Industry: Oil & Gas

- **Separator Outlet Flow Measurements**

Application Note

SONARtrac® Solutions

SONARtrac*® meters allow accurate measurement of separator outlet flows in the presence of liquid carry-over and gas carry-under

The Challenge

The vast majority of the world's oil production is allocated using separator-based measurements. Test separators determine individual well production; and high-pressure production separators are often used to allocate production from individual fields prior to the commingling of produced fluids for further processing. The accuracy of these measurements is based on the assumption of complete separation of the gas and liquid phases.

However, the measurement of oil production includes many variables ranging from varying crude oil properties, water cut, and gas-oil ratios to varying production rates, pressures, and temperatures. Given this variability associated with oil production, completely separating the gas and liquid phases prior to measurement often becomes difficult, if not impractical, to achieve.

Although the variable amounts of gas present during the measurement of the liquid phase and the variable amounts of liquid present during the measurement of the gas phase are often small, the presence of these secondary phases causes most gas and liquid flow meters to over-report the amount of product flowing through the lines. Errors due to incomplete separation are often the largest source of error in well and field allocation measurements. These errors distort the reservoir engineer's view of well-by-well production and introduce systematic errors in the fiscal allocation of production. Measurement errors due to incomplete separation can be avoided by directly measuring and compensating for secondary phases in separator outflows.

Liquid Outlet Solutions

The volume of liquid flowing through the separator liquid outlet is typically measured using turbine, positive displacement, or coriolis meters. The accuracy of the liquid flow rate measurement depends in large part on the conditioning of the liquid stream. Entrained gases present in the liquid typically cause the primary flow measurement device to over-report volumetric flow rate and, where applicable, under-report liquid density. The errors in interpreted liquid flow rate are generally correctable to a high degree of accuracy, provided that the amount of entrained gas is known.

Entrained gases present in a flow meter on a liquid outlet can be traced to two primary sources, either gas carry-under and/or gas break-out. Gas carry-under is due to small gas bubbles being entrained in the liquid as it leaves the separator. Only the smallest bubbles are carried-under, with the volume fraction of gas carried-under increasing with increasing flow rates through the separator. The other primary source of entrained gas at the measurement location is due to gas-breakout. Ideally, liquids exit a separator at saturated conditions. This liquid, however, still contains significant amounts of dissolved gases. Typically, these dissolved gases will continue to outgas from the liquid with decreases in pressure below separator pressure.

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Pressure losses due to flow through piping prior to measurement, and pressure losses due to the flow measurement device itself can lead to additional outgassing prior to measurement. Fortunately, from a measurement perspective, the source of the free gas in the liquid leg has no bearing on its effect on the flow measurement. The impact of free gas on measurement accuracy scales directly with the gas void fraction.

SONARtrac Gas Volume Fraction meters provide an accurate measure of the amount of entrained gases in a liquid continuous mixture by measuring the speed at which one-dimensional sound waves propagate through the mixture. *SONARtrac* meters measure the entrained gas void fraction from 0.01% to 20% to within 5% of reading, offering an unprecedented ability to quantify entrained gas levels. This measurement is then used in a straightforward manner to correct the output of the primary flow measurement device in order to accurately report the liquid flow rate and liquid density, where applicable. For most applications the actual volumetric flow of gas through the liquid leg has a negligible effect on the total gas rate reported by the separator.

Gas Outlet Solutions

Liquid carry-over in the gas outlet from the separator is typically in the form of small liquid droplets entrained as a mist. The amount of liquid carried-over can vary greatly, however liquid carry-over estimates of 2% to 3% of the liquid inlet rate are not uncommon. The impact of liquid carry-over is two-fold. First, the liquid droplets cause differential pressure-based (DP) gas flow meters, i.e. orifice plates, v-cones and venturi meters, to over-report the gas flow rate in proportion to the wetness. Second, depending on the gas-oil ratios and other parameters, the liquid rates passing through the gas leg can constitute a meaningful percent of the total liquid rates.

A *SONARtrac* flow meter used in combination with a DP flow meter enables accurate measurement of the gas flow rate and wetness. DP meters over-report the flow rate of wet gases as a function of Lockhardt-Martinelli number, a non-dimensional measure of the wetness of the gas. *SONARtrac* volumetric flow meters accurately report gas flow rate, independent of wetness. Thus, for dry gases, properly calibrated DP and *SONARtrac* meters will be in agreement. For wet gases, the *SONARtrac* meter continues to accurately report the mixture flow rate, with the difference in the reported flow rates providing a measure of the wetness. Thus, in addition to providing an accurate measure of the volumetric gas flow through the gas outlet, the combination of the *SONARtrac* flow meter and DP flow meter provides an accurate wetness measurement of the gas. The additional liquids flowing through the gas leg (i.e. wetness) can then be added to the liquid leg flow rate to report a total liquid rate through the separator.

System Integration

In the presence of incomplete separation, the determination of oil, water and gas rates involves the coordinated output of each of the separator outflows. This coordination can be effectively implemented using a Separator Outflow Computer (SOC). The SOC combines the outputs of the primary separator flow and density measurement devices with the *SONARtrac* meter outputs to provide secondary-phase-corrected measurements of the produced oil, water and gas flow.

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