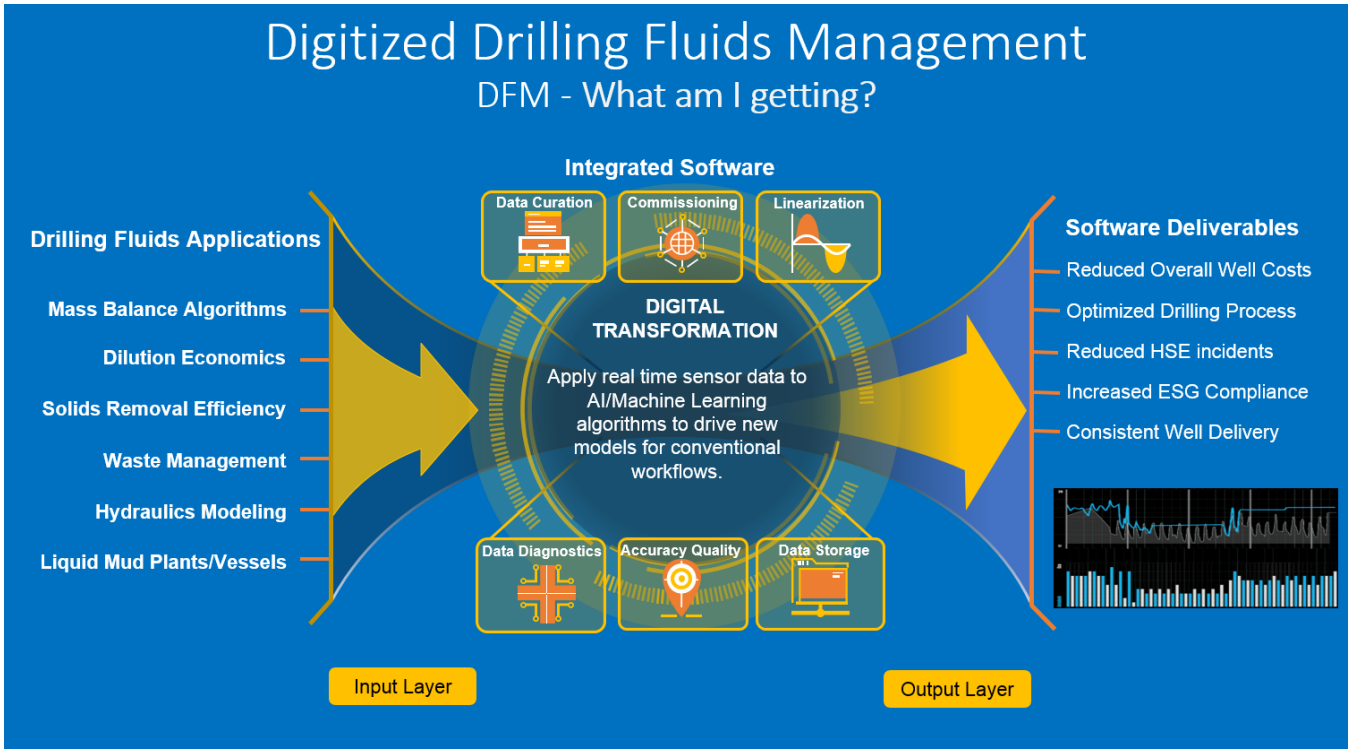
Digital Fluids Management

If mud touches it, we should digitize it!

To recap this past years' worth of **Knowledge Transfer**, we have introduced eight initiatives that have paved the way toward a Digitized Drilling Fluids Management System. No one initiative is going to change the drilling industry by itself but a combination of these initiatives that make up the overall digital solution is the right way forward. One sensor at a time, a digital transformation.



1. ***Digitized Mud Mixing:*** We talked about the importance of digitizing the mud mixing process. A highly sheared, well blended mud has many benefits, the sensors will help quantify the mixing consistency or "mixing index". This will provide a feedback loop as to the current status of a premix prior to bleeding into the active circulatory system. Utilizing sensors in the active mud tank will provide feedback as to the consistency of the fluid that is being pumped directly downhole. This is especially important when "mixing on the fly", often times, there is no opportunity to build a premix in a separate pit and bleed it into the active over several circulations. Monitoring the mixing process has huge value and the sensors will help quantify that value.

2. ***Digitized Mud Formulation:*** We talked about digitizing the delivery of a mix sheet or fluid formulation for the derrickman to follow. The software will do the diagnostics to determine what products need to be mixed and when. The derrickman receives a digital mix sheet, generated automatically based on the real time measurement of all the fluid properties. As an advanced deliverable, the generation of an automatic digital mix sheet is the precursor to automated mud mixing. We cannot automatically mix without first generating the mix formulation.

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3. ***Digitized Solids Control Equipment:*** We talked about installing flow rate, density, OWR & LGS/HGS sensors on the centrifuge suction & effluent lines to provide a feedback loop to mechanically control the centrifuge variables for bowl speed, feed rate & back drive. With the sensors providing a full compositional analysis of everything going in and out of the unit(s), material balance algorithms can help us determine equipment efficiencies, quantify what is being recycled back into the active and provide automatic adjustments when fluid parameters drift out of programmed specification. Because we can quantify the efficiency of the centrifuge(s), we can then infer the efficiency of the shale shakers. This is the heart of all that is drilling fluids engineering, the management of solids should be given the upmost attention. Digitizing this process will create huge value in that solids removal impacts every other workflow on the rig.

4. ***Digitized Waste Management Monitoring:*** We talked about using the sensors to provide real time feedback as to what we are generating for waste both volumetrically and compositionally. That means the sensors will be monitoring the volume of rock generated at the bit vs what volume of rock is being removed from the well vs what volume of rock is being removed from the mud, all in real time. The sensors measure the % oil on those cuttings being discharged, quantify using material balance as to what is being hauled off location. Digitizing this process will draw attention to our drilling fluids management "best practices", it will force us to optimize the process to reduce the volume of waste being generated.

5. ***Digitized Waste Management Facilities:*** We talked about digitizing the QA/QC of all fluids moving in and out of a waste management facility. This deliverable fits very nicely into our ESG (Environmental Social Governance) compliance by quantifying exactly what is being processed, recycled, returned & reused. Increased awareness of the overall system performance is a good KPI to monitor, it will help with identifying areas for improvement and ways to reduce our overall environmental footprint, a cradle to grave monitoring capabilities.

6. ***Digitized Liquid Mud Plants:*** We talked about instrumenting the mixing plant to deliver a QA/QC report of everything moving in and out of the plant. Maintain a quality control tracking system of fluid reconditioning, fluid disposal, fluids recycled, and fluids built. Quantifying compositional analysis using quality control checks captured in real time ensures the deliverables are within the programmed specification of the drilling program.

7. ***Digitized Marine Vessels:*** We talked about instrumenting the supply vessels to include at minimum flow rate, density & OWR. Vessel captains have a thorough record of the movement of all fluids being transferred on and off the vessel. Provides a QA/QC reporting trail of the movements of fluids between the vessels and the rigs.

8. ***Digitized Mass Balance of the Well:*** We talked about digitizing the mass flow of fluids going in and out of the well in real time. Flow rate & density are the two most fundamental fluid properties we utilize in the well delivery process. They both absolutely should be digitized, and it should be a non-negotiable on every rig. The material balance of fluids going in and out of the well goes far beyond well control. While well control should be at the top of the list as to why we would want to measure

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flow rate & density in real time and reason enough to go ahead and digitize it, the truth is, mass flow has so much more untapped value in other aspects of the well delivery process.

- Early kick detection vs ballooning
- Loss circulation severity and “thief zone identification”
- Identify induced fractures vs natural fractures.
- Quantify hole cleaning efficiency and cuttings bed height.
- Quantify the efficiency of any sweep pumped.
- Quantify the effectiveness of a bottoms up.
- Identify sloughing shale and wellbore instability issues.
- Minimize slops generated during a wellbore displacement.
- Calculate a barite sag index in real time.
- Improved cementing operations
- Enhance the current hydraulics models using mass balance data.

Mass Balance Principles:

SUCTION LINE MEASUREMENT

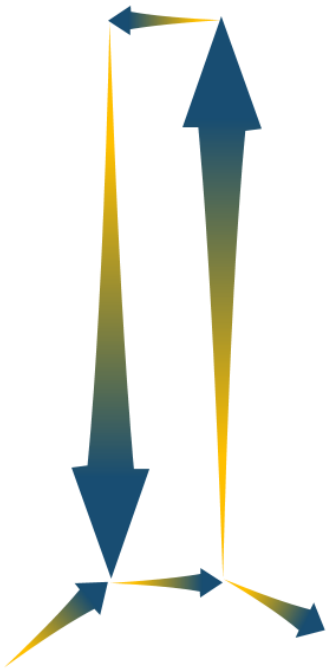
$Density_{IN}$ – 9.3 ppg
$Flow\ Rate_{IN}$ – 500 gpm
$Mass\ Flow\ Rate_{IN}$ – 4650 lb/min
Use 2 x mass flow meters to collect mass flow rate going into the well through each mud pump

Assumptions

Cuttings Density
Cuttings Porosity
Cuttings Expansion
Washout Percentage
Gas Effects
Temperature Effects
Mud Pump Efficiency @ 96%

CUTTINGS GENERATED

$Density_{CUTTINGS}$ – 18.35 ppg
$Flow\ Rate_{CUTTINGS}$ – 4 gpm
$Mass\ Flow_{CUTTINGS}$ – 150 lb/min
Cuttings generated is calculated from the ROP & Bit Size



FLOW LINE MEASUREMENT

$Density_{OUT}$ – 9.4 ppg
$Flow\ Rate_{OUT}$ – 495 gpm
MF_{OUT} – 4653 lb/min
Use the AFH (annular flow height) to capture accurate density measurement at bell nipple.
Use pressure data to enhance flow measurement

Algorithms / Calculations

Early Kick Detection vs Ballooning
Formation Fluid Loss Severity
Hole Cleaning Efficiency
Quantify Sweep Efficiency
Circulating bottoms up excessively long
Lag Time / Lag Volume Calculations
Barite Sag Monitoring

FORMATION LOSSES

$Density_{LOSSES}$ – 9.3 ppg
$Flow\ Rate_{LOSSES}$ – 5 gpm
$Mass\ Flow_{LOSSES}$ – 46.5 lb/min
Calculate the mass flow of the losses using a combination of delta calculations

If we are not measuring it, we are not controlling it!

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