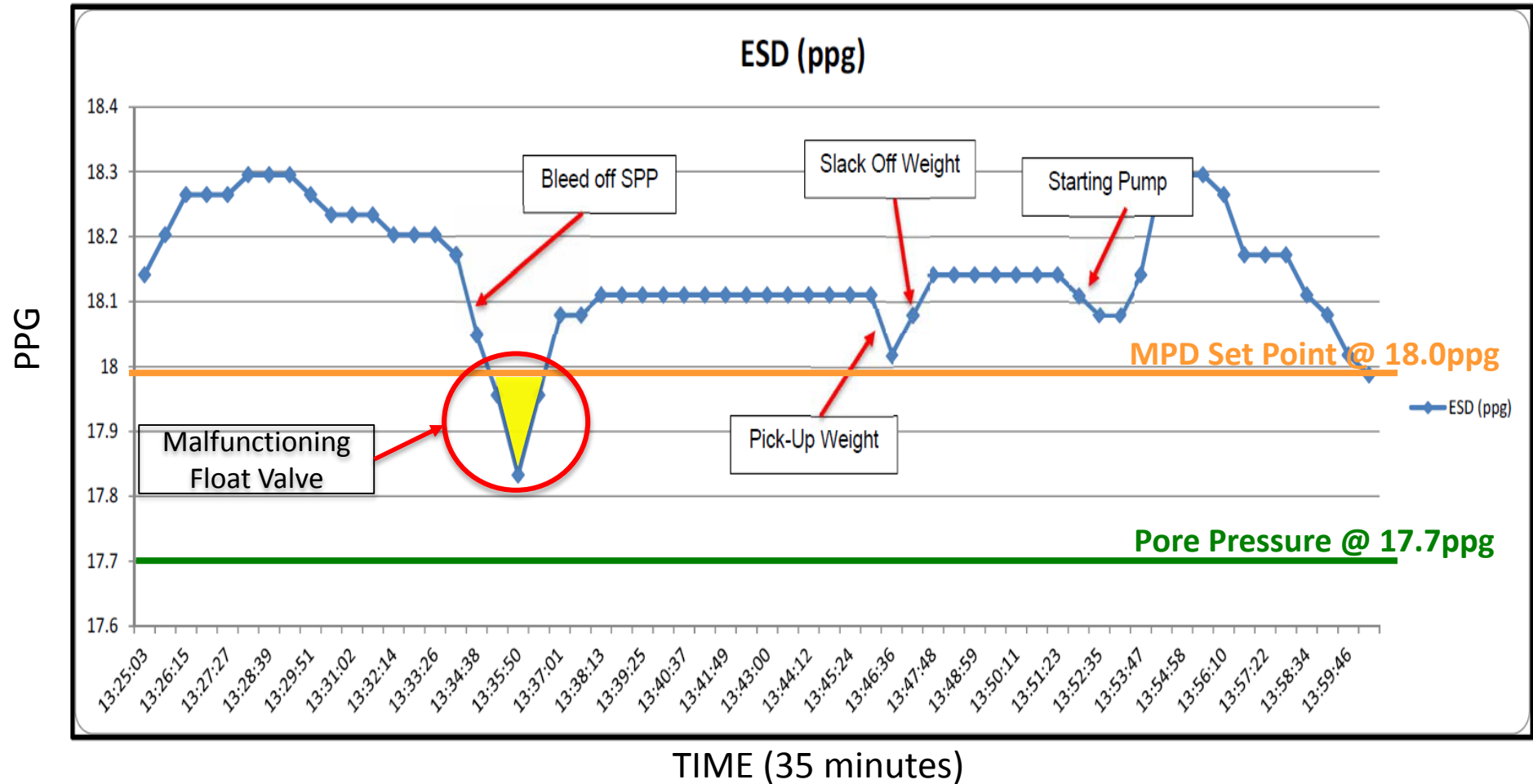
Fracture Pressure: 18.7ppg

MPD Set Point : 18.0ppg

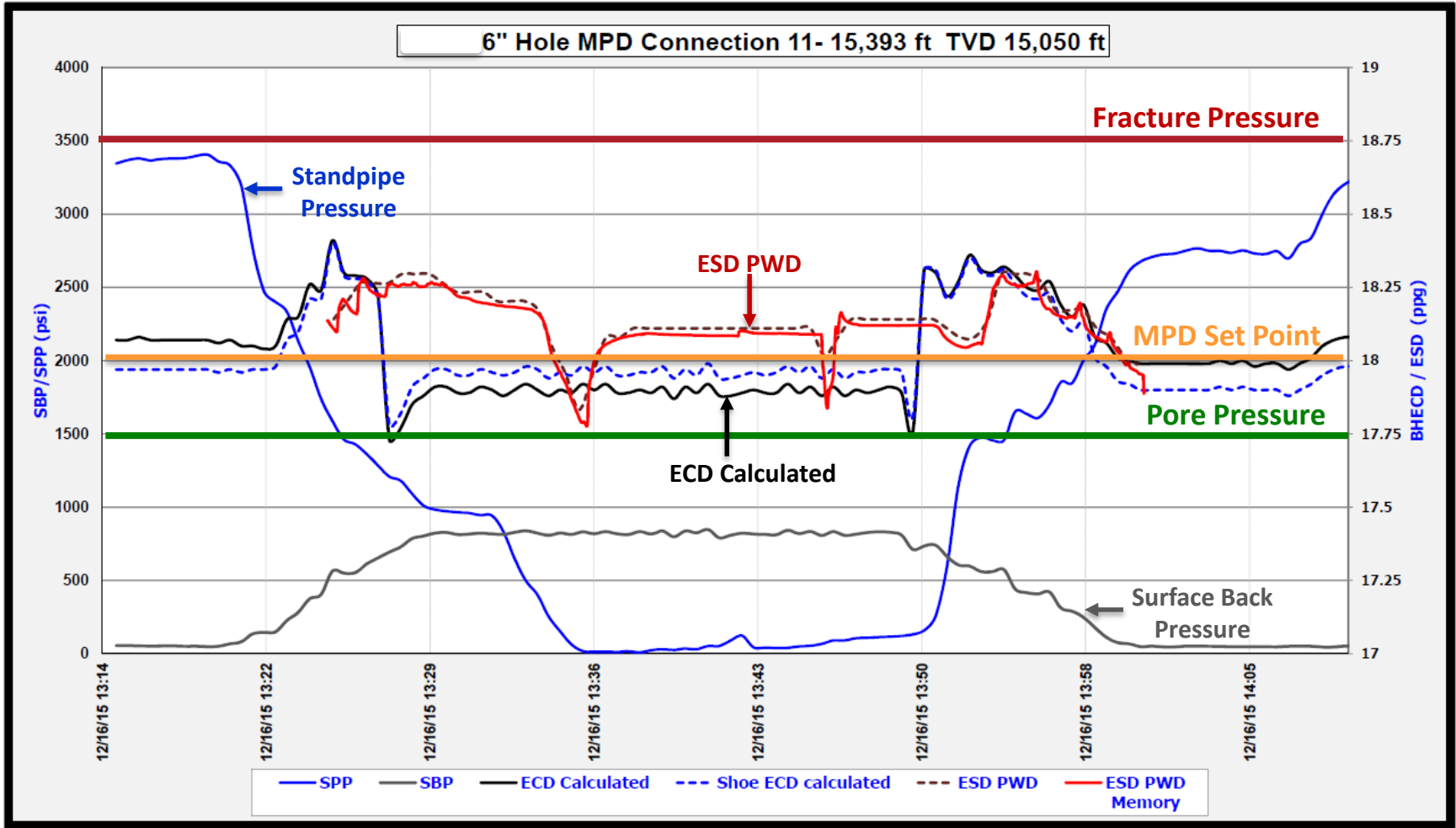
Pore Pressure: 17.7ppg

Critical data points from PWD
Annular Flow-off Measurement

Flow-off Annular Pressure during MPD Connection #11



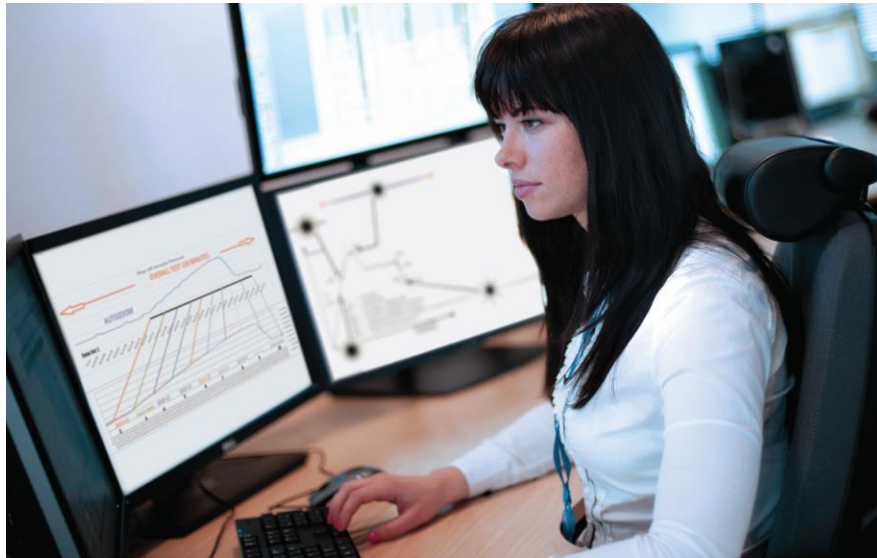
Flow-off Annular Pressure during MPD Connection #11



Shell Niger Delta - Case Study

Results

- Delivered accurate annular flow-off pressure profiles in real-time
- Monitored downhole annular pressure during connections to understand downhole flow-off pressure and adjust MPD back-pressure as required
- Reduced risk of incorrect downhole pressure interpretation based on inferences from surface measurements
- Downhole PWD flow-off measurements identified the third party float valve above the BHA had failed and was not holding back-pressure through the bore of the tools.



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