Definitions and Backdrop

• “Managed Pressure Drilling (MPD) is an adaptive drilling process used to 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.”

• **Dual Gradient Drilling (DGD)** is one of the 4 variations of MPD.
  – The others are Constant Bottom Hole Pressure, Pressurized MudCap Drilling and Returns Flow Control (HSE).

• **Dual Gradient Drilling (DGD):** Creation of multiple pressure gradients within select sections of the annulus to manage the annular pressure profile. Methods include use of pumps, fluids of varying densities, or combination of these.

• Industry has tried to accomplish DGD with the lighter density being provided by solids, liquids and gases.

What Differentiates These Efforts?
DGD Approaches and Systems
(Deployed Before or After the BOP)

Pre-BOP DGD Systems
- Riserless Mud Return
- *Subsea MudLift Drilling
- *Controlled Mud Pressure
- DeepVision

Seabed Pumping
- Shell Subsea Processing System
- Continuous Annular Pressure Management
- Light Weight Solids Additives
- *Low Riser Return System
- *Delta Vision

Post-BOP DGD Systems
- Dilution
  - With Liquids
  - With Solids
  - With Gas

Mid-Riser Pumping

Available
- AGR
- GE/Hydril
- AGR
- Transocean
- Ocean Riser Systems

Active
- Inactive (Transocean)
- Inactive? (Shell)
- Active
- Inactive? (Mauer)
- Inactive
- Active
- Inactive (Transocean)

*Note: These systems can be classified as, “Controlled Riser Fluid Level” systems under the IADC MPD Screening tool under development.
Pressure Profiles in Deepwater Environments
Conventional Drilling

Seafloor

Depth

Seawater Hydrostatic

Surface Casing

Single Gradient Density at TD

Casing Points

Fracture Pressure

Pore Pressure

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Pressure Profiles in Deepwater Environments
Mid-Riser Pumping, Seawater Density in Riser
Pressure Profiles in Deepwater Environments
Seabed Pumping, Seawater Density in Riser
Pressure Profiles in Deepwater Environments
Mid-Riser Pumping, Gas Density in Riser
Continuous Annular Pressure Management (Transocean)

Light drilling fluid is pumped down the annulus formed between the drilling riser and an inner riser (example: 16” casing string) or using dedicated booster lines.

It mixes with the return mud from the wellbore and creates a lighter density mud in the drilling riser.

The mud is processed through centrifuges to separate into the light dilution fluid and the heavier drilling fluid.

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Courtesy of: Transocean Ltd.
CAPM Dual Gradient Well Design with 3 Casing Strings
CAPM Dual Gradient Well Design with 1 Casing String and Sub-Mudline Injection
SubSea MudLift Drilling (GE/Hydril)

A sea-water driven positive displacement pump (MLP) is located above the BOP/LMRP. It withdraws the mud from the well and pumps it back to the surface through a line attached to the drilling riser.

The riser is filled with a seawater-density fluid, or the mud/riser fluid interface can be maintained at any depth.

A Subsea Rotating Device (SRD) sits above the MudLift Pump which can be used to rapidly change the pressure profile in the well.

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Courtesy of: Chevron
SubSea MudLift Drilling Pressure Profiles
(Mudline Positive Displacement Pump)
High density mud below the mudline, seawater density in the riser

Any WD up to 10,000'

Seawater Hydrostatic
Surface Casing
TD
Pore Pressure
Fracture Pressure
Casing Points
Dual Gradient Density at TD

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Controlled Mud Pressure (AGR Subsea)

A disk-pump (head pump) is suspended from the rig and placed near the seabed.

The pump withdraws the mud from the well above the BOP/LMRP and returns it to the rig through an external line.

The riser is filled with seawater.
Controlled Mud Pressure (CMP) Pressure Profiles
(Mudline Head Pump)

(High density mud below the mudline, seawater density in the riser)

Any WD up to 5,000'

Depth

Pressure

Seawater Hydrostatic

TD

Surface Casing

Seafloor

Casing Points

Dual Gradient Density at TD

Fracture Pressure

Pore Pressure

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Low Riser Return System (Ocean Riser Systems)

A pump is suspended from the rig to a fixed depth in the seawater column.

It is attached to the riser, where the mud is withdrawn from the wellbore and returned to the rig through an external line.

The riser is evacuated and flushed with nitrogen, and the gas/fluid interface in the riser is managed.
LRRS Drilling Pressure Profiles
(Pump at fixed depth below sea-level)
(High density mud below the lowered mud level, gas above this dynamic level)

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Thank You! Questions of Any of Us?

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