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SPE 2006 -2007 Distinguished Lecturer Series

Managed Pressure Drilling

A "new" way of looking at drilling hydraulics…
…Overcoming conventional drilling challenges

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Generic definition

Managed Pressure Drilling

MPD is an advanced form of primary well control typically employing a closed, pressurizable fluid system that allows greater and more precise control of the wellbore pressure profile than mud weight and mud pump rate adjustments alone.

As opposed to a conventional open -to-atmosphere returns system, MPD enables the circulating fluids system to be *viewed as a pressure vessel.*

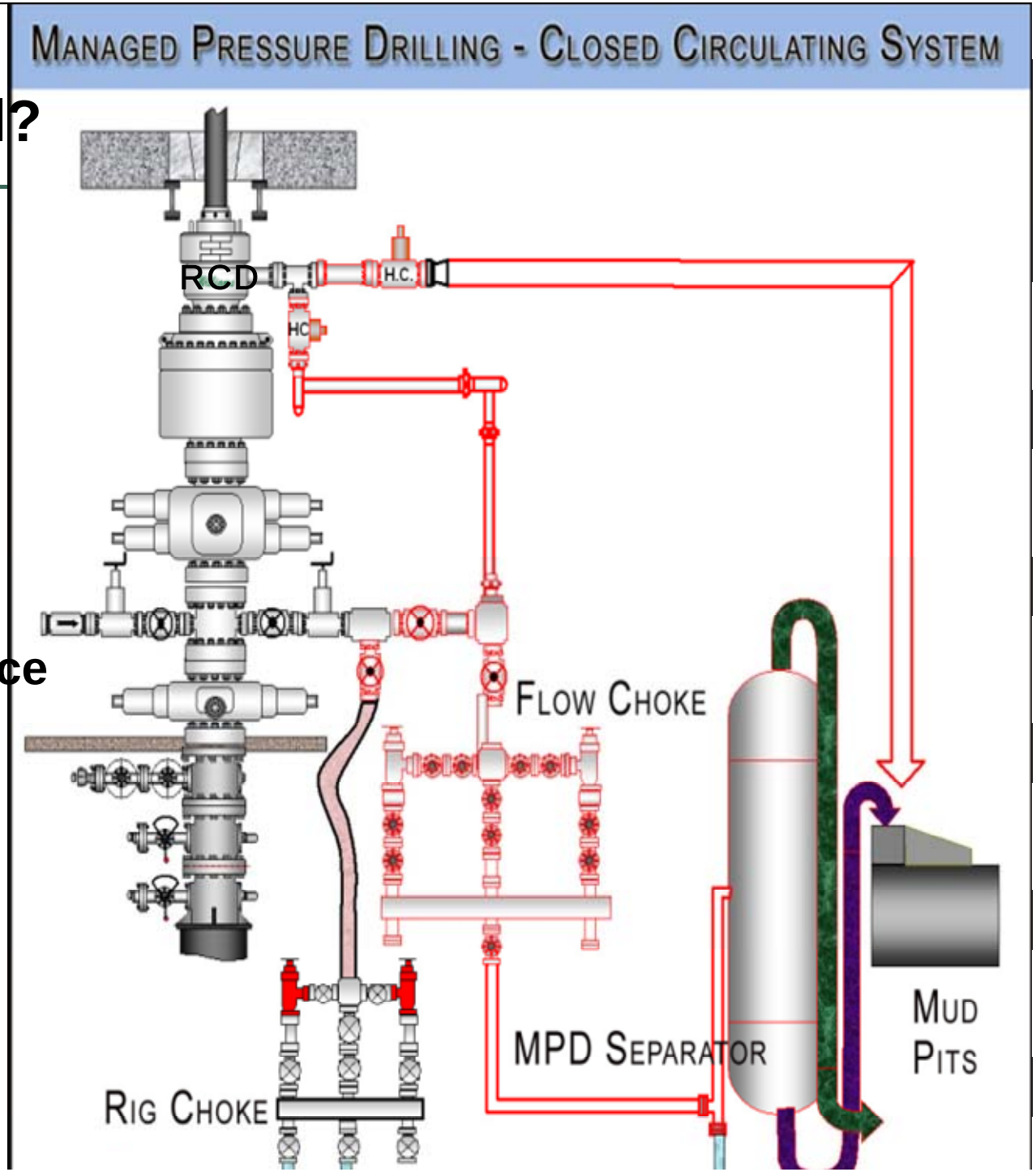
Influx not invited - Conventional Well Control

Pressure Vessel?

Enabling Tools

- Rotating Control Device
- Drill String Floats
- Dedicated Choke

Automatic Choke Preferred for Several Variations of Managed Pressure Drilling



New way of looking at the hydraulics of drilling?

- **Well, maybe to the rest of the world, but not so new in the Arkoma Basin**
  - MPD was being practiced decades ago
- **A rotating control device is required to practice MPD**
- **Manufactured in Fort Smith since 1968, availability of the tool facilitated:**
  - Drilling with compressible fluids (gas, air, mist, foam)
  - Underbalanced Drilling
  - *And over time, "necessity being the mother of invention",* spawned other uses
  - I.e., "I'm drilling conventionally but can't get through this zone with the mud I've got in the hole unless I make jointed pipe connections with casing backpressure."
- **Those "other uses" identified as a technology within themselves in 2003 and labeled Managed Pressure Drilling**
  - Introduced to offshore drilling decision-makers
  - And to land programs globally…
- **Where MPD is being seen and accepted as "new and innovative"**

Connecting the dots – An extension of logical reasoning

1. U.S. Rig Count 1750, 600 RCD's on locations – majority of land programs drilling at least one section with a closed mud return system on rig floor
2. Of those with closed systems, more than half are MPD
   - Dealing with "drilling trouble zones"
   - Shorten the number of days from spud to TD
   - Drill otherwise un-drillable prospects
3. Because MPD addresses NPT - Value to offshore operations much greater
4. Does not invite influx of hydrocarbons but one is tooled up to better deal with any incidental to the operation with less interruption to the drilling program
5. Equipment "kit" for all Variations of MPD fits aboard most offshore rigs
6. Drilling offshore with a closed mud returns system vs. open-to-atmosphere drilling or bell nipples is making uniquely good sense on many fronts
7. Conventional Well Control principals apply
8. UBD-type preplanning, training, discipline applicable to several Variations
9. "Real time Well Control" mentality also important to several Variations
10. Onshore applications not capturing the full potential of the technology

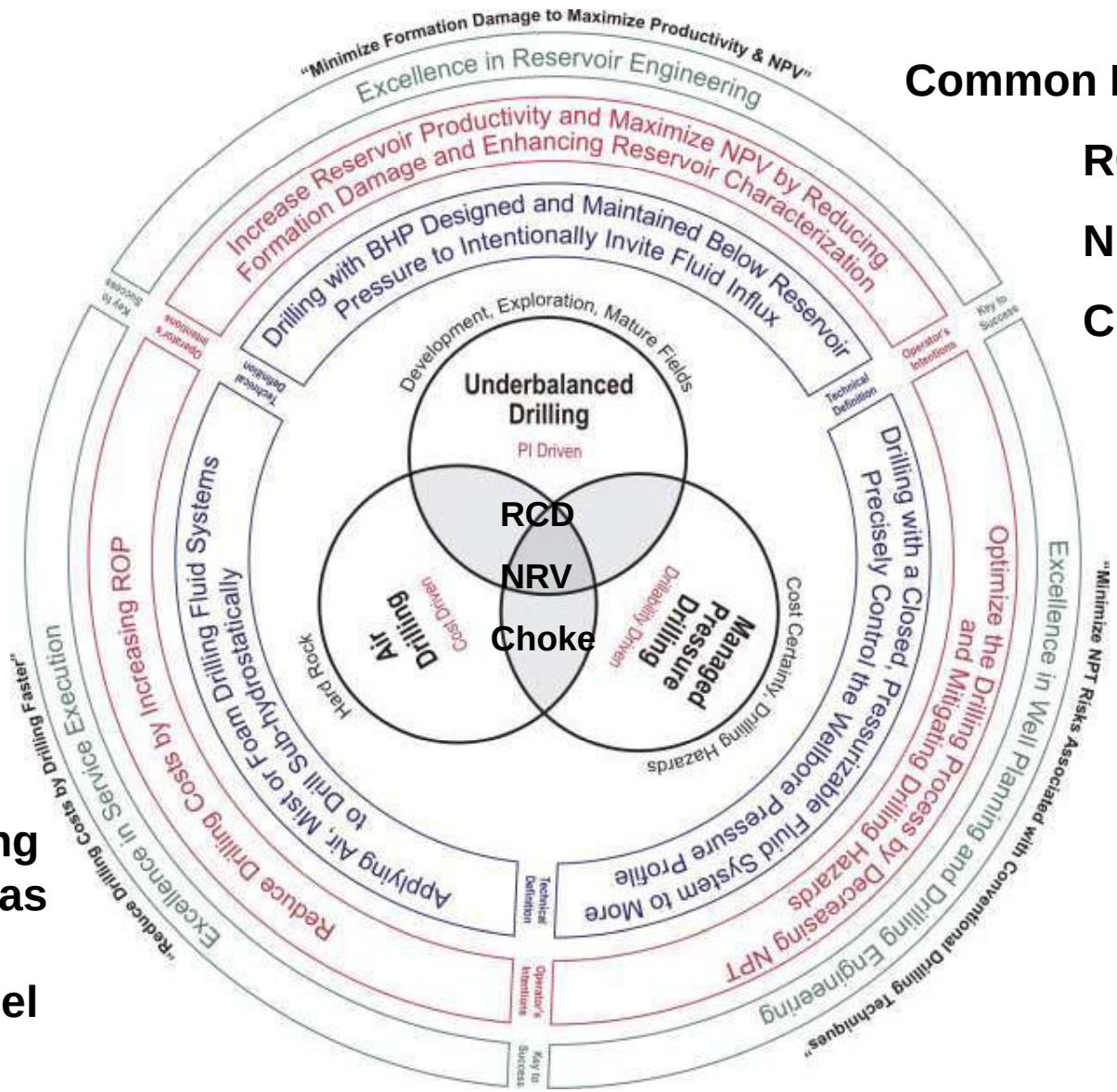
Formal Definition (IADC developed – SPE adopted)

"MPD is an adaptive drilling process used to more precisely control the annular pressure profile throughout the wellbore. The objectives are to ascertain the downhole pressure environment limits and to manage the annular hydraulic pressure profile accordingly.

Technical Notes

1. ***MPD processes employ a collection of tools and techniques which may mitigate the risks and costs associated with drilling wells that have narrow downhole environment limits, by proactively managing the annular hydraulic pressure profile.***
2. ***MPD may include control of backpressure, fluid density, fluid rheology, annular fluid level, circulating friction, and hole geometry, or combinations thereof.***
3. ***MPD may allow faster corrective action to deal with observed pressure variations. The ability to dynamically control annular pressures facilitates drilling of what might otherwise be economically unattainable prospects.***
4. ***MPD techniques may be used to avoid formation influx. Any flow incidental to the operation will be safely contained using an appropriate process."***

“Controlled Pressure Drilling” Family of Technologies



Common Equipment

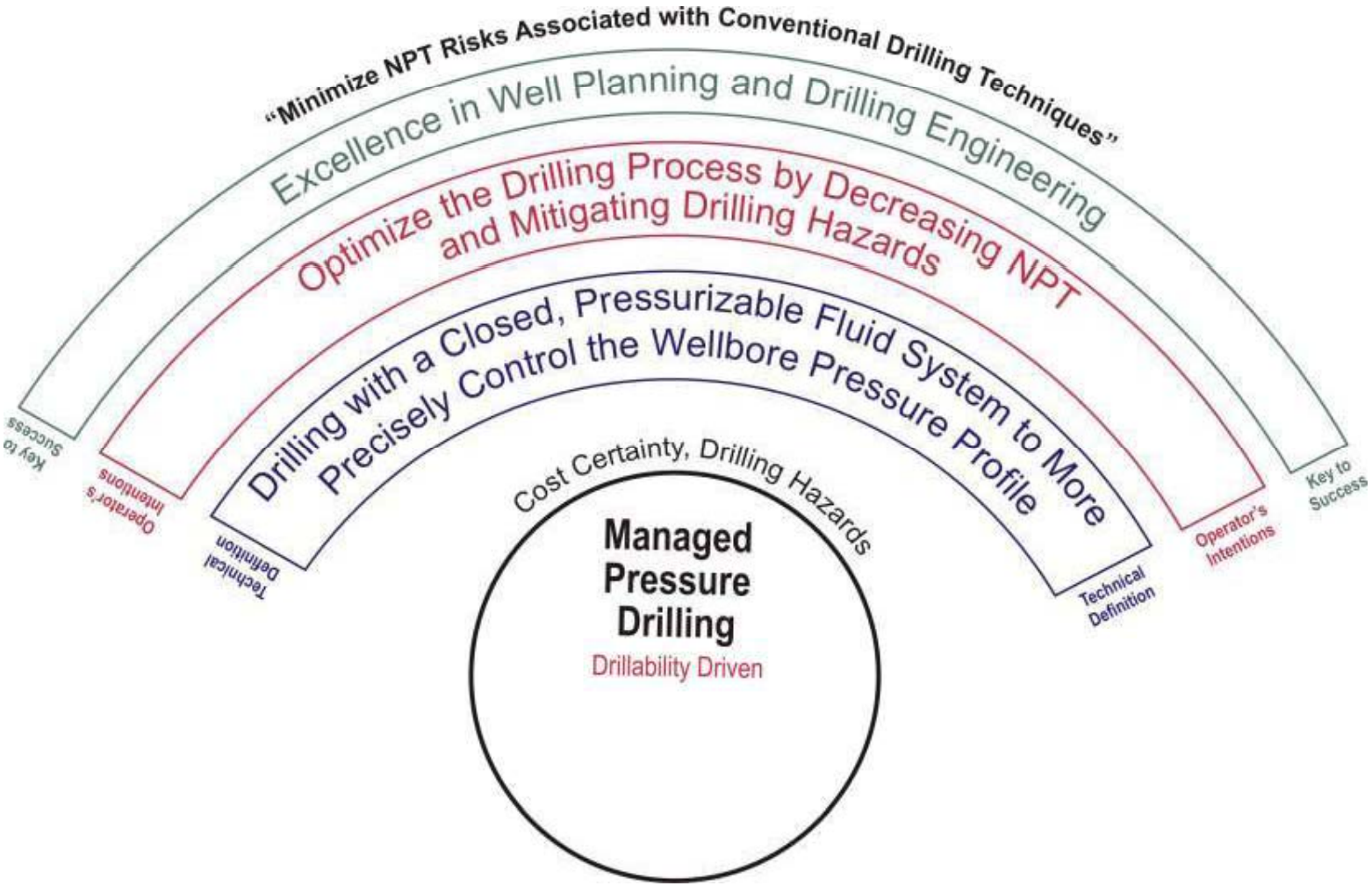
RCD

NRV’s

Choke

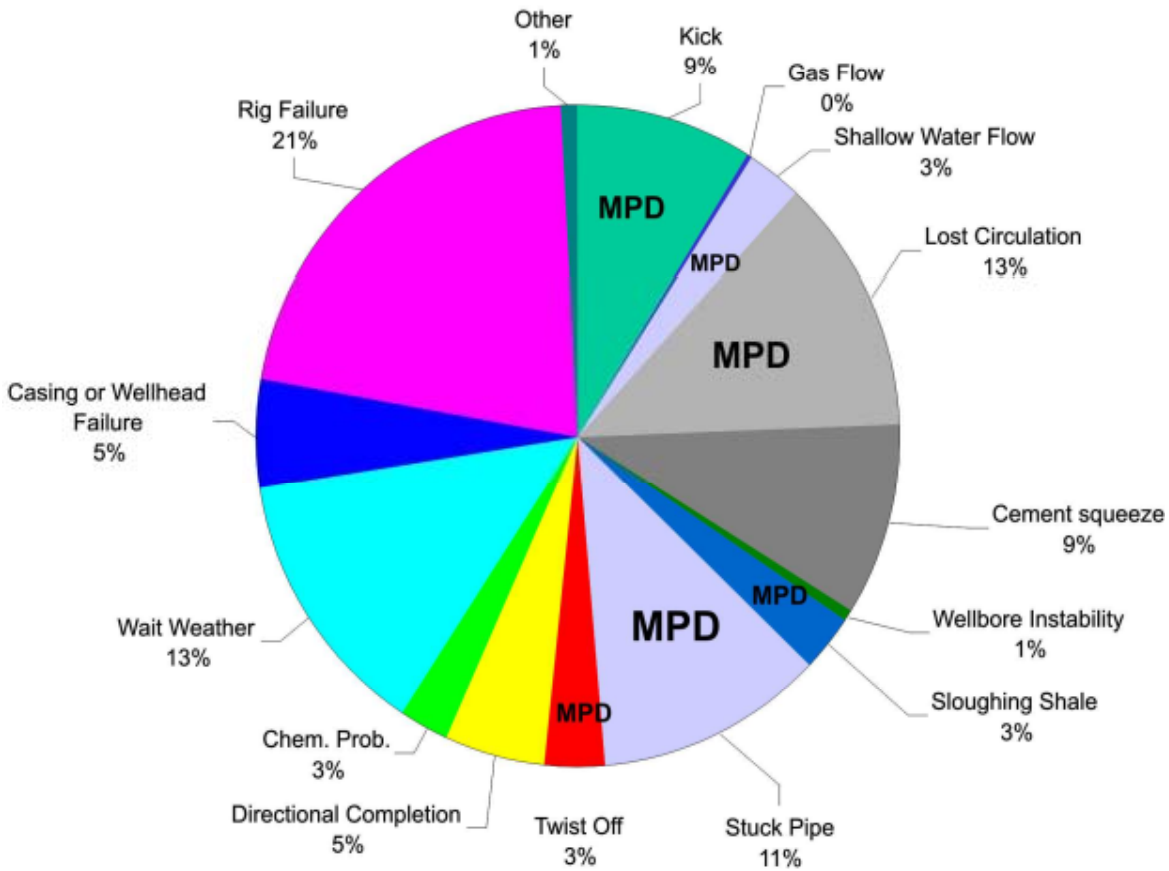
View circulating fluids system as one would a pressure vessel

MPD "More Productive Drilling" - "Make Problems Disappear"



Problem Incidents -- GOM Shelf Gas Wells

Wellbores Drilled 1993 -- 2002; Water Depth = <600 feet



Impact of Trouble Time

Drill Days Lost to Trouble Time

- 22% of 7,680 total drill days from spud date to date TD was reached

Trouble Time Cost Impact – GoM Shelf Gas Wellbores

- Deep wells average dry-hole cost per foot = $444. Average impact = $98
- 'Shallow well average dry-hole cost per foot = $291. Average Impact = $71

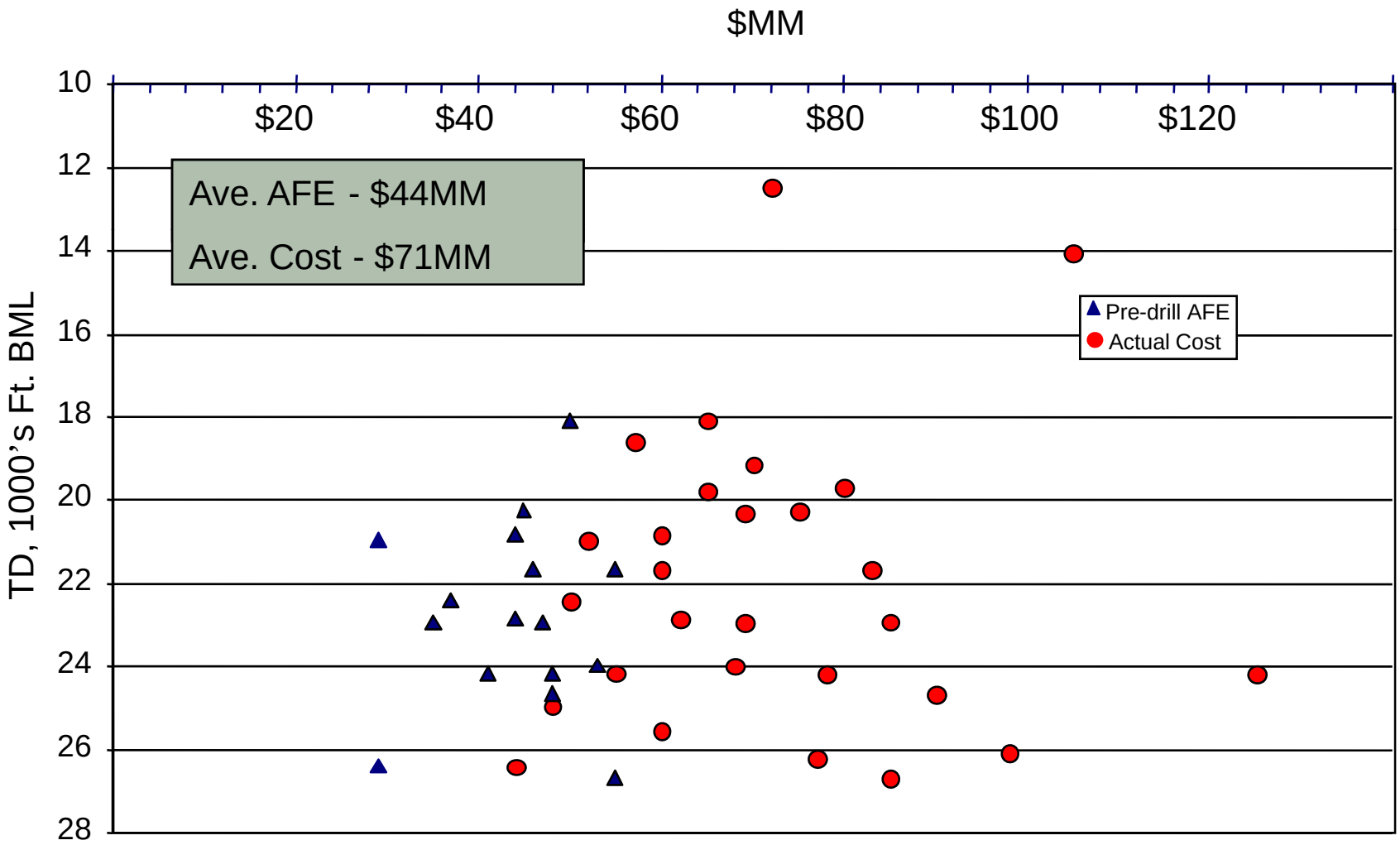
More precise wellbore pressure management can address a significant amount of the NPT

22% of total drill days lost to NPT

Source James K Dodson Company Study

Cost implications of NPT

Ultra-Deep GOM Well Cost ~60% More Than AFE



ConocoPhillips DEA Presentation, 1st Quarter 2004

Categories of MPD

- **Reactive** – Tooled up to more efficiently react to downhole surprises. (Common to U.S. land programs, using surface backpressure to adjust EMW, enhance well control, etc.)

- **Proactive** – Fluids and Casing programs designed, from the start, to drill with ability to:
  - Adjust EBHP/EMW with minimum interruptions to drilling ahead
  - Achieve a deeper open hole
  - Lowest hanging fruit when practiced onshore
  - Greatest savings when practiced offshore

Variations of MPD

- **PMCD (Pressurized Mud Cap Drilling)**
  - Offset wells have experienced total or near ***total losses***
- **CBHP (Constant Bottomhole Pressure)**
  - Offset wells have experienced ***narrow margins***, *kick loss scenarios, ballooning, "breathing", "high ECD"*, *wellbore instability*
- **HSE (Returns Flow Control)**
  - Closed vs. Open-to-atmosphere mud returns at rig floor
- **RC (Reverse Circulation)**
- **DG (Dual Gradient, several methods)**
  - Light fluids or solids injection into casing or marine riser
  - Riserless example – Demo 2000 Deepwater RMR Field Trials JIP

MPD – The Value Proposition

MPD as a Solution to Real Drilling Challenges	Value Proposition	MPD Method: CBHP (Constant Bottom Hole Pressure)	PMCD (Pressurized Mud Cap Drilling)	DG (Dual Gradient)	HSE (Health, Safety, Environment)
Drill "Undrillable" Ultra-tight Pore/Frac Pressure gradients Drill "Undrillable" Vuggy/Fractured carbonates where OB circulation is impossible Drill to target depth in wells with high insitu stresses. Extend the Reach of ERD Wells	**Drill to the target…**				
Increase ROP - drilling closer to balanced. Increase ROP - drill throuh HP LV nuisance gas zones. Reduce Number of Loss/Kick Occurances Reduce Time Spent Dealing with Well Control Events. Detect kicks earlier. Reduce pressure cycles that cause fatigue-related borehole instability. Reduce severe overbalanced pressure induced borehole instability. Reduce open hole exposure-time induced borehole instability. Reduce mud costs. Set casing deeper. Reduce number of casing strings. Reduce required rig size. Trip faster in HPHT environments.	**….while saving money**				
Remove H2S Hazard from Rig Floor Remove HPHT Hazard from Rig Floor Positive Fluid Containment at Surface in Marine or other Environmentally Sensitive Locations	**…and improving safety.**				

Key tools for most Variations of MPD

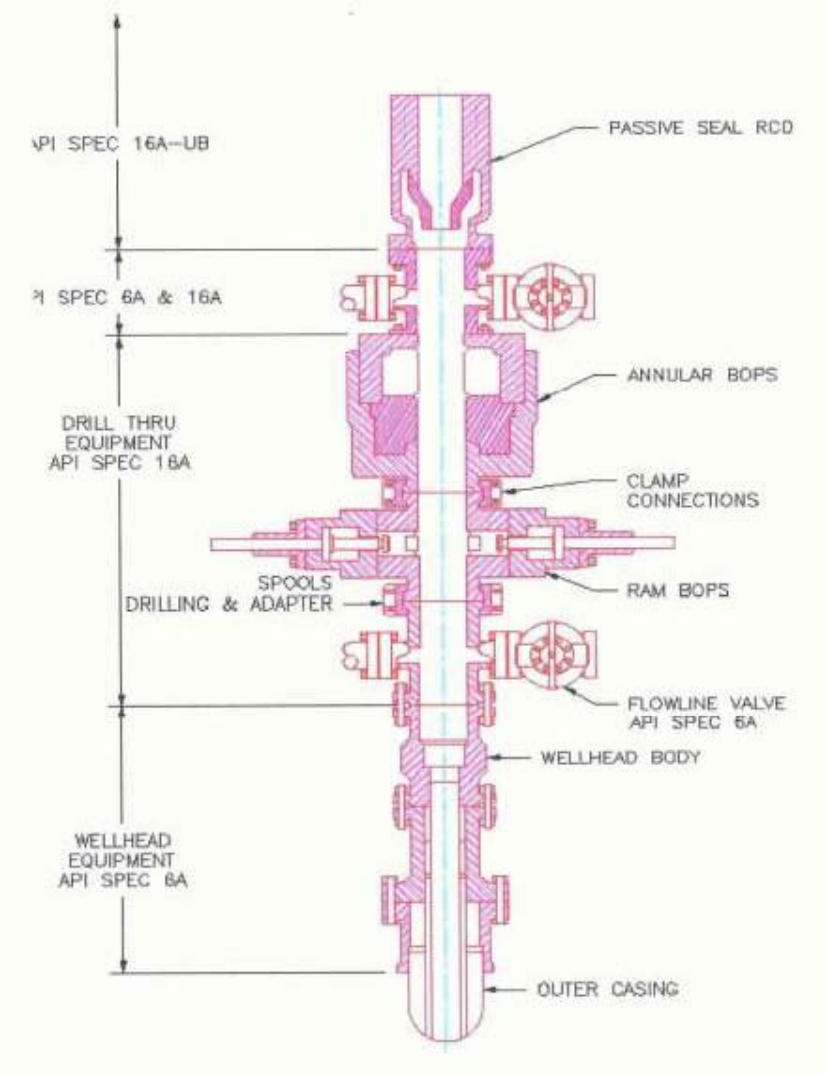
- **Rotating Control Device – Floating Rigs (wave heave)**
  - **External Riser RCD**
  - **Subsea RCD**
  - **Internal Riser RCD (IRRCH)**

    - Fixed Rigs (no wave heave)
  - **Passive & Active annular seal design "land" models**
  - **Marine Diverter Converter RCD**
  - **Bell Nipple Insert RCD**
  - **IRRCH (in marine diverter or surface annular)**
- **NRV's (Wireline Retrievable is an option worth considering)**
- **Choke Options (dedicated recommended, except perhaps for HSE Variation)**
  - **Manual**
  - **Semi-automatic**
  - **PC Controlled Automatic**

RCD's are Key MPD Enablers

- Passive annular seal design shown
- 7/8-in. interference when new
- High pressure capable models have redundant stripper rubbers on a common inner race of the bearing assembly
- Requires no external-to-tool source of energy to function
- Higher the differential pressure, tighter the annular seal
- Does not require a dedicated technician
- This design is most commonly used on MPD applications
- Best rubber performance
  - RCD friendly drill string
  - Good stack alignment

API 16 RCD



For Rigs with little or no wave heave

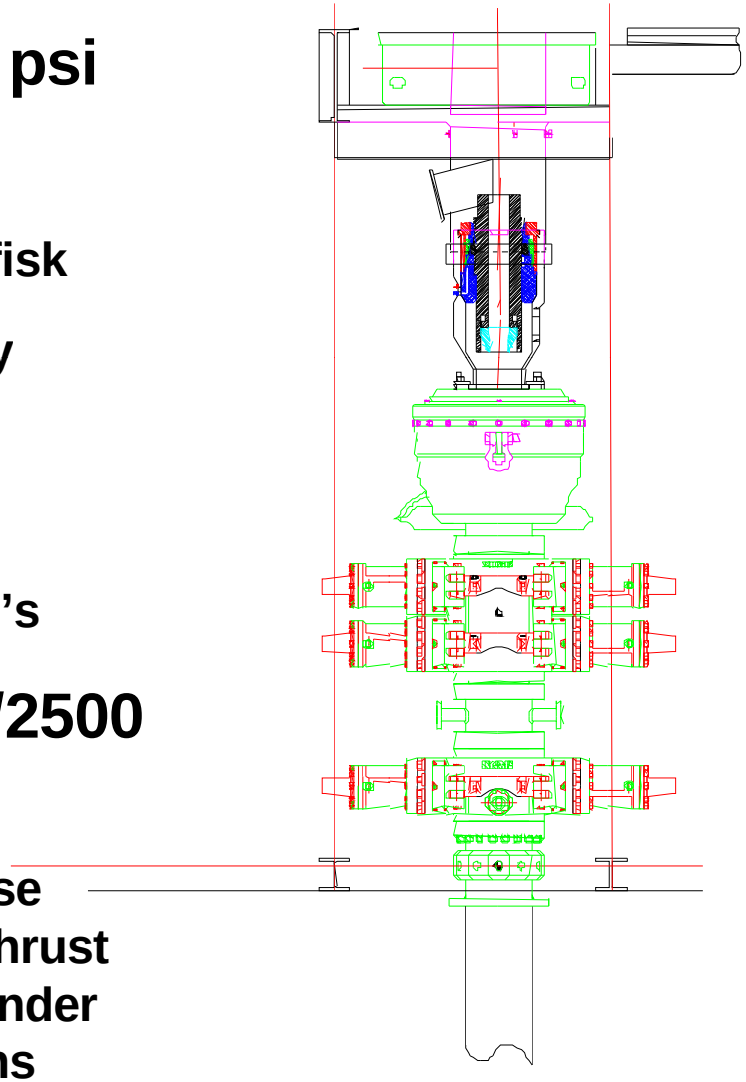
"Passive and active annulus seal designs, single or redundant barrier, low or high pressure Capable RCD's

Marine Diverter Converter RCD – converts typical marine diverter to rotating diverter, also 2nd annular BOP.

Bell Nipple Insert RCD

No Wave Heave

- **Single Stripper Rubber - 500 psi dynamic**
  - **DNV Certified, COP Norway, Ekofisk**
  - **Self Lubricated Bearing Assembly**
  - **No hose connections required**
  - **Remote latching, unlatching**
  - **8.75” I.D. for large Tool Joint O.D.’s**
- **Dual Stripper Rubber – 5000/2500 psi**
  - **Requires lubrication & coolant hose connections to remove heat from thrust and radial bearings when drilling under high differential pressure conditions**



B.O.P. IN DRILLING POSITION

5000 psi static/2500 psi dynamic Bell Nipple RCD

Bearing Assembly

Bottom Stripper Rubber

Remote Operated Hydraulic Latch

Upper Marine Riser Seal Area

Flowline Outlets

M7800 on

Field Trials,

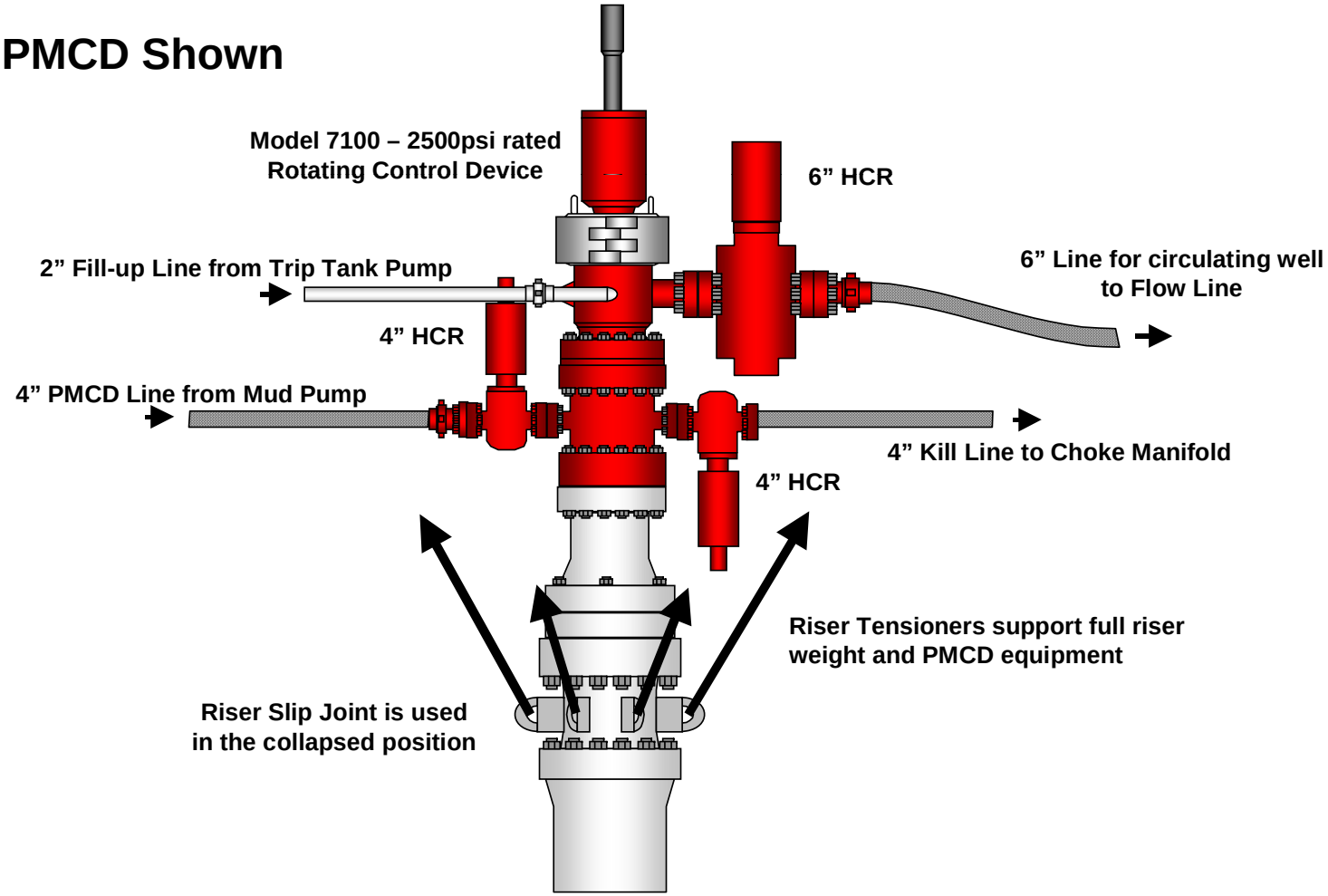
Pemex

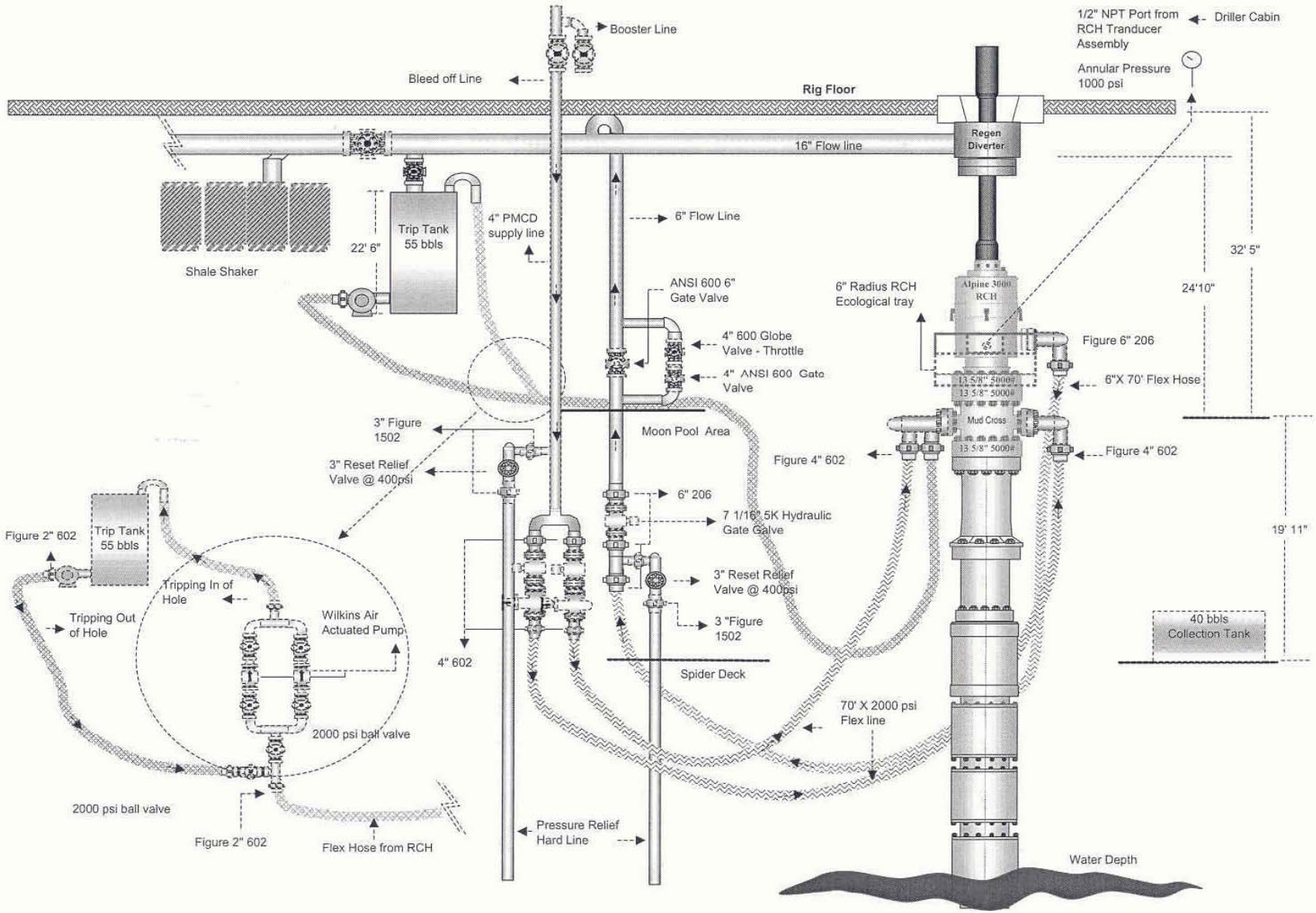
HT/HP well

External Riser RCD for Floating Rigs

All Variations of MPD - PMCD, CBHP, HSE, DG, RC

PMCD Shown

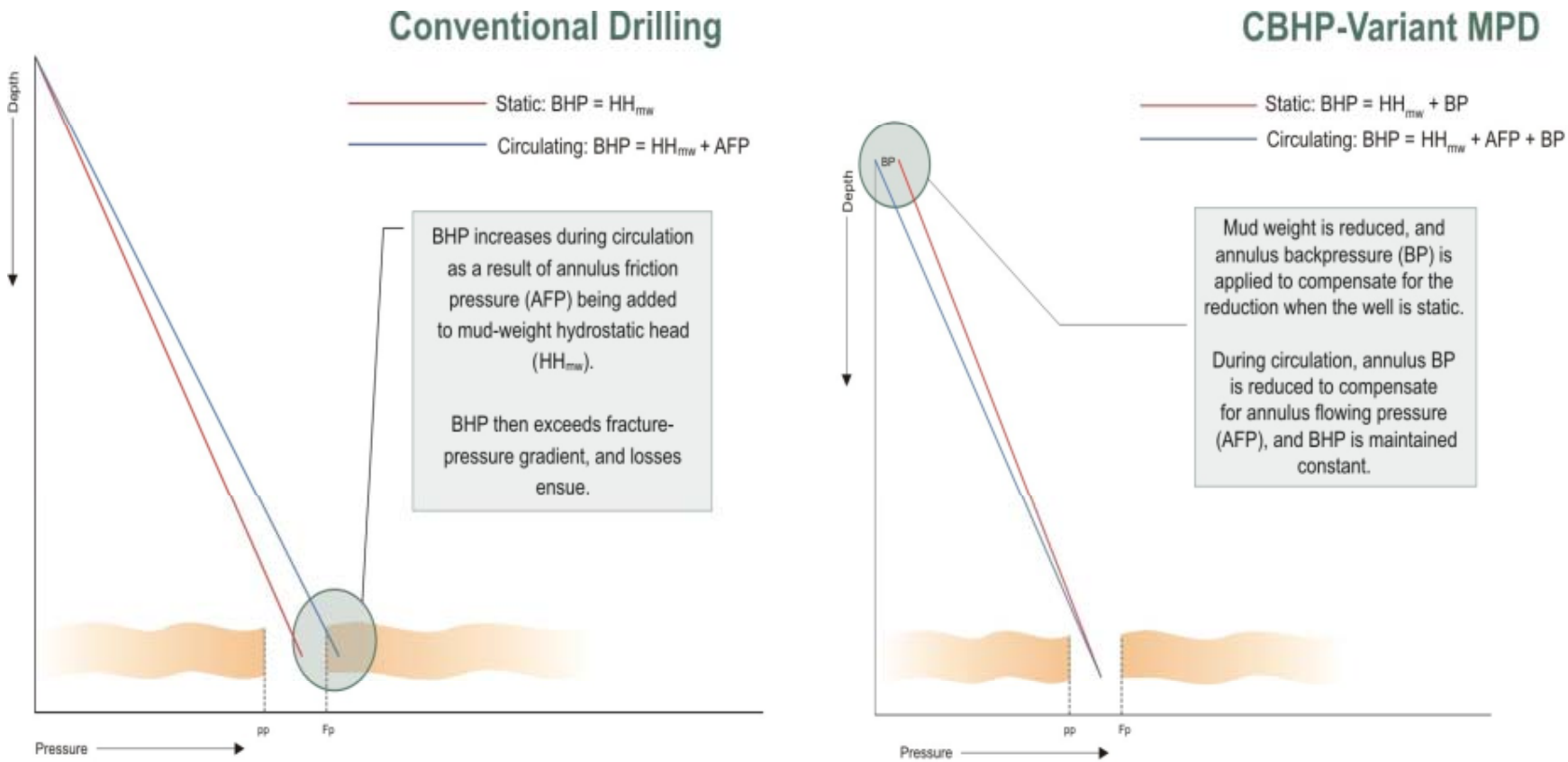



Booster Line
Bleed off Line
Rig Floor
1/2" NPT Port from RCH Tranducer Assembly
Driller Cabin
Annular Pressure 1000 psi
Regen Diverter
16" Flow line
Shale Shaker
Trip Tank 55 bbls
22' 6"
4" PMCD supply line
6" Flow Line
ANSI 600 6" Gate Valve
4" 600 Globe Valve - Throttle
4" ANSI 600 Gate Valve
6" Radius RCH Ecological tray
Alpine 3000 RCH
Figure 6" 206
6"X 70' Flex Hose
13 5/8" 5000#
Mud Cross
Figure 4" 602
32' 5"
24'10"
19' 11"
3" Figure 1502
3" Reset Relief Valve @ 400psi
Moon Pool Area
6" 206
7 1/16" 5K Hydraulic Gate Galve
3" Reset Relief Valve @ 400psi
3 "Figure 1502
Figure 2" 602
Trip Tank 55 bbls
Tripping In of Hole
Tripping Out of Hole
Wilkins Air Actuated Pump
4" 602
Spider Deck
40 bbls Collection Tank
70' X 2000 psi Flex line
2000 psi ball valve
2000 psi ball valve
Figure 2" 602
Flex Hose from RCH
Pressure Relief Hard Line
Water Depth

Other Tools

- Downhole Casing Isolation Valve (Downhole Deployment Valve)
- Nitrogen Production Unit
- ECD Reduction Tool
- Real time Pressure & Flow Rate Monitoring
- UBD technology & mentality (except for the HSE Variation)
  - Training
  - Planning, HazId/HazOp's
  - Project Management
  - Real time decision-making
- Continuous Circulating "Valve" or "System"
- ECD Reduction Tool

Conventional vs. Constant Bottomhole Pressure Variation

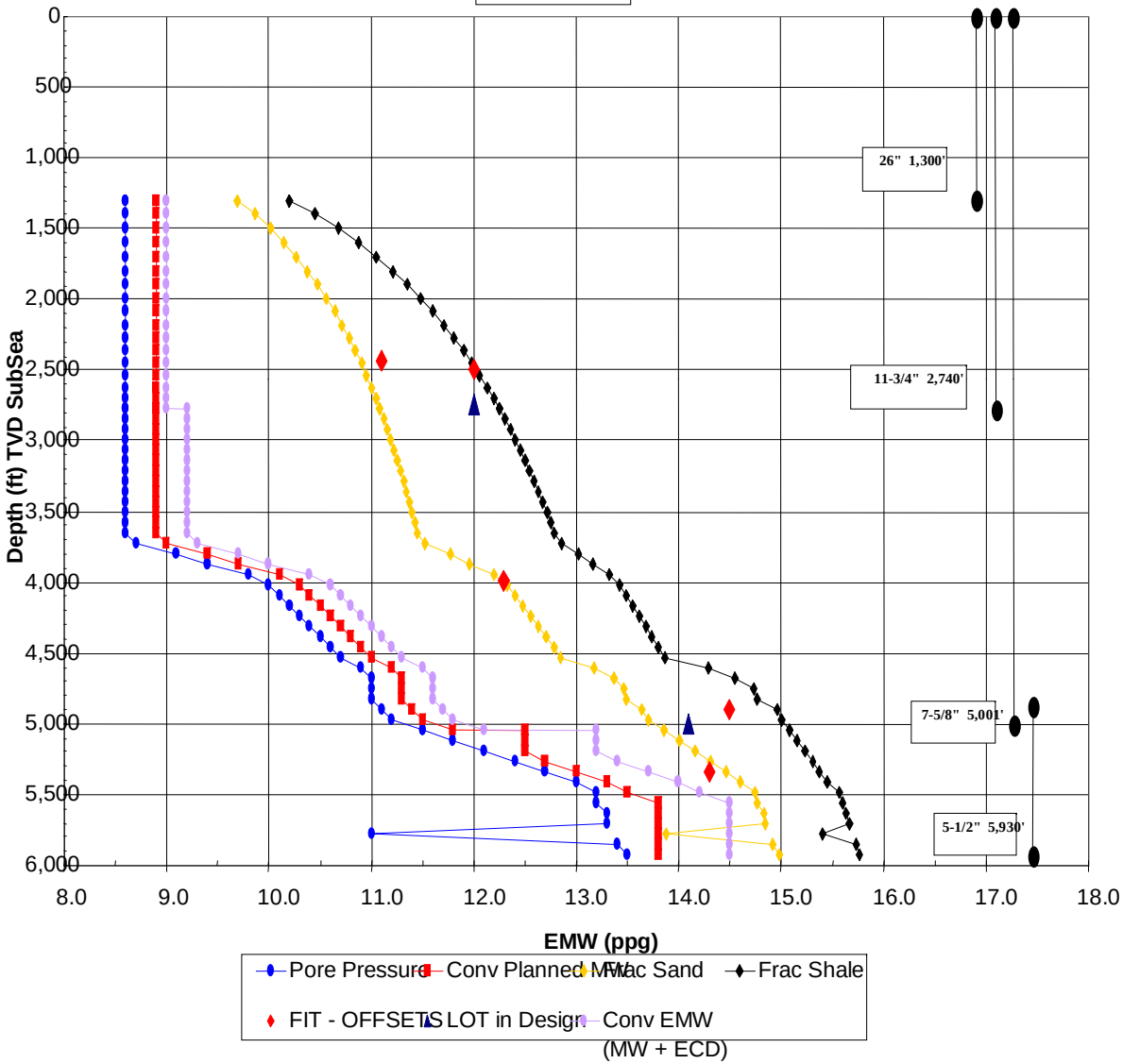


Pressure-versus-depth illustration of conventional drilling compared to CBHP MPD. Applied annulus backpressure is controlled by an RCD that allows maintaining BHP at a constant value that does not exceed formation fracture gradient, even when circulating.

Uniquely Applicable – Narrow, Inconsistent, or Unknown P/F Margins

Conventional Drilling - GoM

Open Mud Returns System



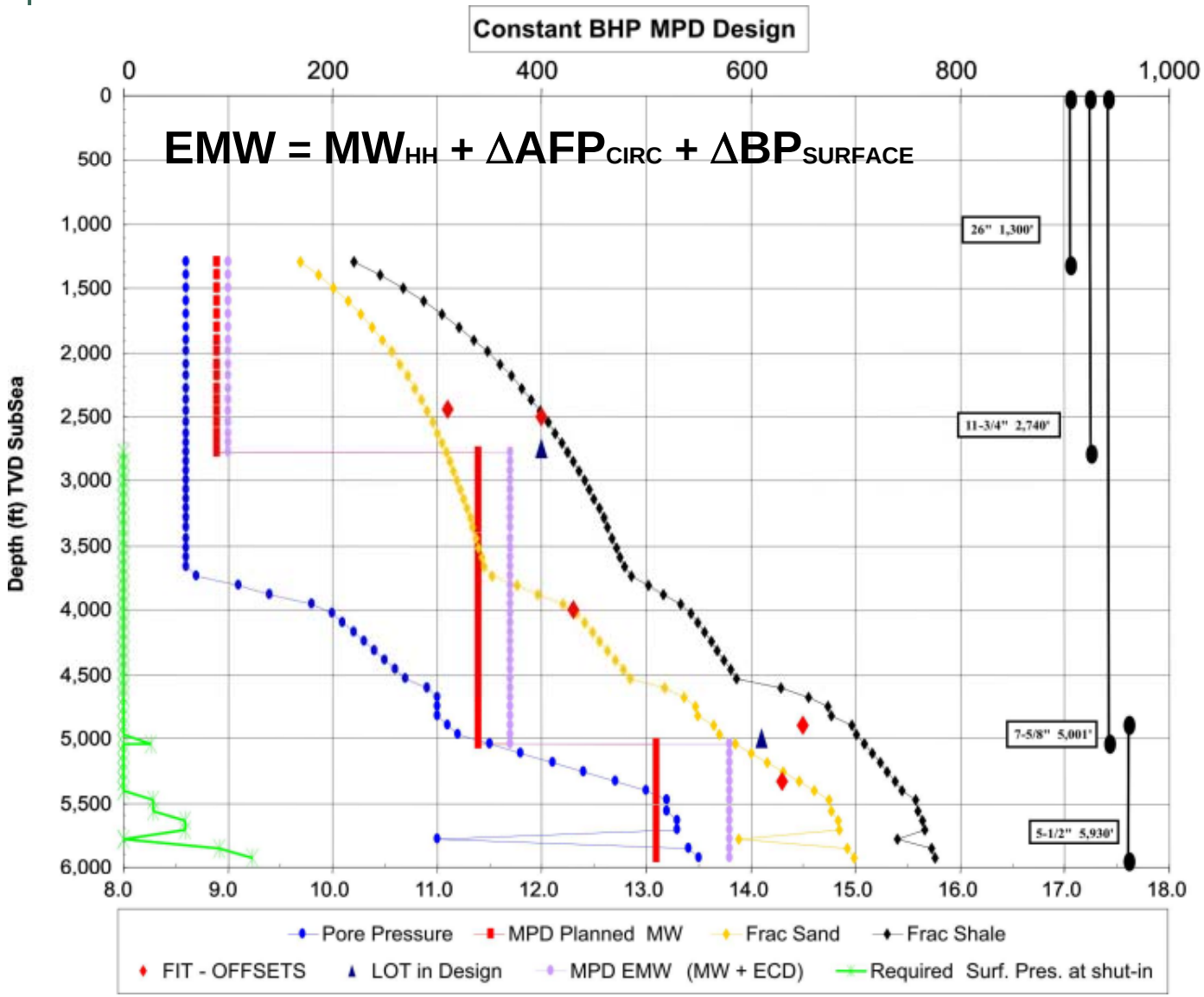
25 mud changes to TD

Can't drill in narrow margins without exceeding fracture gradient

Classic Kick-Loss scenario

MPD Example - GoM

Proactive CBHP Variation



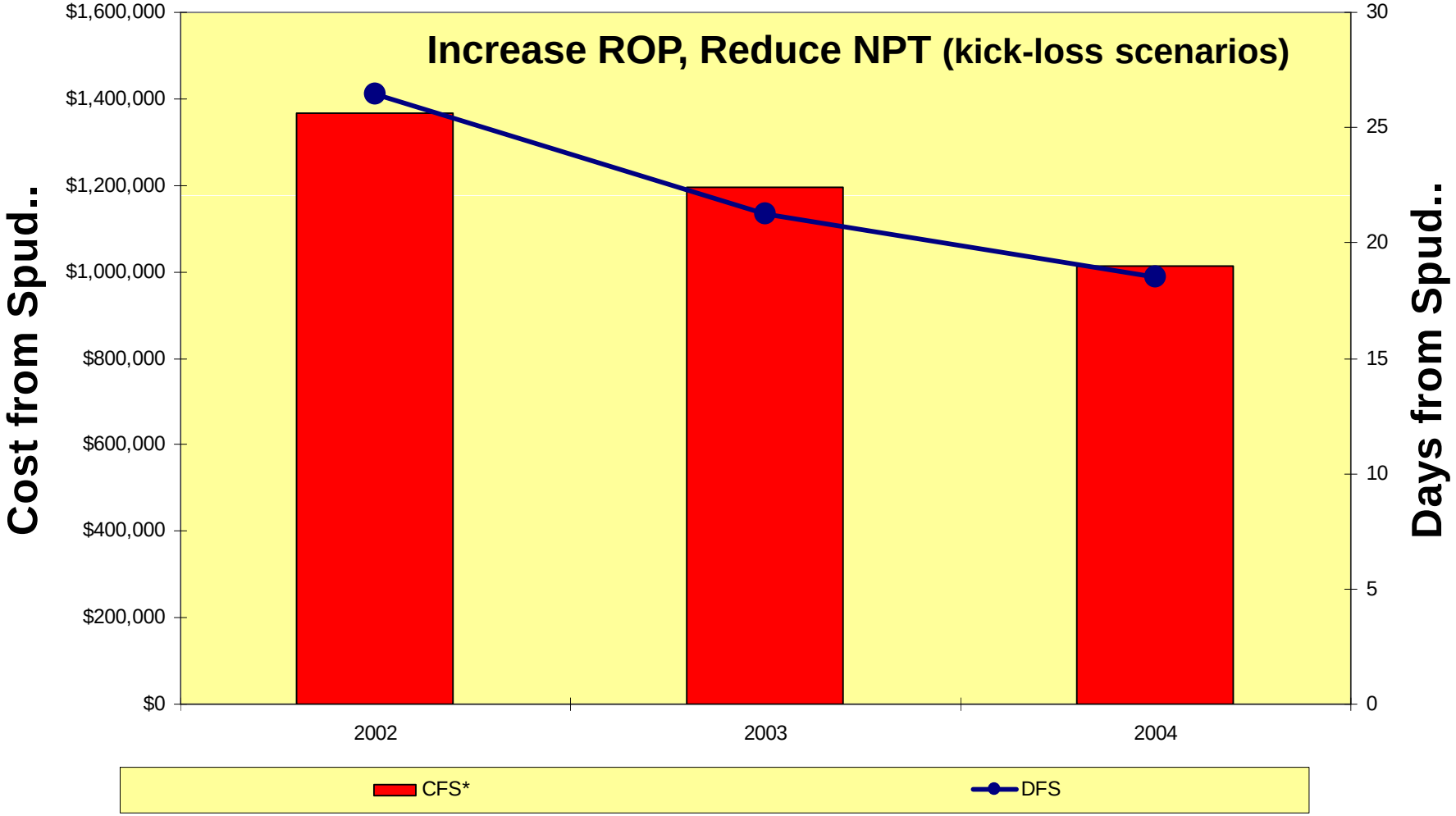
Only three mud density changes to TD

Surface backpressure applied during connections

No losses upon resuming circulation

Onshore Value Case - Proactive CBHP

Wild River/Cecilia Drilling Performance



Offshore Value Case – Proactive CBHP

CBHP Managed Pressure Drilling Reduces Drilling Time by 83%, Provides Operational Savings of $1 Million

Location:	**Chuc 172, southwest Gulf of Mexico**
Formations:	**Medium Cretaceous, Lower Terciary**
Depth:	**12,457 ft (3,797 m)**
Pore pressure:	**2,844 PSI (196 bar)**
Well type:	**Deviated**
Hole size:	**8-1/2 in.**
No. of wells:	**1**

Objectives

- Drill the well without the total circulation loss experienced in a previous well.
- Drill the well in less time than the 30 days allowed.

Results

- The well was drilled with no loss of circulation, using the constant bottomhole pressure (CBHP) variant of managed pressure drilling (MPD).
- Drilling time was reduced from 30 days to 5 days (83 percent).

PMCD on Fixed Rigs

- Photo – Jackup for Chevron Angola, drilling conventionally
- Upon encountering severe losses, RCD Bearing & Stripper Rubber Assembly is installed, mud cap spotted…
- …Drill ahead with seawater & no returns

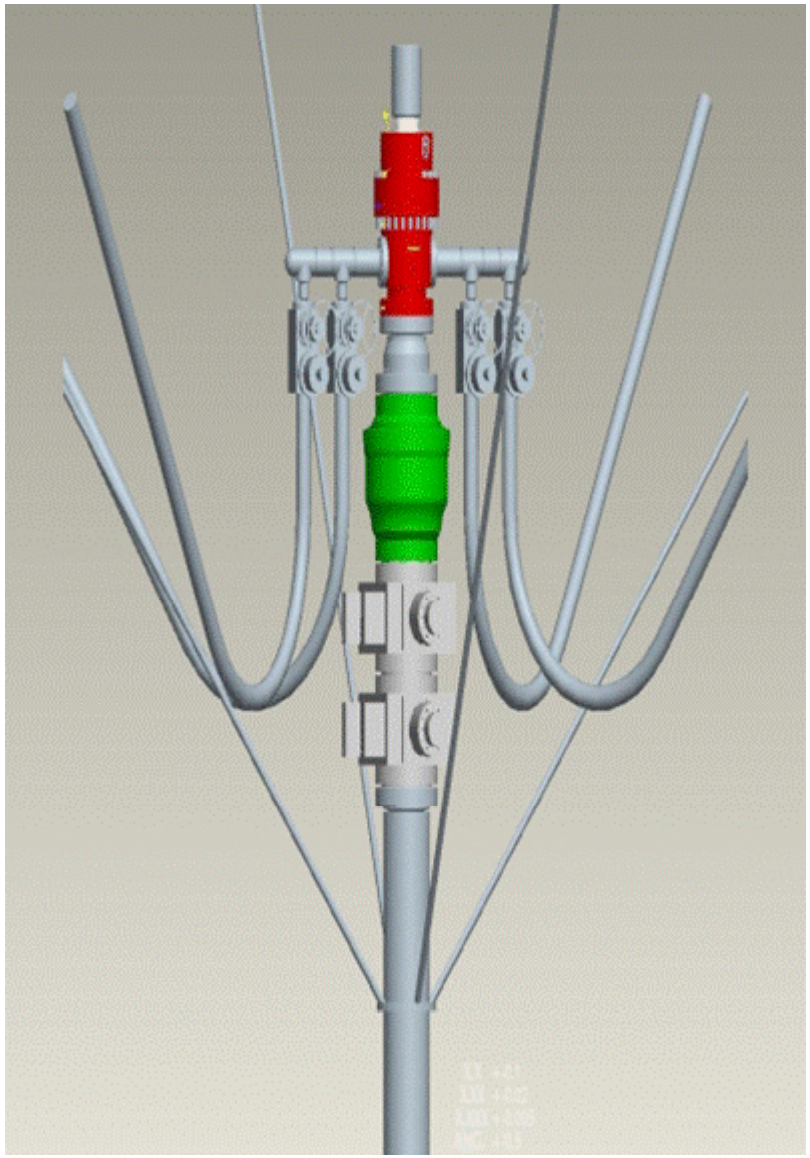
External Riser RCD w/Subsea BOP

- Riser telescoping slip joint locked, seals pressured - 500 psi riser system
- X-over spool connect to proprietary flange of slip joint Inner Barrel
- Note importance of hoses clearing riser tensioner cables in catenaries swing
- Taller spool or swivel flange may be required on drill ships to accommodate changes in heading

External Riser RCD w/Surface BOP

Pressure containment capability usually determined by that of flexible flowlines

- **Remote operated valves on manifolds?**
- **Length of hoses to compensate for heave and reach hard piping?**
- **Number and size of hoses to accommodate returns rate and desired redundancy?**
- **Annular BOP size?**
- **Drill pipe size and tool joint O.D.?**
- **Overpressure relief device to diverter dump line?**
- **Hose flush by-pass to prevent cutting settling when not circulating for extended periods?**
- **Secondary spills containment device?**
- **Will drill string stabilizers be used?**
- **Maximum temperature of returns**?
- **Moored Semi or DP Drillship?**



PMCD & CBHP MPD - Floater w/ Surface BOP

- Santos Indonesia
- PMCD - Drilling with seawater and no returns to deal with near total losses in cavernous voids
- After casing is set below that trouble zone, CBHP with mud in deeper open hole to deal with narrow margins

- SBOP equipment configuration readily adapted to SPC
- In this instance used to implement Pressured Mudcap with Sedco 601

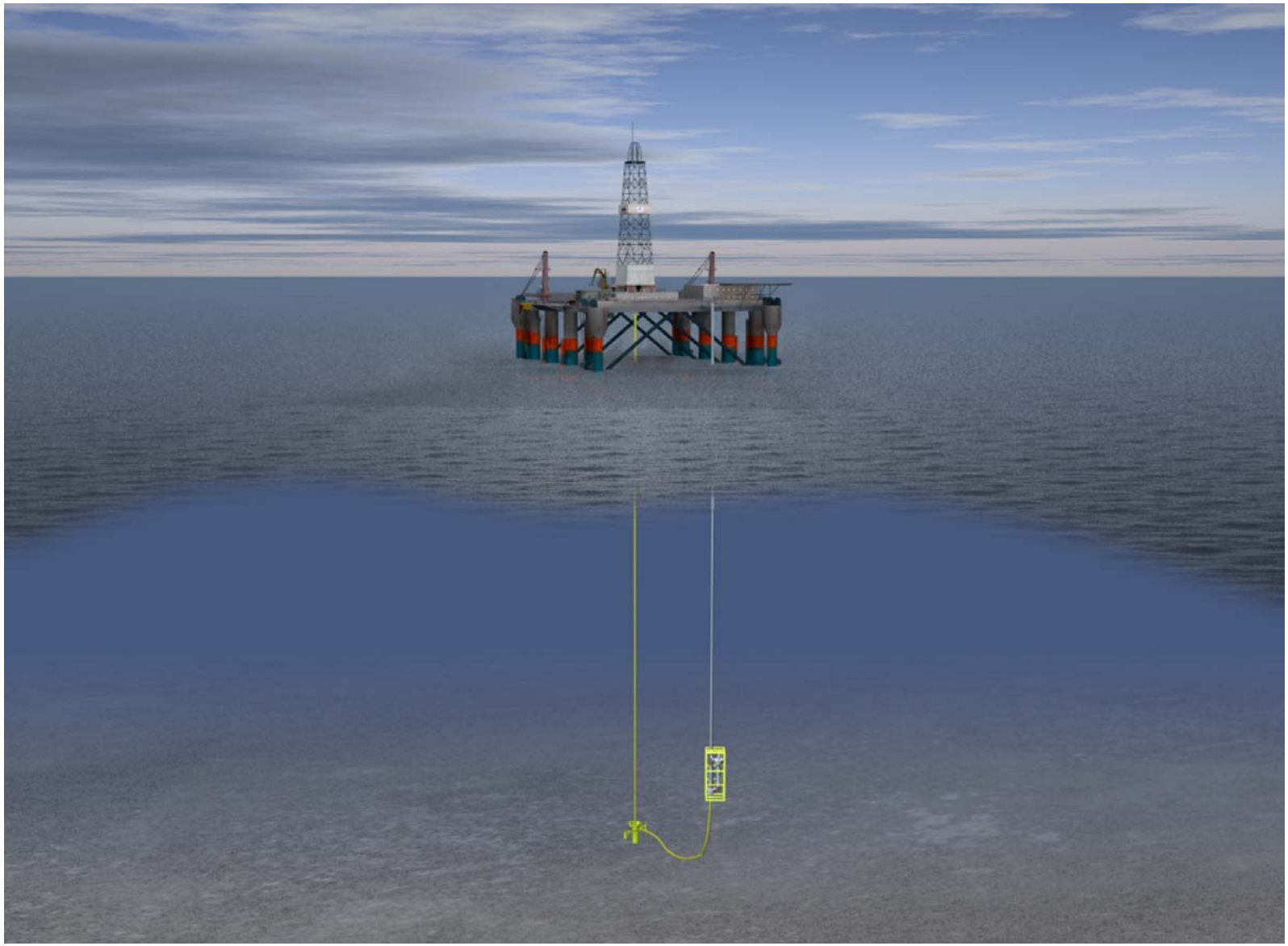
Asia Pacific Region MPD Activity – June 2006

MPD Type	Country	Operator	Project Duration	Formation Type	Rig Type
HSE	Vietnam	Cuu Long (ConocoPhillips)	5 year program	Fractured Granite Basement	Jack Up GALVESTON KEY & ADRIATIC 11
HSE/CBHP	Vietnam	JVPC (Japan Vietnam)	6 month program	Fractured Granite Basement	Jack Up TRIDENT 9
PMCD	Malaysia	Sarawak Shell	3 wells	Carbonate	Semi-Submersible STENA CLYDE
PMCD	Malaysia	Sarawak Shell	8 wells on 3 fields	Carbonate	Semi Tender WEST ALLIANCE
PMCD	Malaysia	Sarawak Shell	2 wells	Carbonate	Semi-Submersible OCEAN EPOCH
PMCD	Malaysia	Sarawak Shell	2 wells	Carbonate	Jack Up DEEP DRILLER 2
HSE	Malaysia	Petronas Carigali	1 well	Fractured Schist Basement	Jack Up ENSCO 52
CHBP	Malaysia	Petronas Carigali	1 well	Fractured Schist Basement	Jack Up ENSCO 52
PMCD	Indonesia	Santos	11 wells	Carbonate	Semi-Submersible SEDCO 601
PMCD	Indonesia	KNOC	1 well	Carbonate	Semi-Submersible SEDCO 601
PMCD	Indonesia	KNOC	5 + 2 wells	Carbonate	Drillship FRONTIER DUCHESS
PMCD-DDV	Indonesia	Pearl Oil	4 wells	Carbonate	Jack Up SHELF EXPLORER

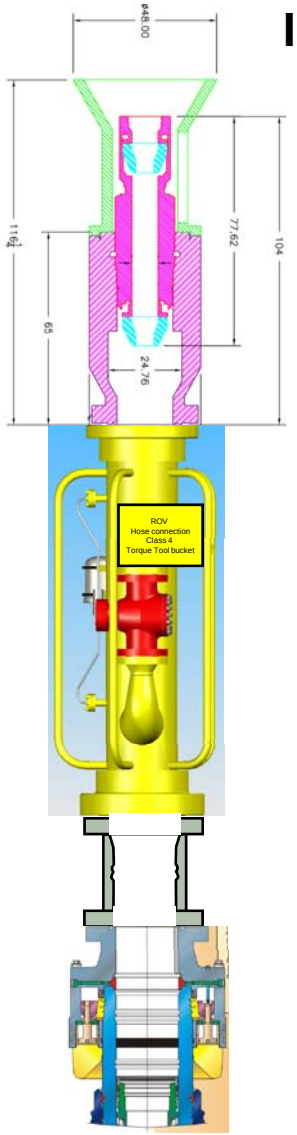
Asia Pacific MPD Activity to-date (March 2007)

- 84 drilling programs
- From all types of rigs; land, jackup, platform, moored semi-submersibles, dynamically positioned drillships
- Variations practiced safely and with good results
  - HSE
  - PMCD
  - CBHP
- 13 operator companies
- 11 otherwise un-drillable wells, >recoverable assets

Riserless Dual Gradient - Demo 2000 Deepwater Riserless Mud Recovery JIP



Integrated Riserless Top Hole Drilling Package



Subsea Rotating Control Device
w/ Guide Funnel

AGR Norway
Suction Module

SMO Running/Retrieving/Testing Sub

Vetco E H-4 Connector

Conclusion

- **The challenging hydraulics of the world's remaining prospects indicate MPD will evolve to become a key enabling technology.**
- **Adds technical, economic and HSE viability.**
- **Increases recoverable assets.**
- **Step-change technology.**
- **Synergistic with DwC and several other emerging technologies.**
- **Following U.S. example, onshore MPD is growing globally.**
- **Proactive MPD is lowest hanging fruit for U.S. land operations**
- **All "first adopters" of MPD offshore plan future wells.**
- **A candidate technology to deal with the Boyles Law challenges of drilling for commercial quantities of methane hydrates**