Performance Comparison of Commonly Used Surface Flow-Meters

WELL INTEGRITY PLATFORM

WIP Knowledge

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The detection of losses and kicks in real time in accurate manor is extremely important to the integrity of the wellbore and safety of the rig site. Fundamentally kicks occur when the wellbore hydrostatic pressure falls below formation pore pressure, causing the well to become underbalanced; this allows unwanted fluids to enter the wellbore[1]. In contrast losses happen when the opposite occurs when the mud weight is too high and the wellbore pressure exceeds formation fracture resistance, causing fluids to enter into the formation. This can also happen when encountering natural fractures or by inducing fractures and also this can occur in very permeable or unconsolidated formations[2]. Multiple causes for both scenarios exist, such as a high equivalent circulating density, surging, swabbing, depletion, and formation pressures being lower or higher than were expected[3]. These scenarios can become expensive in terms of both time and money. Therefore, it is vital to find suitable ways to monitor the wellbore. One of the methods that is used to continuously monitoring the wellbore is delta flow. Delta flow method simply is monitoring and comparing the flow rate in and out of the well to give direct and quick indication of the loss and kick events. Calculating delta flow is simply done by subtracting the flow into the well from the flow out of the well. A positive value indicates a kick and a negative value indicates fluid loss to a subterranean location[4&5]. The majority of inflow measurements today are still done by counting the strokes of the mud pumps. By knowing the displacement volume per stroke and the efficiency of the pump the inflow volume can be determined. Other more accurate methods that use Coriolis flow-meters; in this case a Coriolis flow-meter is installed between the active mud tank and the mud pumps. In other hand, flow-meters used to measure the flow out rate is normally installed in fluid return line as close to the bell nipple as possible so to get the fastest measurement of fluid flow. When flow rate is measured in the fluid return line the fluid is usually contaminated with cuttings form the drilling process as well as possibly small gas bubbles and wear material from the drill string or the casing. So the measured fluid can by no means be described as a pure fluid which brings some challenges in measuring its flow, hence the application of some commercial flow-meters is not feasible. The type of measurement used by most of available flow-meters can be split into two main categories based on their measurement output, mass flow or volumetric flow. Mass flow is the amount of mass moving through an instrument over time, so the unit of measure is mass per amount of time whereas volumetric flow is the measure of a substance moving through a device over time. The main advantage of the mass flow flow-meters over volumetric flow-meters is that mass or weight does not change depending on the temperature or pressure[6]. Figure 1 illustrates all flow-meters that use methods of obtaining the volumetric or mass flow rate without obstructing elements in the flow path such as turbine or vortex flow-meters do.

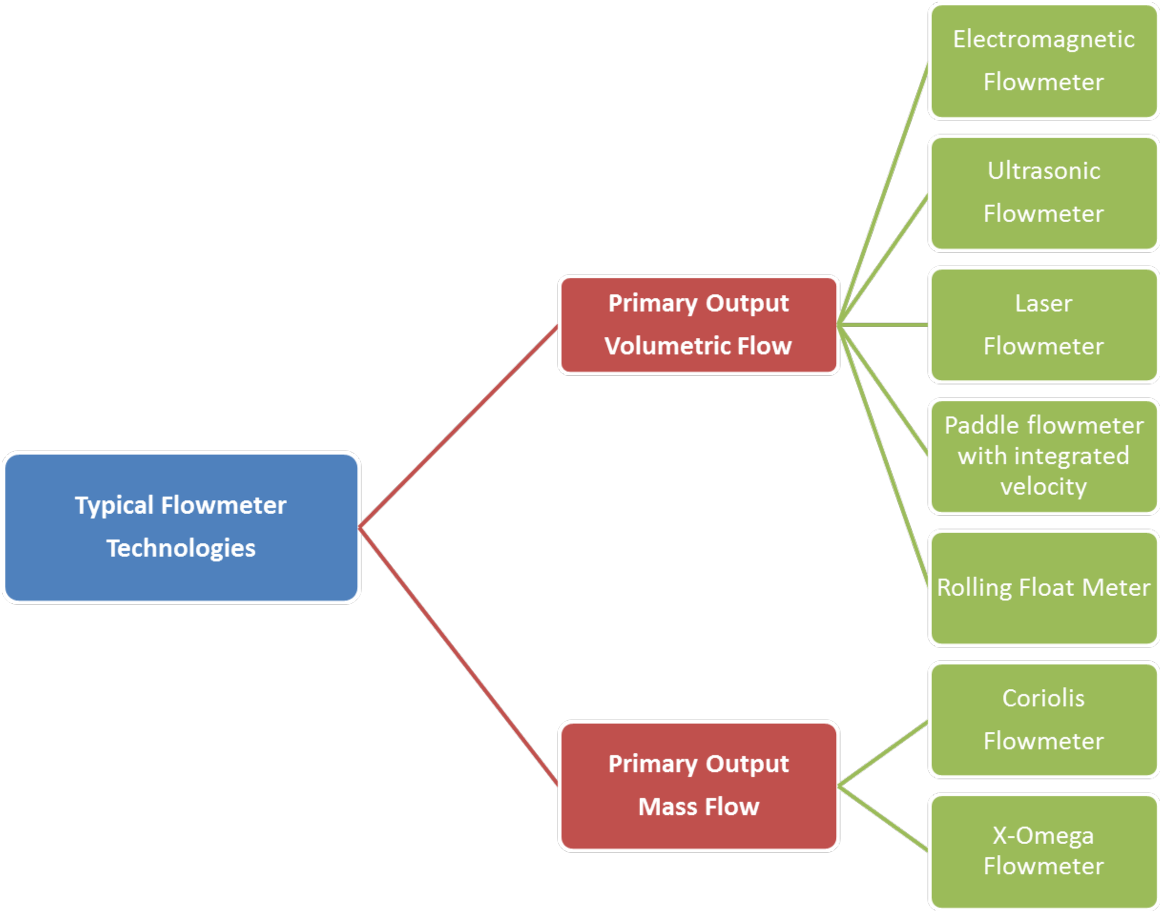

Figure 1. Typical Flow-meter types used at the rig site. Modified from Wyatt, 2013[7]

The overall performance of any flow-meter is driven by multiple factors, such as:

- Effect of the pressure drop,
- Regular maintenance required,
- Type of drilling operation,
- Existing system,
- Effect of the fluid properties,
- Cost,
- Rig footprint changes required.

Thus the criterions used to select the best flow-meter vary and depend on the environment of use. The matrix diagram below shows how well the different types of flow-meter fulfill the requirements for flow measurement on drilling rigs with regards to their capability of delivering accurate and effective measurements. The flow-meters are ranked with the specific applications using a color coding system with green indicating good, yellow indicating marginal and red indicating poor. The more reliable and accurate the flow-meters are the greener segments are visible.

Flow-meter Type	Pressure Drop	Accuracy	Low Maintenance	Slurry Flows	Viscosity independent	Non-Conductive Fluids	Non-Intrusive	Closed System	Open System	Cost
Coriolis[8]	Yellow	Green	Green	Green	Green	Green	Green	Green	Yellow	High
X-Omega[9]	Yellow	Green	Green	Green	Green	Green	Green	Green	Red	High
Electromagnetic[10&11]	Green	Yellow	Green	Green	Yellow	Red	Green	Green	Yellow	Middle
Laser[12]	Green	Yellow	Green	Green	Yellow	Green	Green	Red	Green	Middle
Ultrasonic[13&14]	Green	Yellow	Green	Yellow	Yellow	Green	Green	Yellow	Green	Middle
Rolling Float[15]	Green	Red	Yellow	Green	Green	Green	Green	Red	Yellow	Low
Paddle with Integrated with Velocity Measurement[16]	Green	Red	Green	Green	Green	Green	Green	Red	Yellow	Low

Figure 2. Matrix for flow-meter performance evaluation (Green = good/Red = poor/ Yellow = marginal). Modified from Emerson Process Management 2009**Fehler! Verweisquelle konnte nicht gefunden werden.**

As mentioned earlier, depending on the environment of use whether in a closed system or open system a different type of flow-meter might be the best option. Coriolis or a X-omega would be best suited to a closed system as they can form part of the flow system and they need limited maintenance allowing for constant flow measurement also with this type they are able to measure the mud density as well. So, they could be used in MPD (managed pressure drilling) and UBD (underbalanced drilling) applications because in these drilling environments accurate flow in and flow out data along with an accurate drilling fluid density measurements are needed. In contrast for an open system applications, other flow-meters will be preferred, such as the laser flow meter and possibly the ultrasonic would be suitable because they both offer high accuracy and reliability comparing to rolling flow-meter and piddle. However, Electromagnetic flow-meter can be an alternative of both of them in case only water based mud will be used.

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