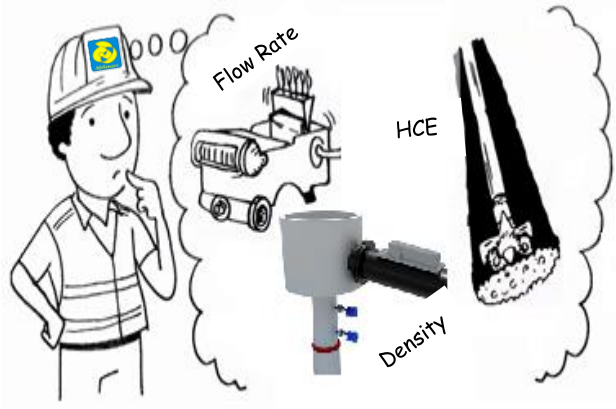
FLOW RATE & DENSITY – TOOLS IN OUR TOOLBOX

What are the two most critical roles of your driller?

- ✓ To monitor the well for **Gains & Losses**, our drillers need to always know their fluid movements, its vitally important, it's not something anyone wants to get wrong.
- ✓ To monitor the well for the amount of drilled cuttings being removed, our drillers need to always know their **Hole Cleaning Efficiency**, we excavate large volumes of rock and our drillers need to know that we are adequately removing the drilled cuttings from the well.



How can we help our drillers meet their two most critical objectives?

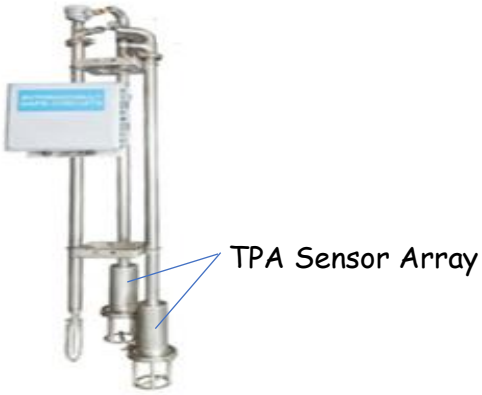
✓ We need to provide our drillers with the information they need to do their job effectively using real time **Instrument Data**, we must give our drillers the right tools to do their job.

✓ We need to provide our drillers with **Data Analytics**, alarms, alerts, early warning indicators of things that matter, things that can impact our drillers deliverables. We don't need to place more information in front of our drillers, we need to place the right information in front of our drillers.

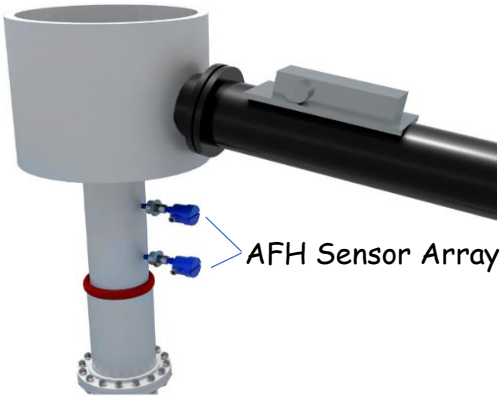
What sensors would help our drillers with their two key deliverables?

✓ Flow Rate & Density going in and out of the well in real time

TPA – measures density at the mud pump suction, flow rate is captured from the mud pump stroke counter converted to volumetric flow rate.



AFH – measures volumetric flow rate & density at the flow line, directly in the bell nipple, partially filled pipe application.



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What data analytics can be extracted from Flow Rate & Density?

1. **Gains & Losses** can be inferred using a delta calculation between what volumetric flow went into the well vs what came out. Any gain/loss will be captured, quantified, totalized, and presented to the driller as gain/loss information, reliable, actionable data. The data diagnostics that can be applied to the alarms & alerts will help the driller with critical decision making.
    a. Early kick detection
    b. Loss circulation severity
    c. Ballooning signature pattern
    d. Identify natural fractures vs induced fractures based on the signature pattern of the delta flow loss
    e. During cement operations identify cement top verification based on delta flow data
    f. Reduce slops generated during oil based mud displacement based on density delta between mud and brine spacer
    g. Barite sag can be identified quickly and clearly based on delta density in & out
    h. Completions operations can monitor density of the clean up train of each fluid type as it circulates out of the wellbore
    i. Lag time/lag volume calculations

2. **Material Mass Balance** means we convert all our data into mass flow outputs, simply flow rate x density = mass flow rate
    a. Flow Rate IN x Density IN = Mass Flow Rate IN (at the mud pumps)
    b. Mass Flow Rate at the Bit = based on the hole size and rate of penetration we calculate the mass flow rate of cuttings generated at the bit.
    c. Flow Rate OUT x Density OUT = Mass Flow Rate OUT (at the flow line)
    d. Calculate the delta on the mass flow of drilled cuttings generated vs what was physically removed at surface through the AFH sensor. This information will be quantified, totalized, and sent to the driller as Hole Cleaning Efficiency data. This data can be used to extract other valuable data diagnostics:
        i. Cuttings carrying index
        ii. Sweep efficiency
        iii. Quantify a bottoms up circulation
        iv. Identify leading indicators of cuttings beds forming
        v. Identify sloughing shale

Couple material mass balance with real time hydraulics to gain a complete picture as to what is going on downhole. Adding additional sensors for PV/YP and OWR can open up a window into drilling optimization that has never been viewed before. The overall objective is to create consistency to our drilling process, we need to minimize the NPT events experienced, uncover areas to improve ILT, reduce the number of days on well as well as minimize overall risk associated to well delivery. We do this by starting off our digital transformation with flow rate & density.

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