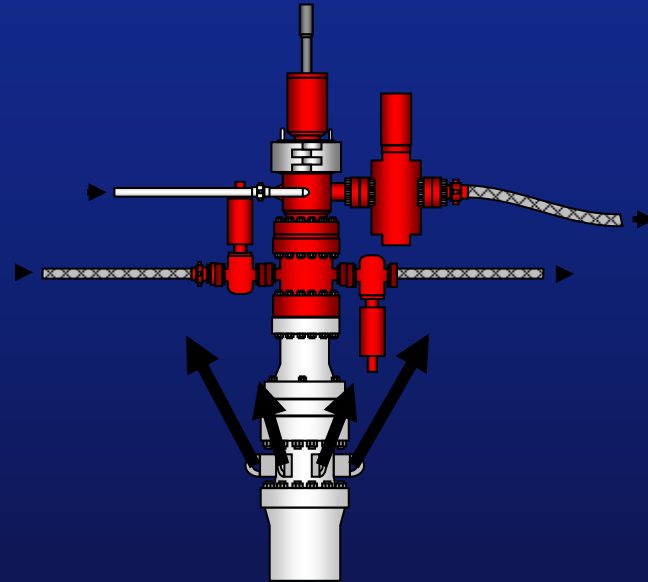
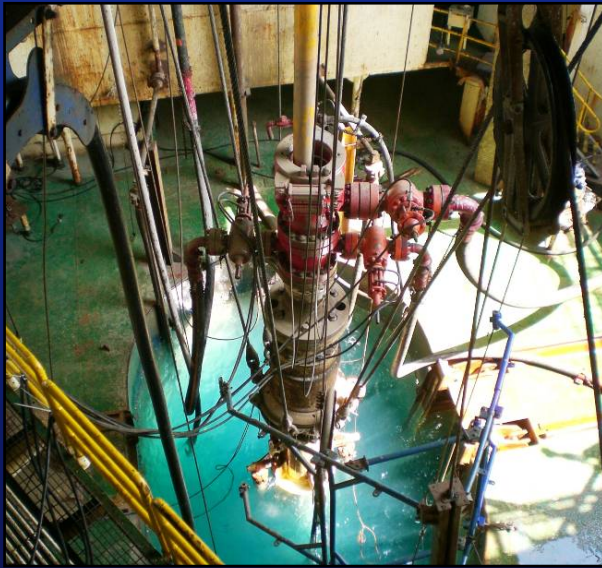


Managed Pressure Drilling (MPD) Systems & Applications

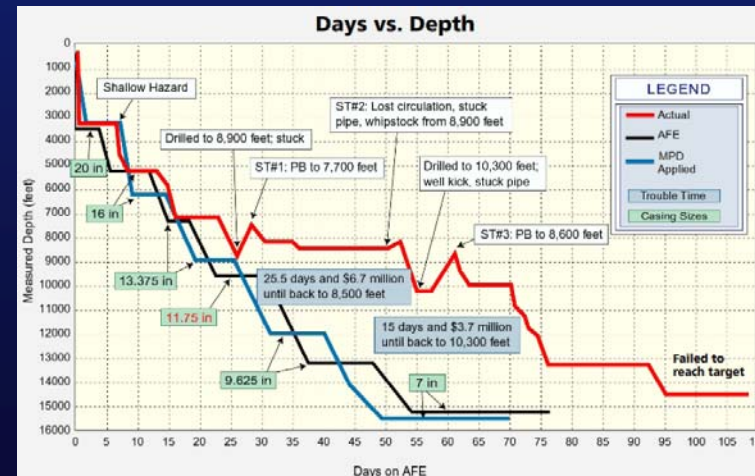


Ken Muir
VP, Engineering
Keep Drilling Pte. Ltd.

www.keepdrilling.com

Managed Pressure Drilling – WHY?

- Conventional Drilling hasn't changed much in over 100 years – it's still an “Open to Atmosphere” system
- The easy drilling is behind us – drilling problems are increasing – **and it's getting worse**
- Drilling performance curve is flat – technology advances are cancelled out by increased drilling problems
- Independent studies reveal that **25 – 33%** of new wells can't be drilled conventionally
- Drilling costs are now higher than facilities costs (used to be the other way round)
- MPD is a safer drilling method
- We need a better way to drill



Drilling Methods

OVERBALANCED DRILLING: Drilling with BHP higher than formation pressure = CONVENTIONAL DRILLING.

Objective: To minimise the chance of an influx.

PERFORMANCE DRILLING: Drilling with low BHP to enhance ROP & bit life. Used in well construction = AIR or GAS DRILLING.

Objective: To enhance penetration rate

UNDERBALANCED DRILLING: Drilling with the BHP below reservoir pressure – naturally lower or induced = UBD.

Objective: To minimise reservoir damage

MANAGED PRESSURE DRILLING: Drilling with precisely controlled BHP to avoid influx, fluid loss or borehole instability. Pressure profile managed by addition of surface pressure or by change in hydrostatics or friction pressure.

Objective: To minimise pressure related drilling problems

MPD Advantage

Conventional Drilling:

$$\text{BHP} = \text{MW} + \text{Annulus Friction Pressure}$$

BHP control = only pump speed & MW change,
because it's an "Open to Atmosphere" System.

Managed Pressure Drilling (MPD):

$$\text{BHP} = \text{MW} + \text{Annulus Friction Pressure} + \text{Backpressure}$$

BHP control = pump speed change, MW change &
application of back-pressure, because it's an
"Enclosed, Pressurized System".

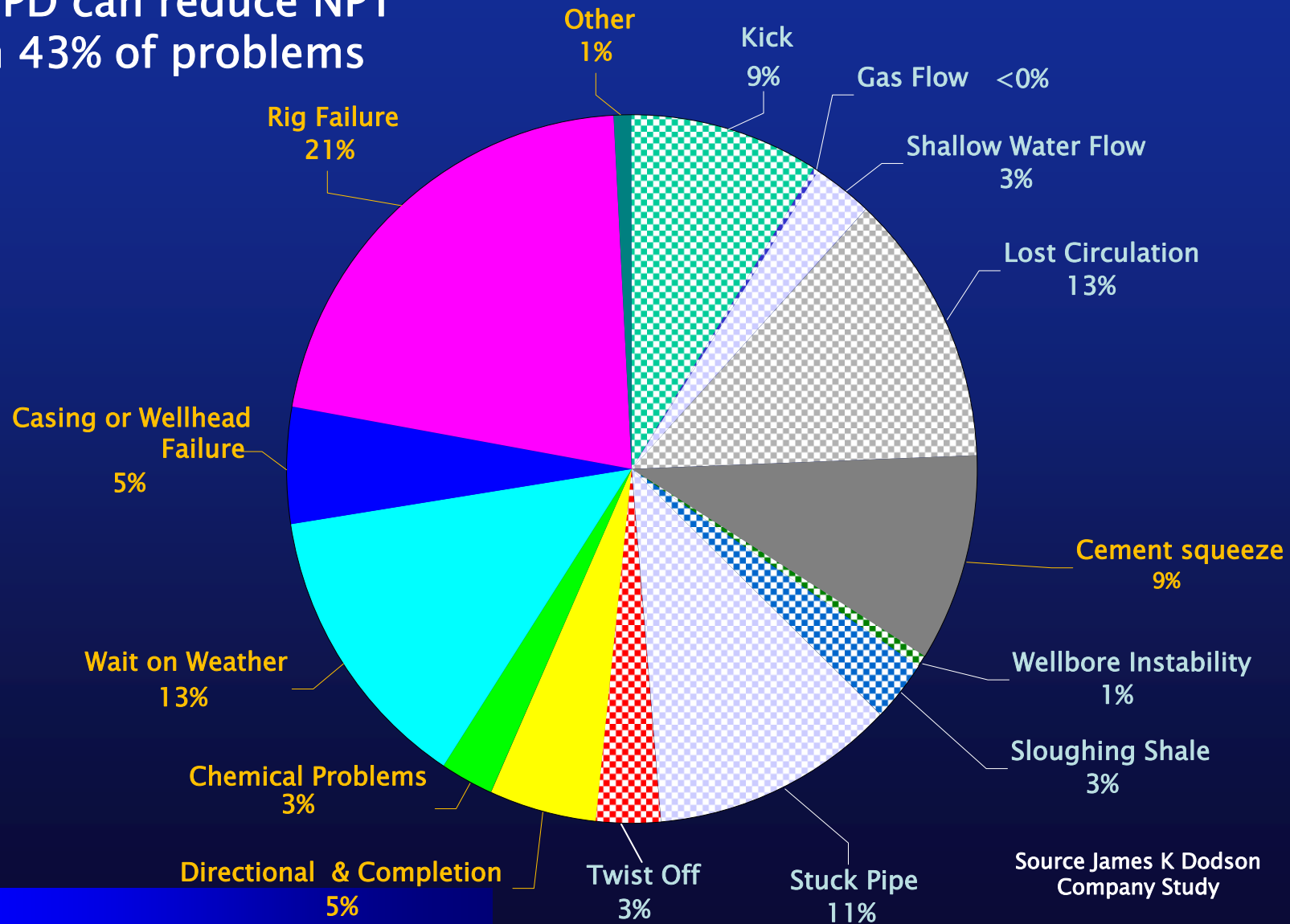
MPD Advantage

IADC Definition:

- “The objectives are to ascertain the downhole pressure environment limits and to manage the annular hydraulic pressure profile accordingly”
- MPD does not change the downhole pressure window – pore pressure and fracture gradient remain unchanged
- but MPD helps us to remain in the “window”

Problem Incidents – GoM Gas Wells

MPD can reduce NPT in 43% of problems



Source James K Dodson
Company Study

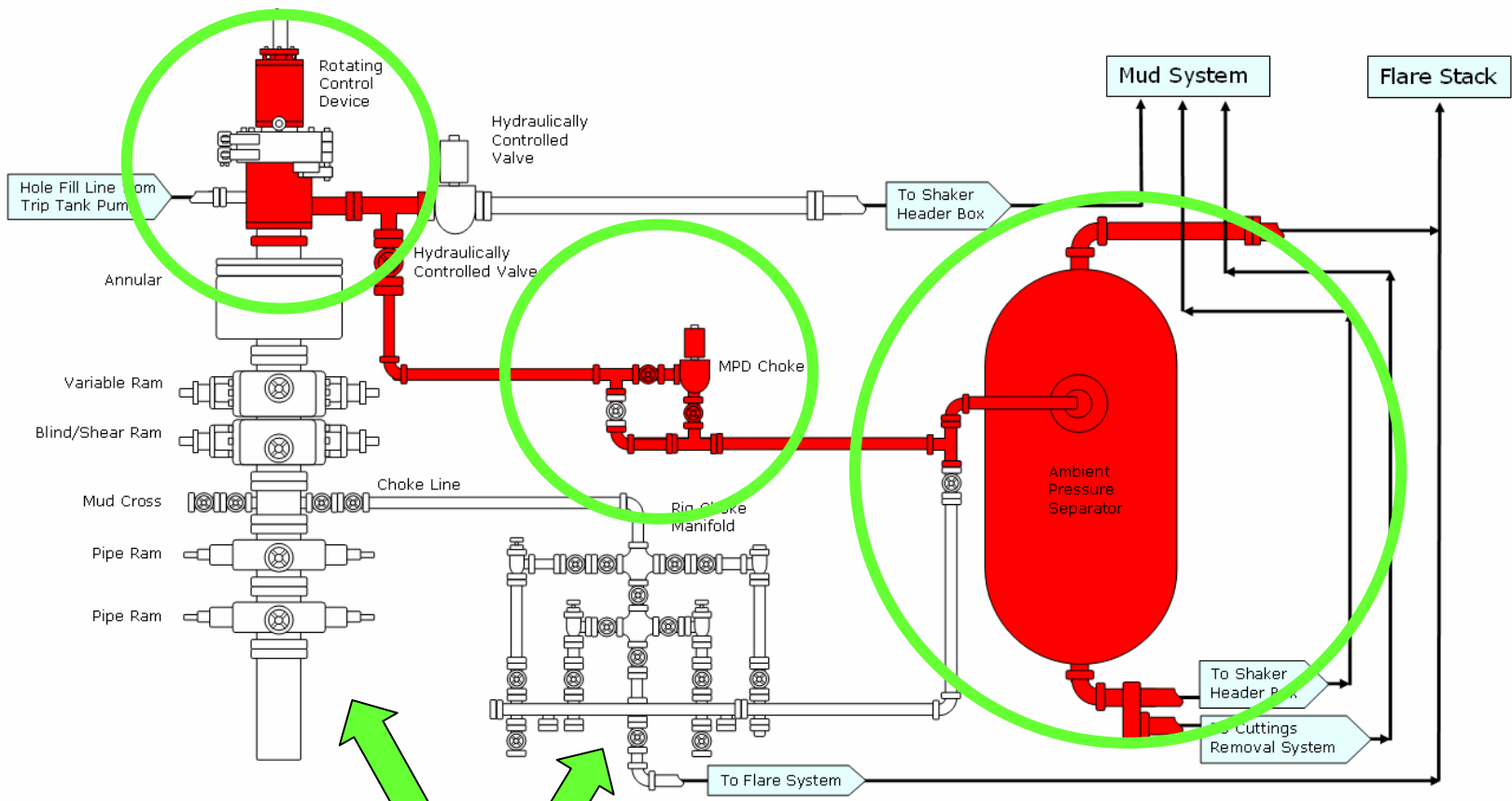
Who is using MPD?

- In the US & Canada – 600 operations are performed using MPD with enclosed wellbore solutions every day
- For several operators it has already become their normal way of drilling their wells
- In Asia Pacific, a range of operators have used MPD solutions over the last 3 years.

Users include:

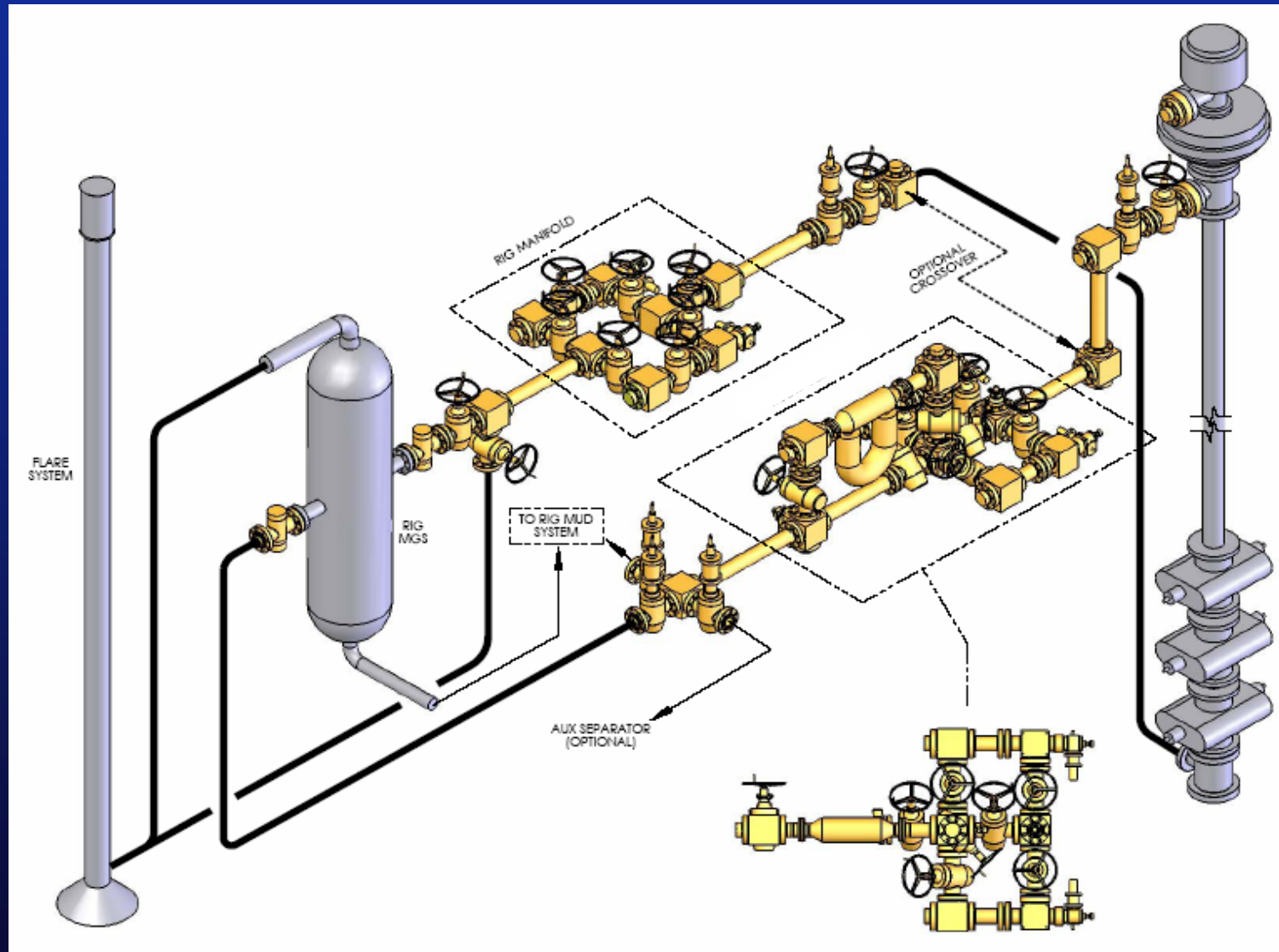
- ConocoPhillips
- Santos
- Shell
- Petronas Carigali
- Hess
- KNOC
- Medco Energi
- Total
- InterOil
- Tately
- Hoan Vu
- JVPC

MPD System Components



Conventional BOP & Choke Manifold (no change)

Automated MPD System



Manual CBHP System

Make a connection and keep BHP within a 50psi window

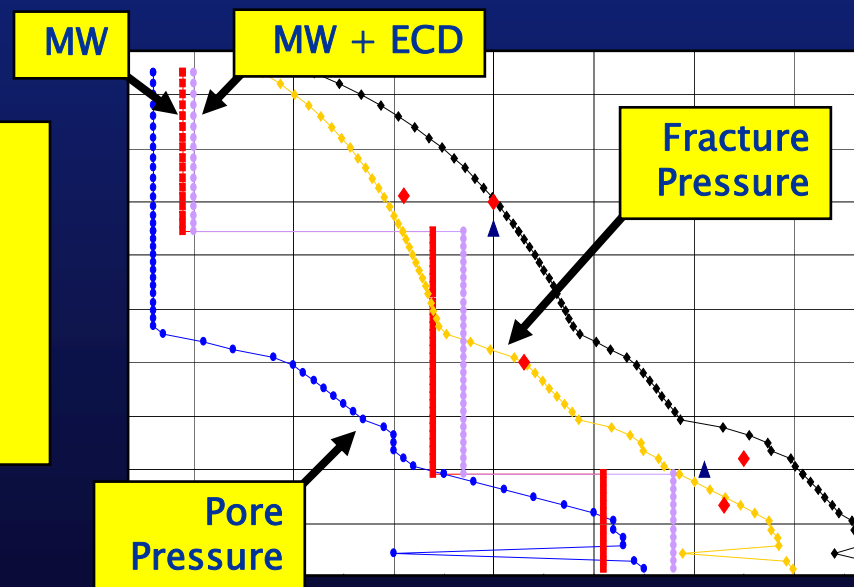
Step	Choke Pressure (psi)	Pump Rate (gpm)	Pump (spm)	Pump Press (psi)	Friction DP (psi)	BHP (psi)
Pump Rate while drilling	20	196	70	2995	393	1566
Increase choke pressure	48	197	70	3003	393	1617
Decrease pump rate	48	183	65	2646	345	1566
Increase choke pressure	113	183	65	2691	345	1611
Decrease pump rate	113	170	60	2395	300	1566
Increase chore pressure	155	170	60	2397	258	1608
Decrease pump rate	155	155	55	2081	258	1566
And continue with steps until pumps are stopped						
Decrease pump rate	323	85	30	990	90	1566
Increase chore pressure	347	85	30	1014	90	1590
Decrease pump rate	347	71	25	931	66	1566
Increase choke pressure	359	71	25	843	66	1578
Decrease pump rate	359	45	16	596	54	1566
Increase chore pressure	413	45	16	650	54	1620
Decrease pump rate	413	0	0	413	0	1566

50psi range

Types of MPD

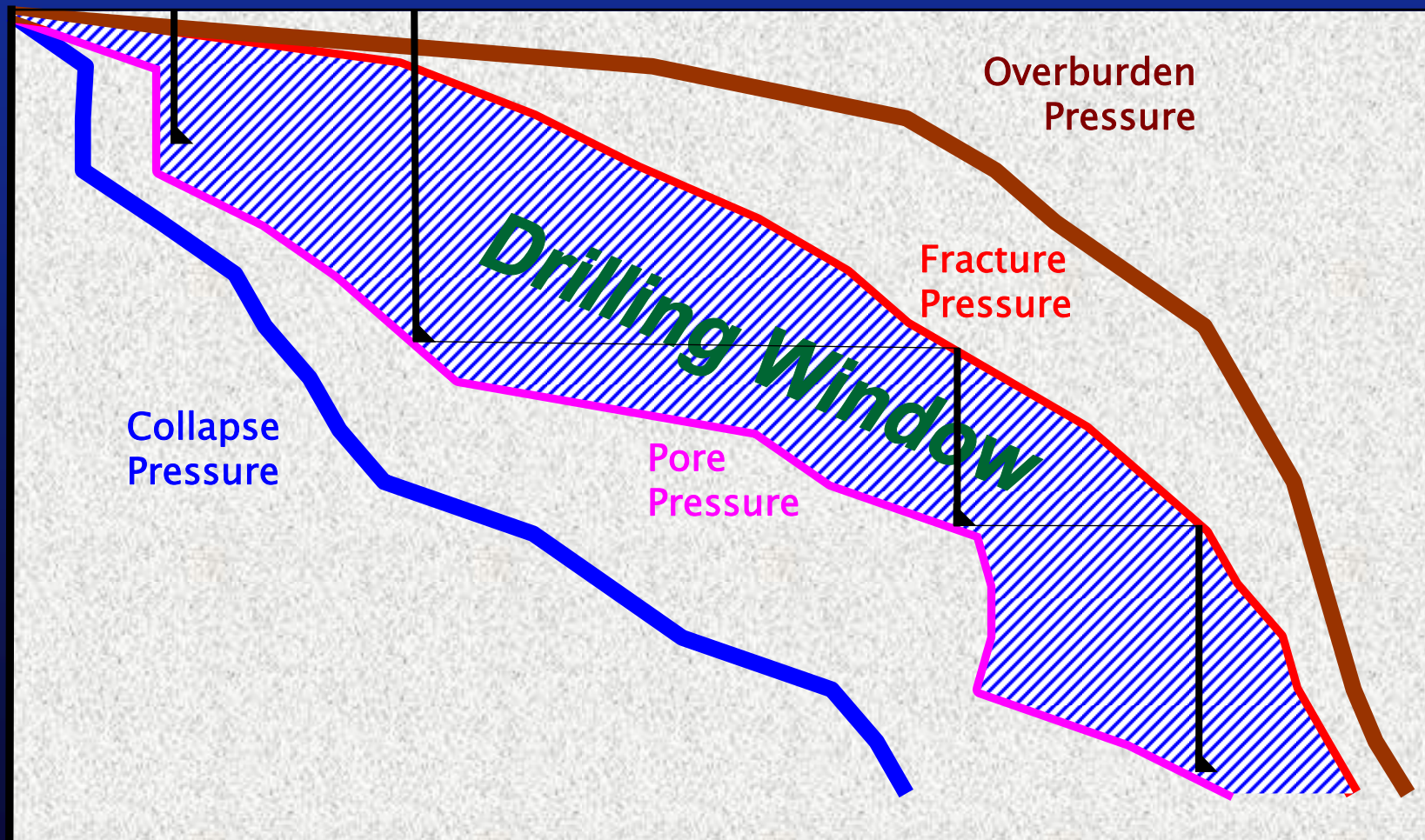
- Returns Flow Control (Enclosed wellbore vs. open-to-atmosphere)
- Pressurized or Floating Mud Cap Drilling (PMCD)
- Constant Bottom Hole Pressure (CBHP)
- Dual gradient (DG)

MPD allows the BHP to be adjusted to penetrate the “Windows” between Pore Pressure & Fracture Pressure



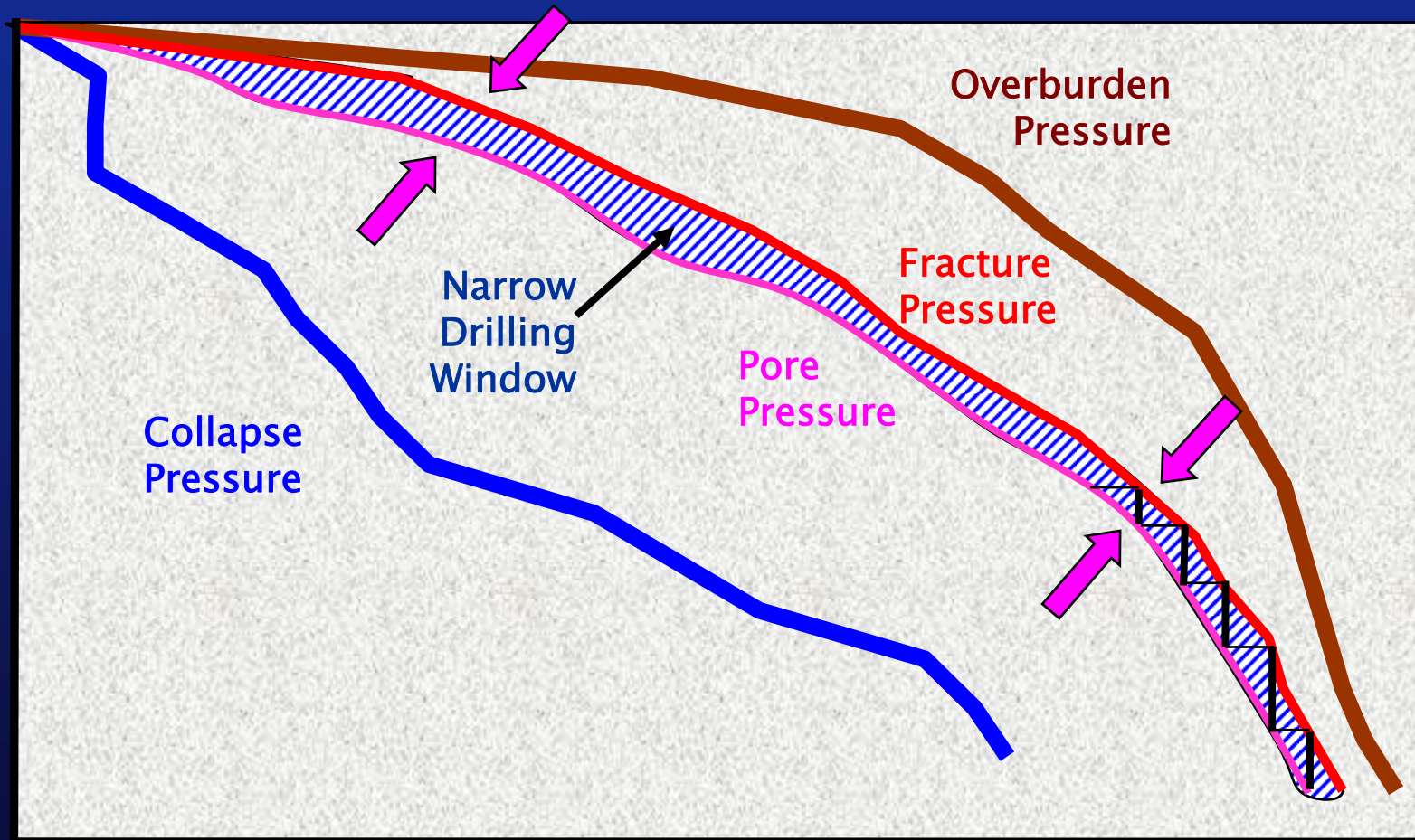
Pore – Fracture Pressure Window

Easy to drill wells in a large “Drilling Window”

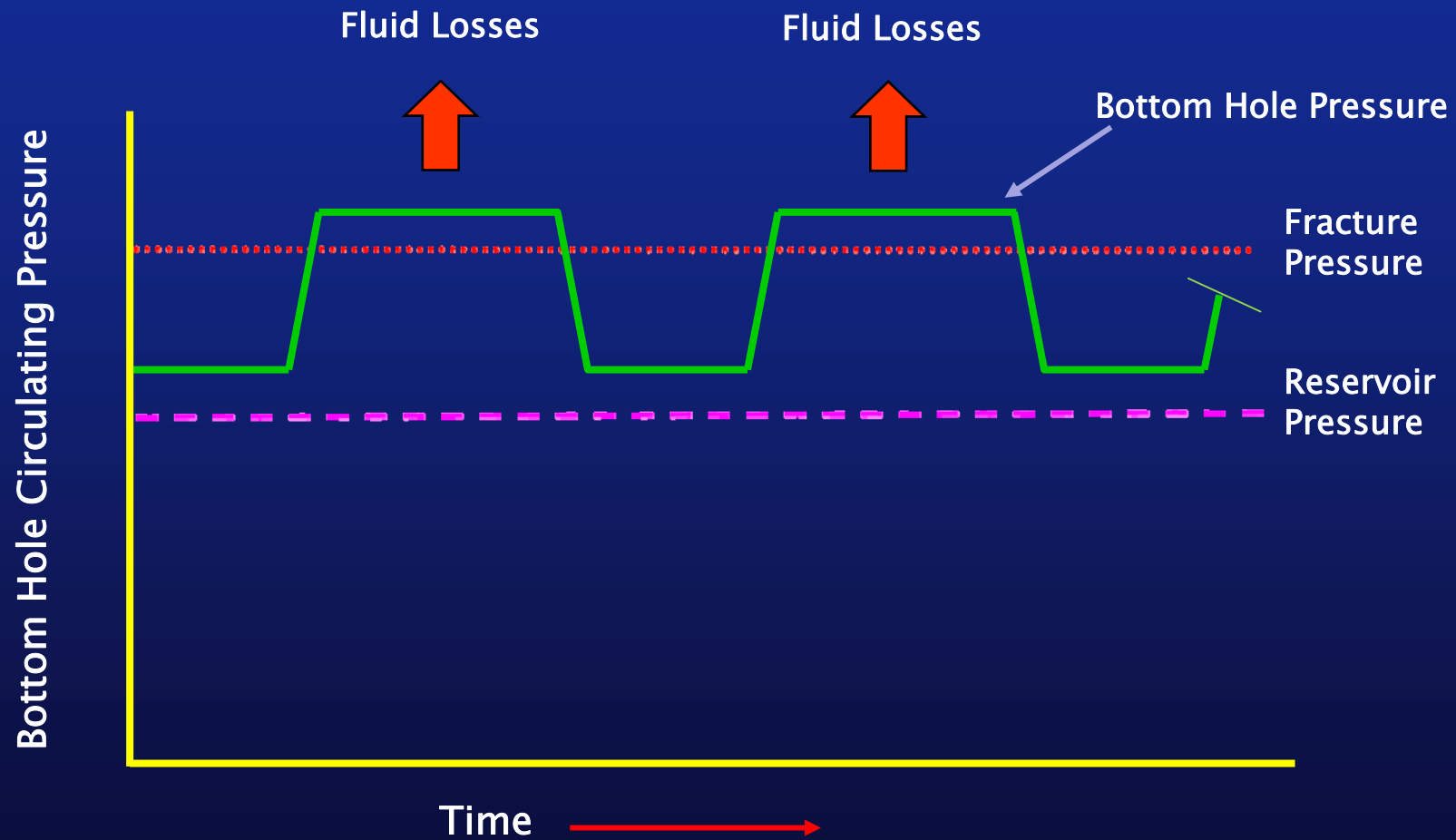


Pore – Fracture Pressure Window

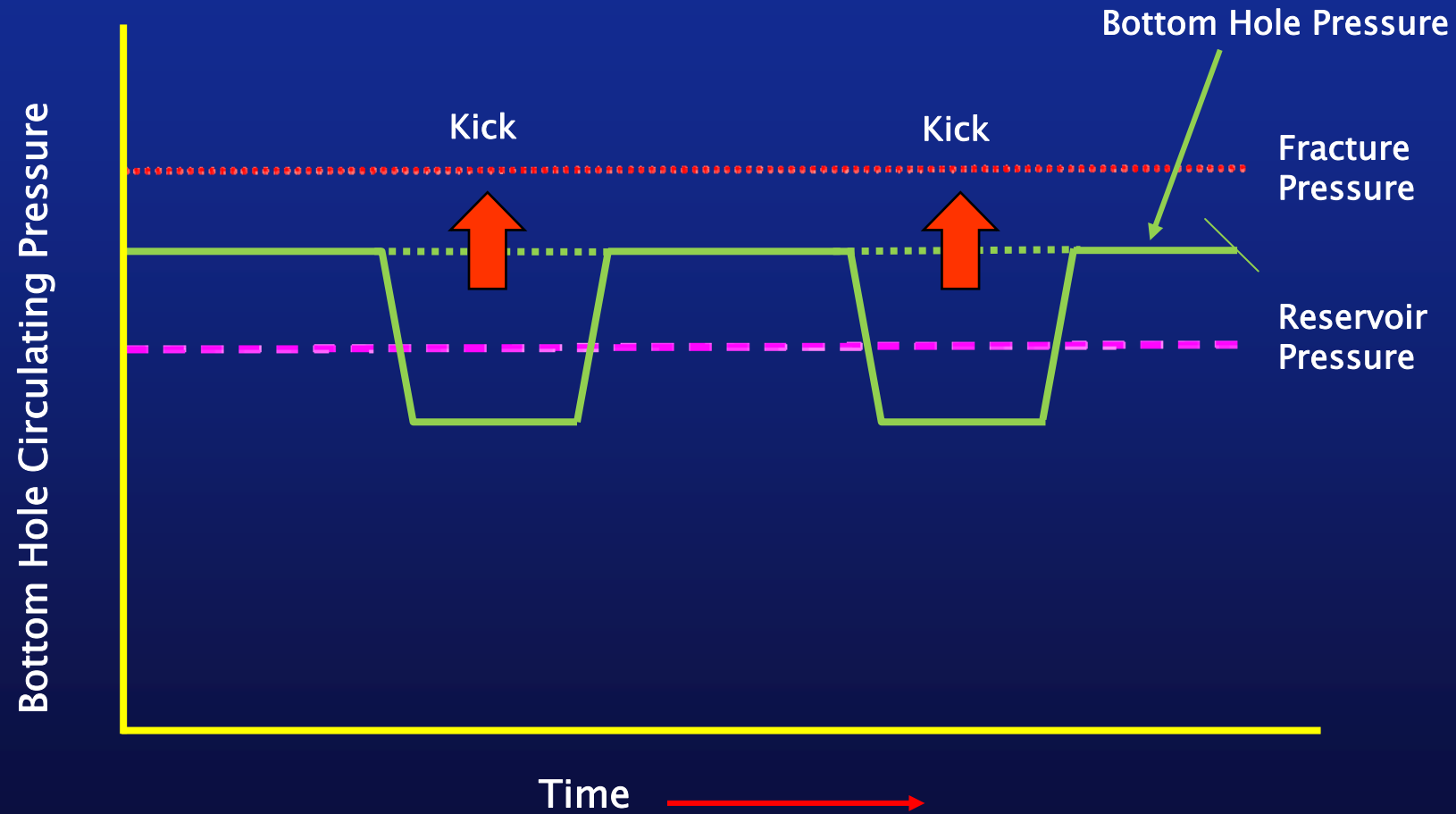
Narrow “Drilling Windows” are not easy to drill



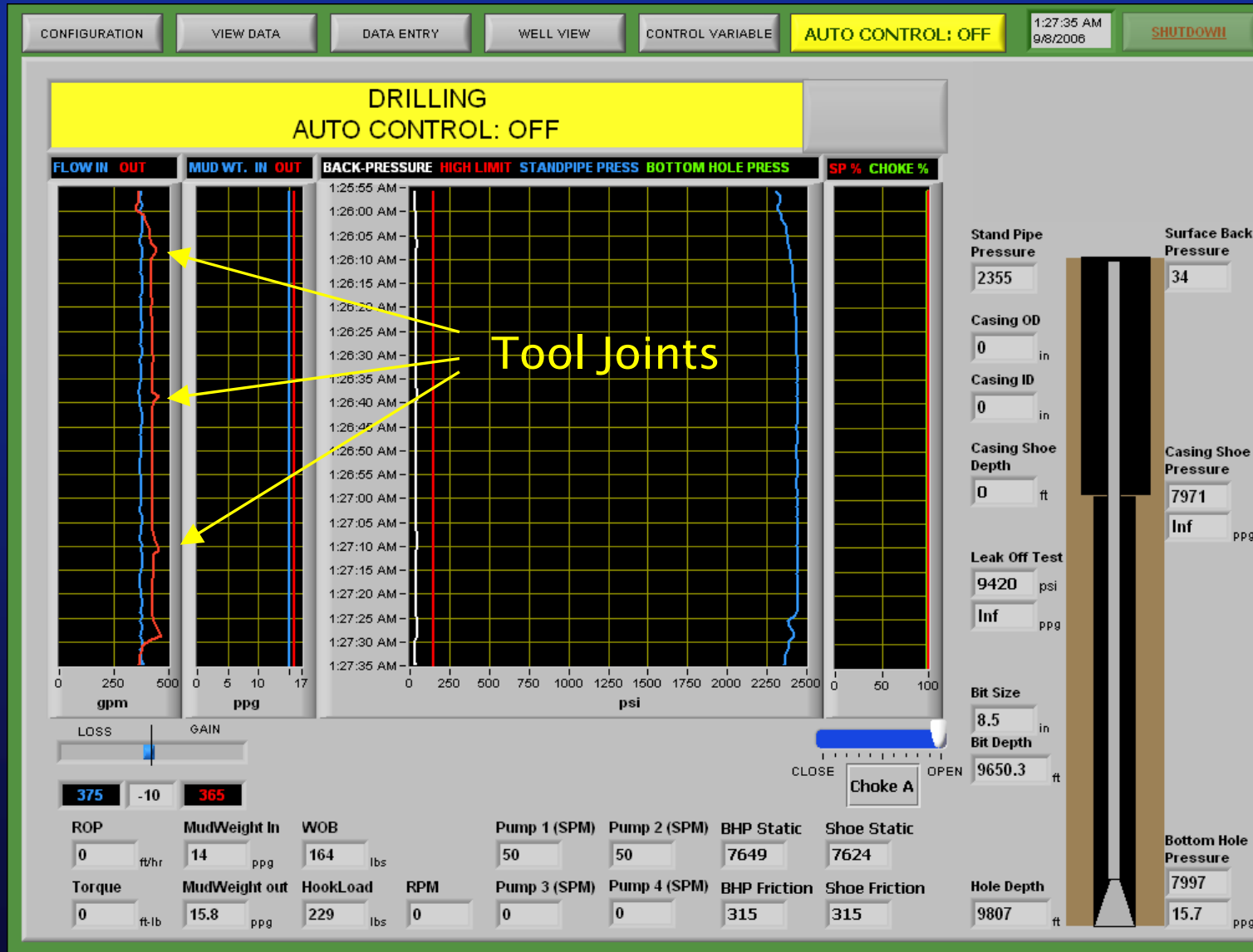
Constant Bottom Hole Pressure – CBHP



Constant Bottom Hole Pressure – CBHP



Automated MPD System – Reaming to Bottom

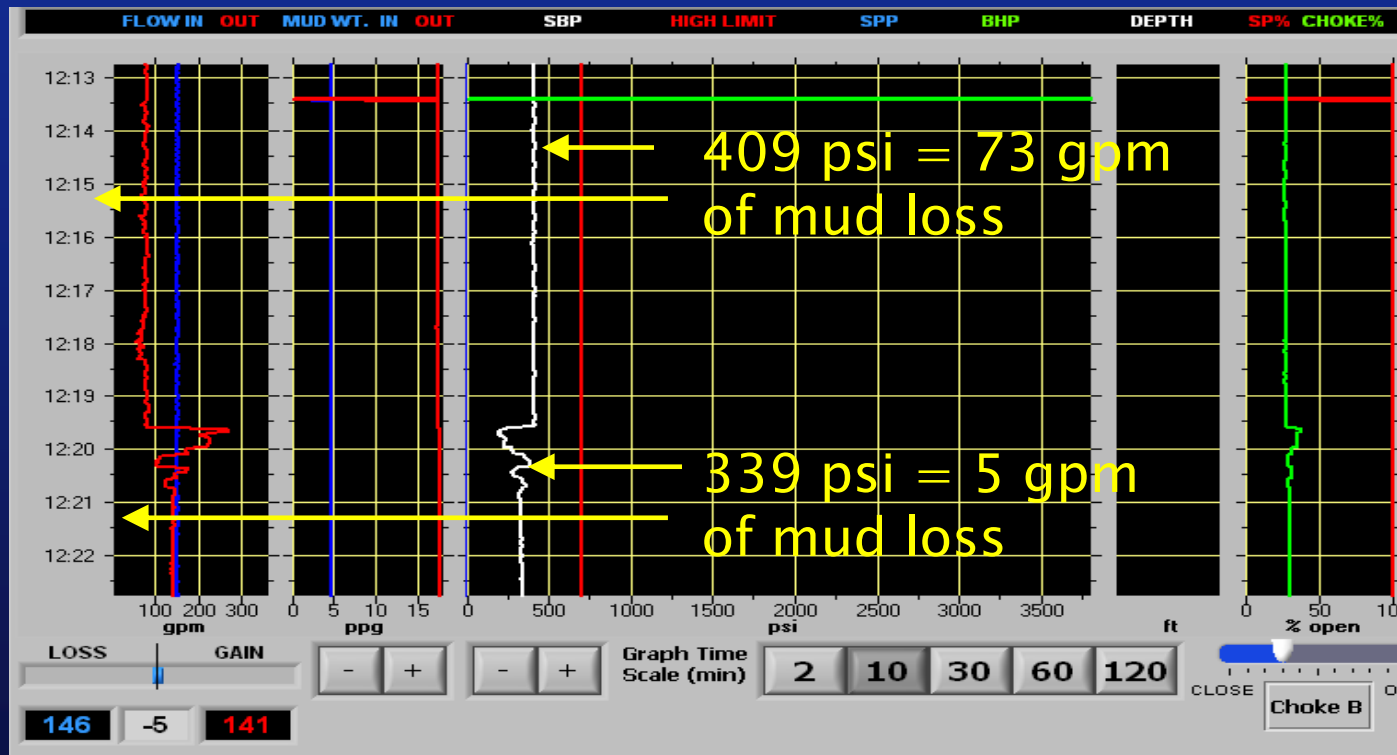


Automated MPD System



Kick Tolerance is greatly reduced

Automated MPD System



Accurate determination of the fracture gradient

Low Pressure RCD

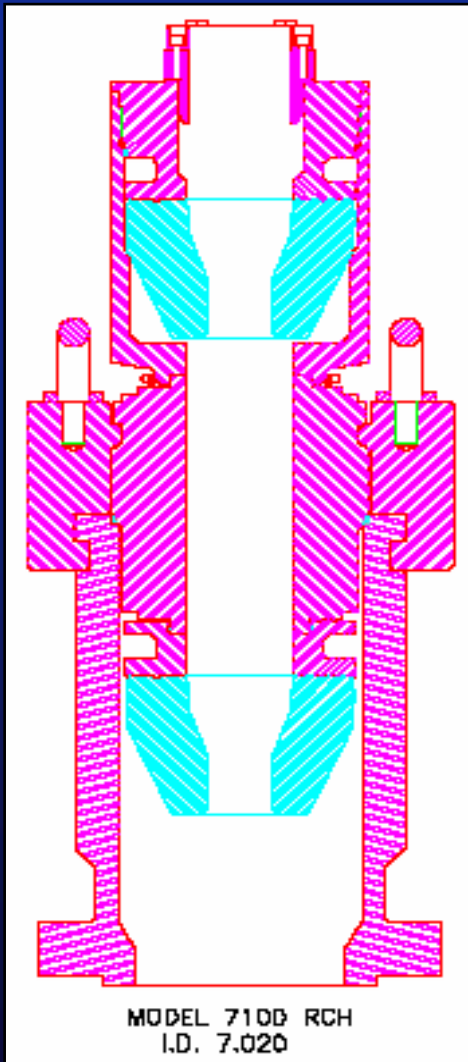
Over 600 wells are drilled with Rotating Control Devices (RCD) every day in the US & Canada



Low pressure RCD with spare seal elements and components for pressure testing and logging.

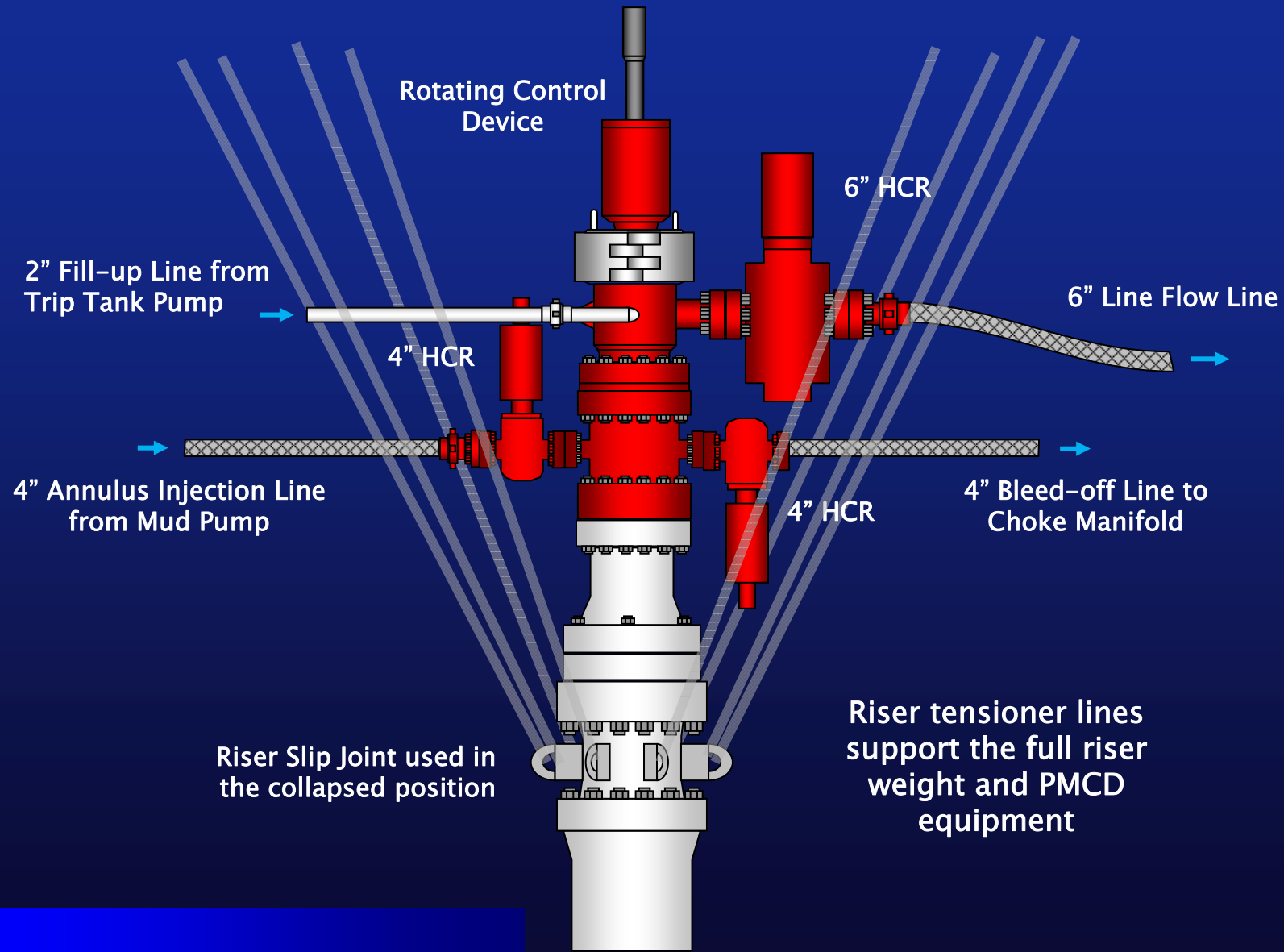
Pressure Rating:
Rotating and/or Stripping: **500psi**
Static: **1,000psi**

High Pressure RCD



Pressure Rating:
Rotating and/or
Stripping: 2,500psi
Static: 5,000psi

PMCD System – Floating Rig

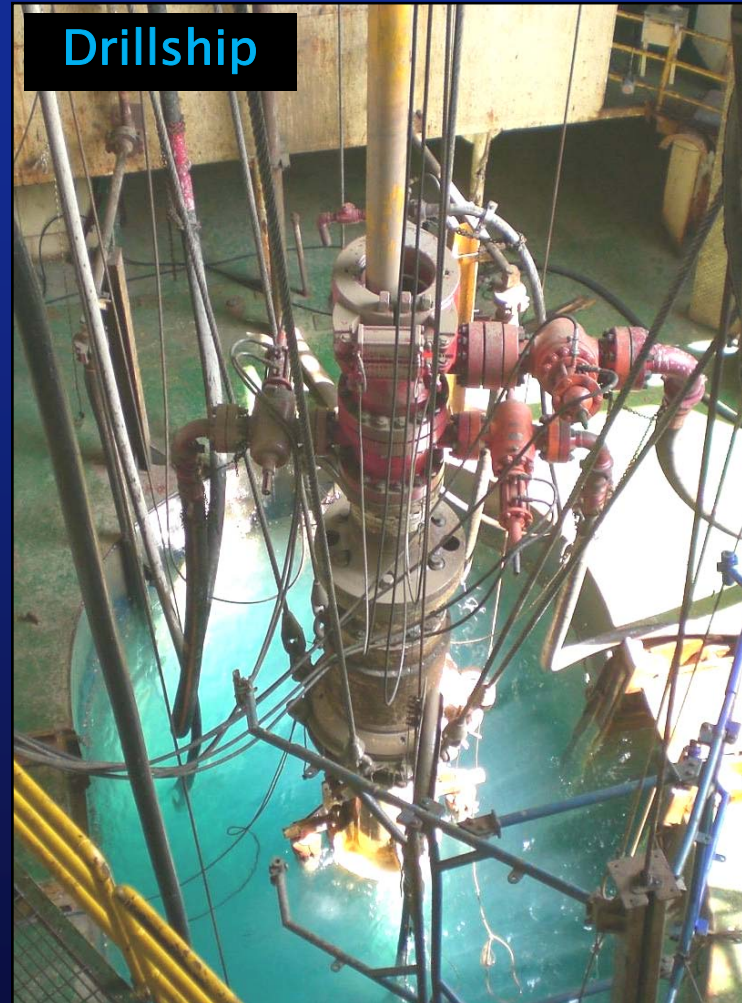


PMCD System – Floating Rigs

Semi-submersible

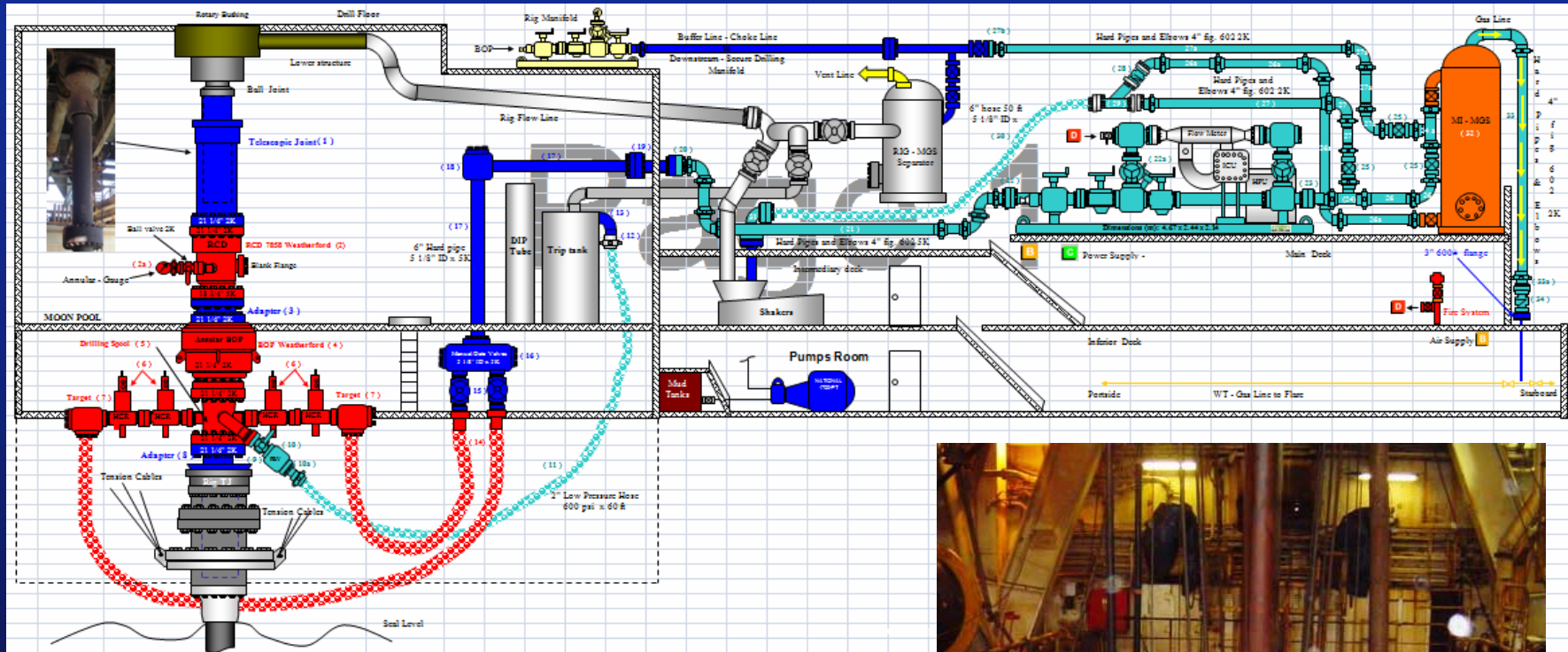


Drillship



MPD has already been performed on Drillships, Semi-sub, Jack-ups & Platform Rigs

Automated MPD – Floating Rig



- Full Automated MPD System for floating rig applications in harsh environment conditions
- Project due to commence July 2008



MPD Applications

- Kick Control (Influx Control)
- Severe Drilling Fluid Loss – Fractured or Vugular Formation
- Differential Sticking – Stuck Pipe – Twist-off
- Tight Pore Pressure – Fracture Pressure “Windows”
- Depleted Reservoir Drilling
- HPHT Drilling
- Unknown Pore Pressure

MPD Applications contd.

- Unstable Wellbore (Wellbore Instability)
- MPD + ERD (Extended Reach Drilling)
- Low ROP
- Drilled Gas (Nuisance Gas)
- High H₂S Levels
- High ECD
- Ballooning / Breathing formation

KICK CONTROL – Advantages of MPD

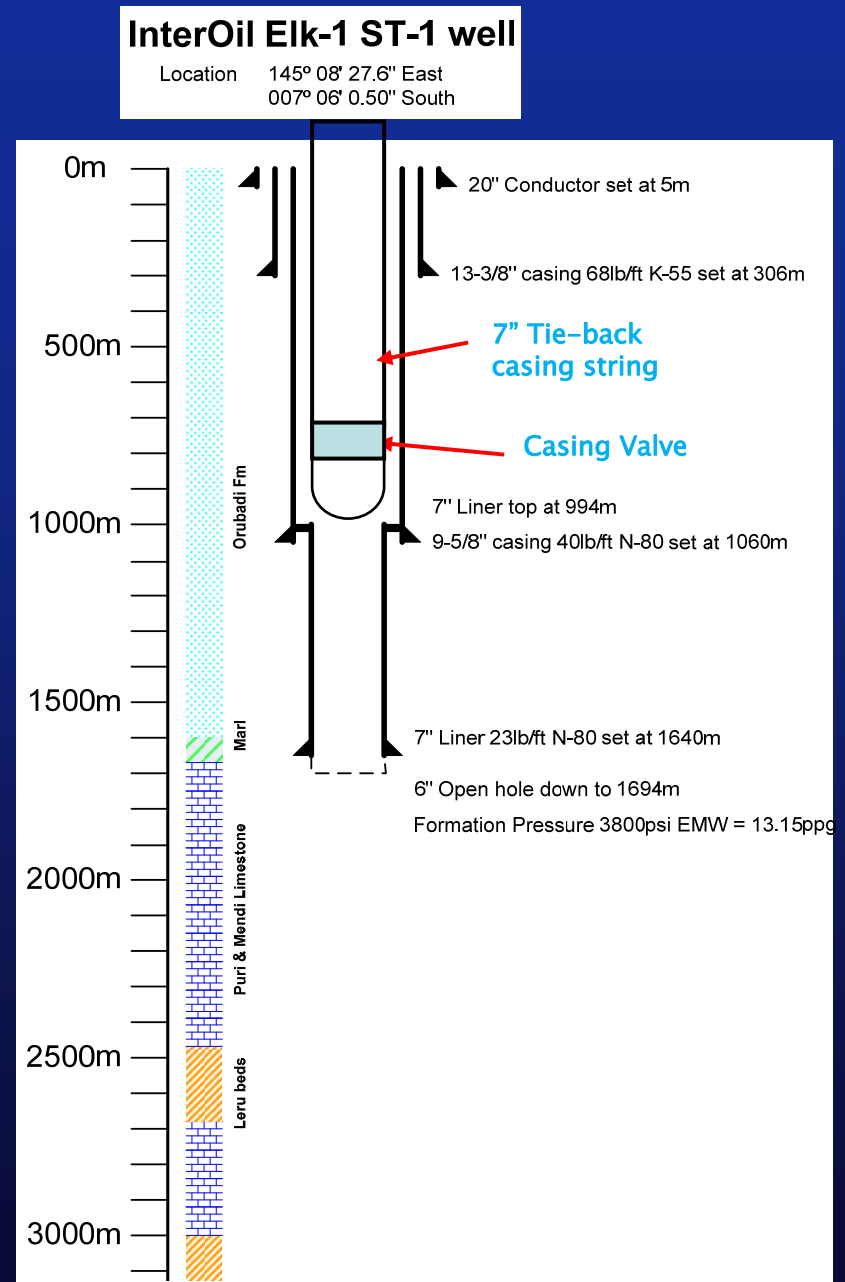
Safety	<ul style="list-style-type: none">• Response and influx size reduced using an enclosed system• Enclosed wellbore is safer than “open to atmosphere” system because back-pressure can be applied immediately• The majority of kicks are low pressure events that can easily be handled by an RCD• Lower risk of exceeding MAASP with MPD (because of the smaller influx) and consequently lower risk of breaking down the casing shoe• Lower risk of taking second influx with MPD (longer critical choke control needed while circulating out the larger influx)
Time & Cost	<ul style="list-style-type: none">• The drillstring can be moved all the time, reducing the risk of differential sticking – potential huge cost saving• One full circulation at slow circulating rate can take hours, plus time to weight up the kill mud. Typically 12 – 24 hours can be saved (the time loss varies – GOM deepwater – the average time loss due to taking a kick is 10 days)• Reduces wear & tear on BOP and rig choke system

PMCD – Advantages & Disadvantages

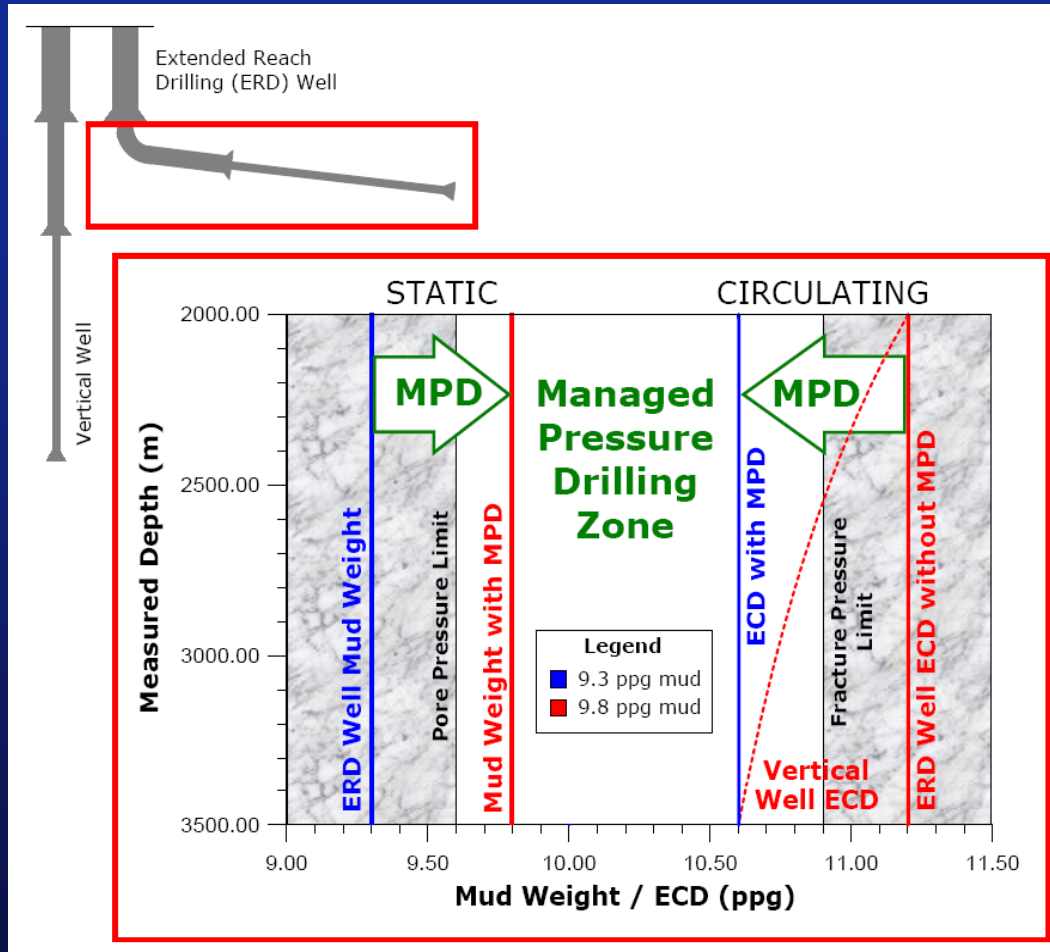
Advantages	<ul style="list-style-type: none">• Permits safe and efficient drilling through severe or total loss zones – highly cost effective compared to conventional drilling• Well can be drilled to TD with virtually no loss of rig time – no major AFE Overruns• Limits damage to the reservoir caused by LCM, gunk and cement• Very good technique for H₂S environments because the gas is pushed back into formation – no gas to surface
Disadvantages	<ul style="list-style-type: none">• There are no returns to surface – Geologists don't like this technique – no samples• At TD, or for intermediate trips, there still remains the issue of how to get out of the hole with total losses – casing valve or pumping technique• PMCD uses large volumes of fluid – a week of drilling could require 120 – 150,000bbls of fluid including drillpipe & annulus injection

Case History

- Ran 7" casing "tie-back" string to top of liner hanger with casing valve to allow drillstring recovery
- Changed to PMCD
- Injected water in annulus with high surface pressure on RCD (1,400psi)
- Drilled out tie-back shoe, gunk plug plus 3m of new formation. POOH closing casing valve to isolate reservoir pressure
- Reservoir section drilled in two further trips
 - SPP range 1,900 – 2,100psi
 - CP range 1,250 – 1,400psi
 - ROP ~ 4 – 5 metres/hour



MPD + ERD



$$\text{ECD (ppg)} = \frac{\text{Annular Pressure Loss (psi)}}{\text{TVD (ft)}} + \text{Current Mud Density (ppg)}$$

PROBLEM: Compare two wells of 3,500mMD. A vertical well with APL of 478psi and 10.6ppg ECD using 9.8ppg mud, and an ERD well with TVD of 2,000m. The ERD well would have the same APL but an ECD of 11.2ppg.

X Greatly increased ECD
X At reduced depth – weaker formation

MPD SOLUTION: Drill with 9.3ppg mud giving a 10.6ppg ECD and trap annulus pressure during connections to control any influx or maintain wellbore stability

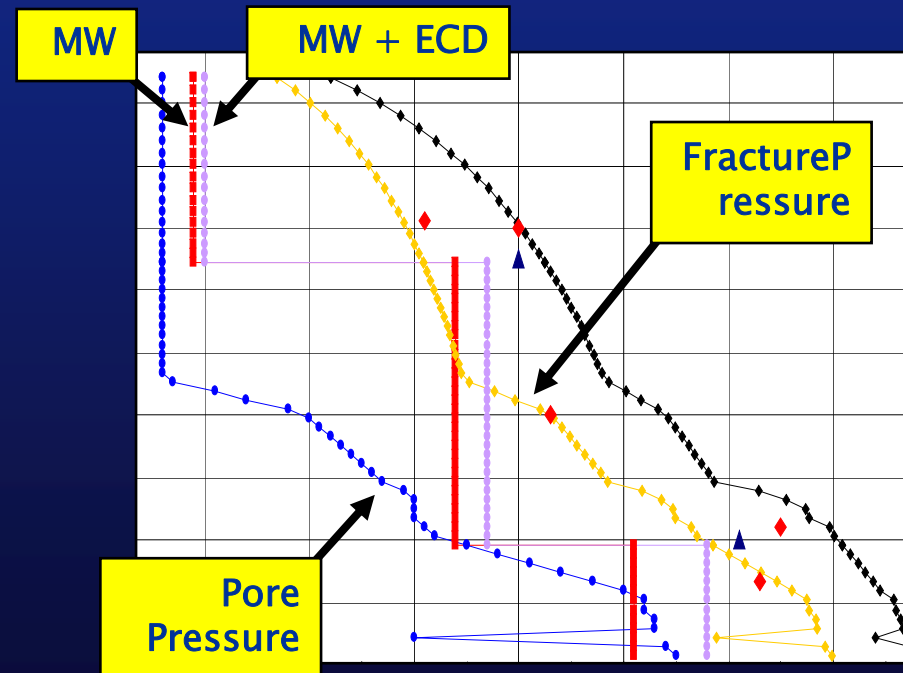
High ECD

PROBLEM:

- While drilling a 6-1/8" hole at 3,064mTVD with 13.2ppg mud and an APL of 575psi, ECD is so high that losses are being caused. The pump rate must be reduced and ROP controlled to avoid hole cleaning problems and stuck pipe
- Circulating BHP adds 1.1 - 1.6ppg, so ECD = 14.3 - 14.8ppg

MPD SOLUTION:

- Drill with a light fluid. Can be statically balanced but with the MPD system for additional security
- Eliminate the 0.5ppg drilling margin - enclosed wellbore
- Or go statically underbalanced with a 12.1ppg MW and trap 575psi in the annulus on the choke during connections (ECD = 13.2ppg)



Ballooning / Breathing Formation

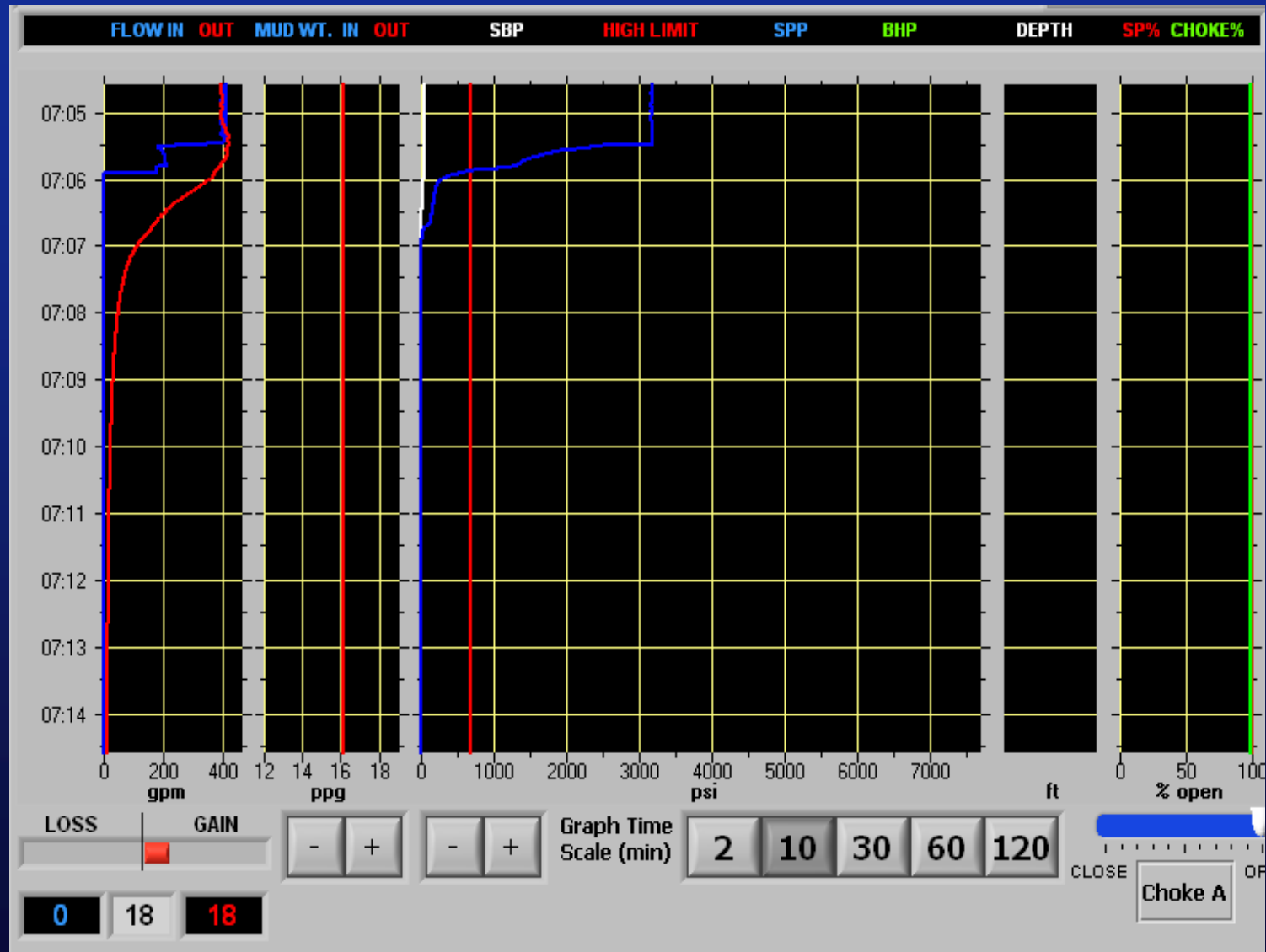
PROBLEM:

- The formation charges up with fluid and pressure while drilling and releases this fluid pressure back into the wellbore when the pumps are shut down
- The drilling supervisor thinks the well is flowing and orders the mud weight increased – which increases the BHP – which charges up the formation even more – so it flows even more at the next connection

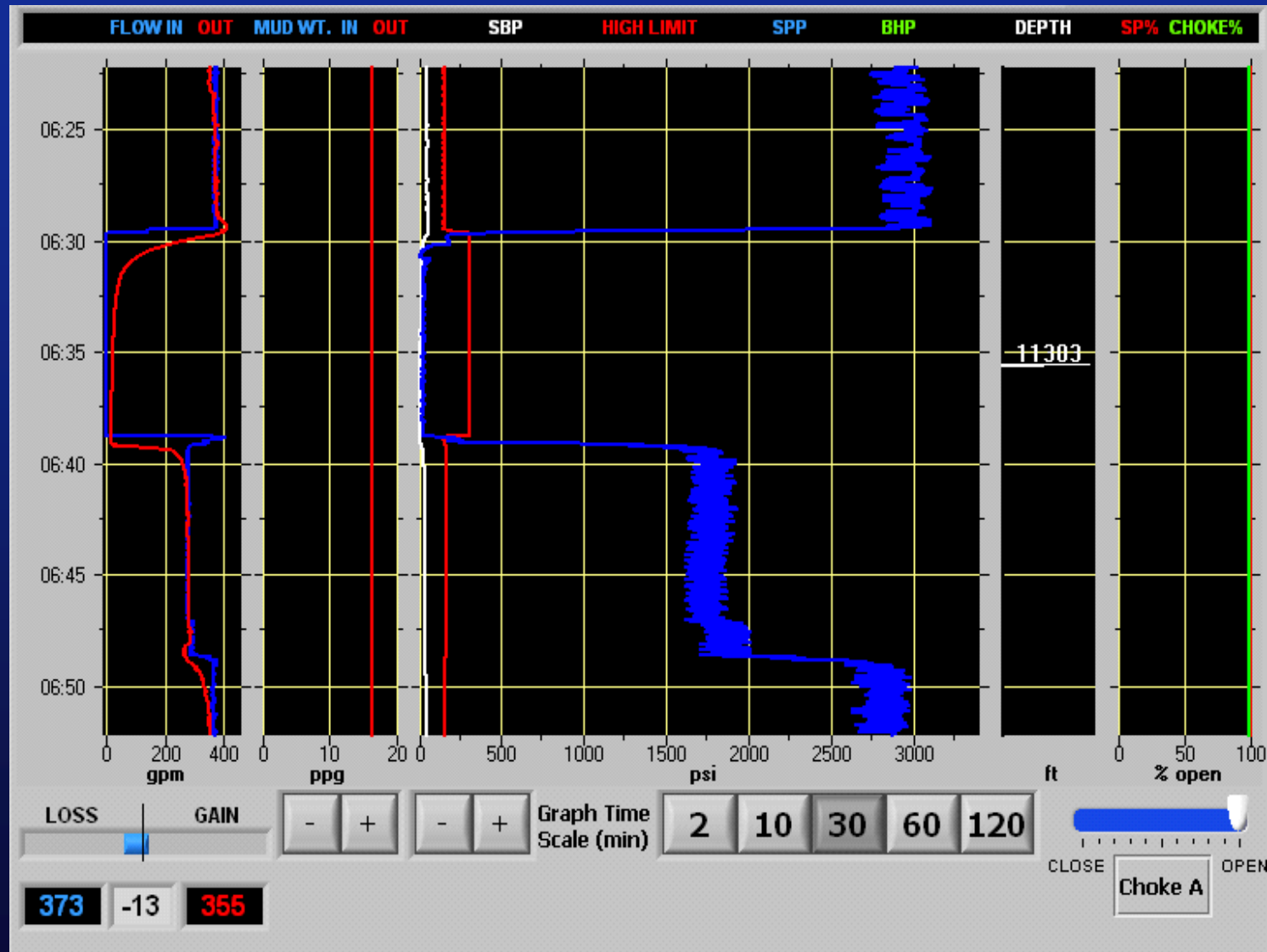
MPD SOLUTION:

- If the well is flowing due to an influx – the flow trend will be gradually increasing – but if the problem is ballooning formation then the flow trend will be decreasing
- An Automated MPD System, with highly accurate flow measurement can clearly identify what is happening.

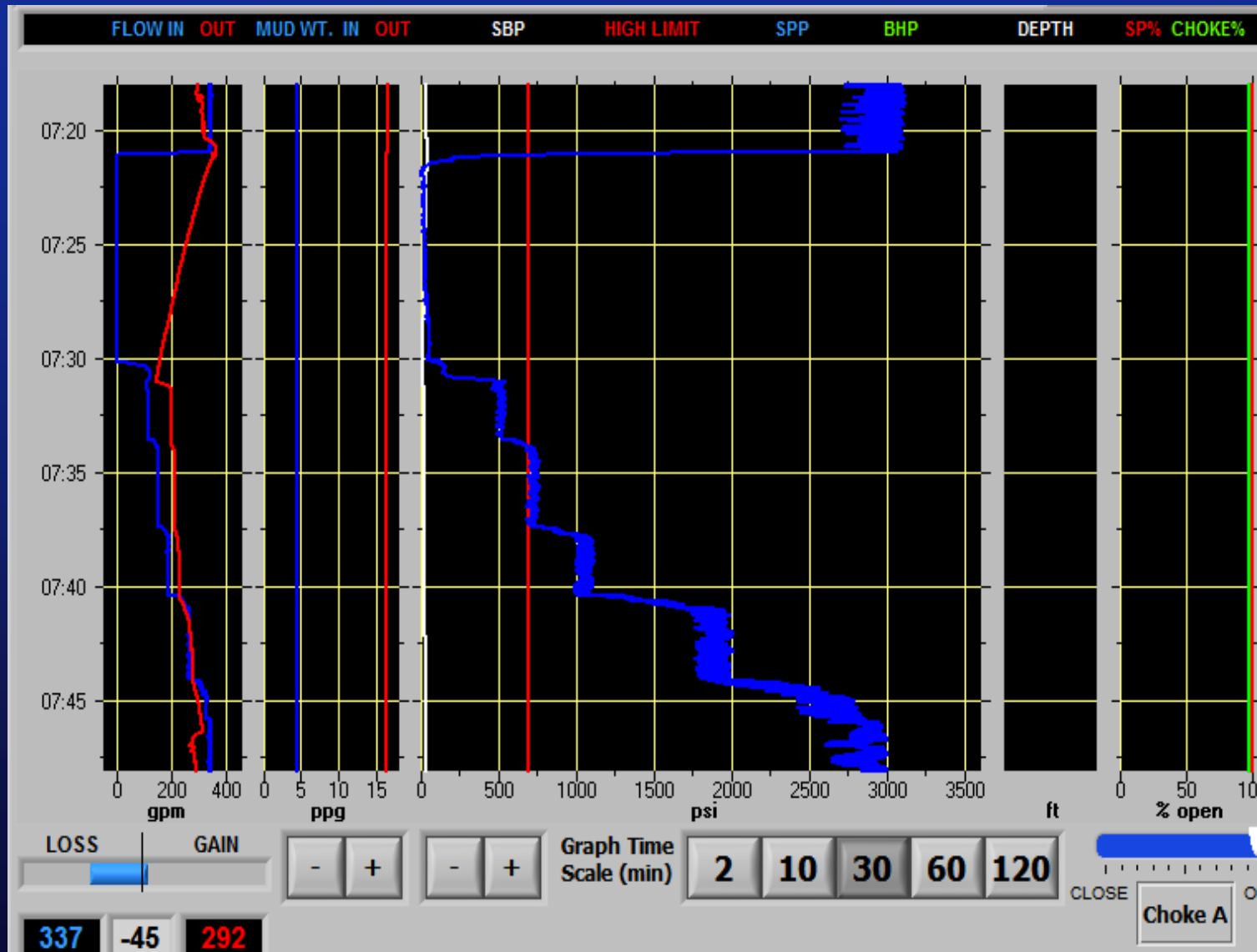
Ballooning Formation – decreasing trend



Ballooning Formation



Ballooning Formation – a Clear Picture



Kick Tolerance

- Kick Tolerance = the volume of gas that can safely be shut-in and circulated out without breaking down the last casing shoe
- Company policy states kick tolerance limits – and management approval is required for low kick tolerance volumes (<25bbls?)
- Enclosed wellbore systems automatically resist the tendency for the flow to increase. An influx automatically causes an increase in back-pressure. (Not the case for “Open to Atmosphere” systems)
- An automated MPD system detects the flow instantly and automatically applies back-pressure, stopping an influx and matching inflow to outflow very quickly
- As the use of MPD becomes “normal practice”, Drilling Engineers will design wells with deeper casing seats – even removing intermediate casing strings. Why design for a 25bbl kick when MPD reduces the influx to less than 10% of this figure?

MPD – Conclusions

- MPD forces Drilling Engineers & Supervisors to change their ideas – **there is a better way.**
- Conventional methods are often used well past the time that economics dictate a new approach is required – **often wasting US\$ millions on a well.**
- Enclosed wellbore solutions are inherently safer and more efficient than conventional “Open to Atmosphere” systems – **a well in “MPD Mode” is a well in “Safe Mode”).**
- Many examples exist where MPD delivered a well when conventional methods failed – **in fact this is the target market for MPD**