MEMBRANE-BASED GAS SENSING FOR ROBUST PAY IDENTIFICATION

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Abstract

We have field tested a non-traditional gas sensor that shows exceptional performance for quick response and robust sensing of hydrocarbon gases in drilling fluid. Immediately realized benefits include

- greatly reduced chance of missing the identification of pay zones,
- better characterization of hydrocarbon shows and
- increased drilling safety

through the such factors as

- the reduction in time between the drilling penetration of a formation and

the transmission of the mud gas data to the drilling operator and the evaluation engineer/geologist, and

- a robust detection and quantification of the gas regardless of over- or underbalance condition, mud weight, or mud composition (water-, oil-, synthetic- or foam-based).

This sensor, based on existing membrane technology and an efficient extractor/detector configuration (Brumboiu, 2000), has been successfully field tested and its performance validated in a high pressure gas well drilled with oil-based mud. This type of sensing technology has shown tremendous potential for high-temperature/high-pressure drilling environments and underbalanced drilling, as well as traditional drilling environments.

Existing technology for gas sensing while mud logging incorporates a dependence on the ubiquitous gas trap, either in traditional, inconsistently manufactured form or in modified forms attempting to quantify the true mud-gas concentration ((Wright, 1993; De Pazzis, 1989). The problems inherent with all the current applications include the need to characterize the extraction efficiency of the gas trap in a continuously changing mud return stream, the dilution of the extracted gas with large proportions of air (adversely affecting the lower detection limits), the optimal physical placement of the gas trap in an environment that is constantly changing due to both changing drilling conditions and human operator intervention, the physical size of the equipment, and the distance the extraction point remains from the detection instrumentation. The new gas probe is small, physically robust with respect to extraction efficiency and calibration, has no moving parts aside from a low-volume air pump, can be inserted into a mud stream virtually anywhere in the return mud line, and uses a simple sensor located about 2 meters from the extraction point.

We will discuss the results of the field test, run in a high-density oil-based drilling fluid, by

- objectively evaluating the sensor performance in terms of accuracy and consistently robust operation,
- comparing the sensor performance against a traditional gas trap/total HC analyzer and
- comparing the results of both the gas trap and membrane sensor systems with laboratory measurements of mud gas concentration.

Introduction

Conventional technology uses an agitated flash separator, the "gas trap", Figure 1 (Wright, 1993) to remove a portion of the gas from the drilling fluid, and then pulls a sample of the gas phase into the logging unit, where it is analyzed. The problems inherent with all the current applications, which are based on this "gas trap" technology, include

- the need to characterize the extraction efficiency of the gas trap in a continuously changing mud return stream,
- the dilution of the extracted gas with large proportions of air (adversely affecting the lower detection limits),

- the optimal physical placement of the gas trap in an environment that is constantly changing due to both changing drilling conditions and human operator intervention,
- the physical size of the equipment,
- water vapor condensing in the suction line from the trap to the logging unit (a particular problem when air temperatures are below freezing) and
- the distance the extraction point remains from the detection instrumentation (sometimes well over 100m).

The new gas probe, shown in Figure 2,

- is small (about 15 cm in length),
- is physically robust with respect to extraction efficiency and calibration,
- has no moving parts aside from a low-volume air pump,
- can be inserted into a mud stream virtually anywhere in the return mud system (either into a mud return pipe, at the bell nipple or at the shaker box),
- uses a simple sensor located about 2 meters from the extraction point, and
- includes control, calibration and measurement electronics in a sealed module with a low-voltage digital output (WITS format) compatible with virtually all well-site data logging systems.

The gas probe consists of a very thin polymer tubing wound around a stainless steel mandrel (Figure 2-b). Hydrocarbons are extracted from the surrounding fluid, through the walls of the polymer tubing, into a flowing air stream, which carries the hydrocarbons to a detector which measures the total hydrocarbon content of the stream. The detector output signal is digitized, calibration factors appropriate for the type of drilling fluid (water-, oil- or synthetic-based) are applied, and the result, the concentration of total hydrocarbon in the drilling fluid, is transmitted to the data logger.

Field Test Results

The gas probe was field tested at a gas well in South Texas. During the week-long test, the well was being drilled with a 16 ppg hematite-weighted, diesel-based mud. Downhole mud temperatures ran about 290 °F; at the surface location of the probe (in the shaker box at the exit of the mud return line), the mud returns were measured to be 150 °F.. The distance from the probe, which was inside the shaker box, to the detector was approximately 6 feet. Output from the detector, WITS formatted digital ASCII data, was sent at six-second intervals through a shielded cable approximately 200 feet to the mud logging unit. In the unit, data was simultaneously recorded from the Total Gas Analyzer (gas from the trap) and from the membrane probe.

A comparison of the two data sets is shown in Figure 3. The traditional mud log gas monitoring and analytical system was calibrated daily and had undergone a complete QC check before the comparison test was performed. The data from this equipment, total gas (HC) concentration measured with a classic flame-ionization detector, are considered to be of high quality and consistent with what is currently being acquired in our onshore and offshore mud logging operations.

Several things were consistently observed during the duration of the test, and can be seen in this plot. First, the gas probe data gave a consistently higher concentration. This is because the probe was calibrated to read the total hydrocarbon gas concentration in the drilling fluid. This calibration was done in the manufacturer's shop, and checked at rigsite, and is found to be relatively independent of the mud rate, mud density, and temperature. The gas concentration measured using the trap, however, is relatively difficult to calibrate because the extraction efficiency is highly dependent upon mud properties, flow rate, trap placement, and air rate which carries the gas to the logger's unit for analysis. Second, the data from the gas probe is less noisy. Third, the gas probe measures changes in gas concentration about 2 minutes earlier than the trap-extracted stream, because of the greater distance the sample must travel from the trap to the logger's unit (in this case, over 100 m, compared to less than 2 m for the gas probe).

The field test lasted for six days, with consistent operation of the probe throughout. Lab calibration substantiated its 2% accuracy specification. Analysis of mud samples collected at rigsite confirmed the measurement capability of the membrane probe, and provided an independent evaluation of the gas trap and membrane probe data.

In summary, with the field test of the membrane gas probe, we see the application of a gas sensor based on a technology completely different from what has been the standard in the oil field for many years. This technology is now available commercially to measure total hydrocarbon gas concentration in drilling mud returns, as part of a manned mud logging operation or as an unmanned, stand-alone monitor. We have seen that the probe performs robustly in an oil-based drilling mud, is relatively insensitive to changes in mud density and flow rate, and, with virtually no attention after installation, performs at least as well as a constantly monitored, well-maintained gas-trap type gas logging system.

In addition to the robust performance with little maintenance, the membrane-type probe offers distinct advantages of simplicity and speed (that is, reduced lag time between gas concentration changes and the time these changes are measured and noted on the drill floor). These advantages can yield better thin-bed resolution from the gas log, more nearly quantitative characterization of a gas show, and safer drilling operations because of quicker response to gas increases. The results of the field test have lead to our deployment of this gas probe onto Shell rigs in the deepwater Gulf of Mexico, including one on which we have logged six months of near-continuous operation with one probe. Under development, as a result of the success and acceptance of this technology, is a gas-chromatographic version of the membrane-based sensor, which will give hydrocarbon compositional information, with the advantages of speed, simplicity and robust performance seen in the current total-gas version.

References

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About the Authors

Dennis Dria is a Senior Research Engineer for Shell International E&P, Inc., in their Technology Applications and Research Directorate. His areas of current research and technology implementation include mud logging, production logging, reservoir monitoring and completions design for sand management. He has also worked for Shell Western E&P, Inc., as a petrophysical engineer, and as a research chemist for the Standard Oil Company. He holds a BS in Physics and Mathematics from Ashland University and a Ph.D. in Petroleum Engineering from The University of Texas, and is the author or co-author of 14 U. S. Patents.

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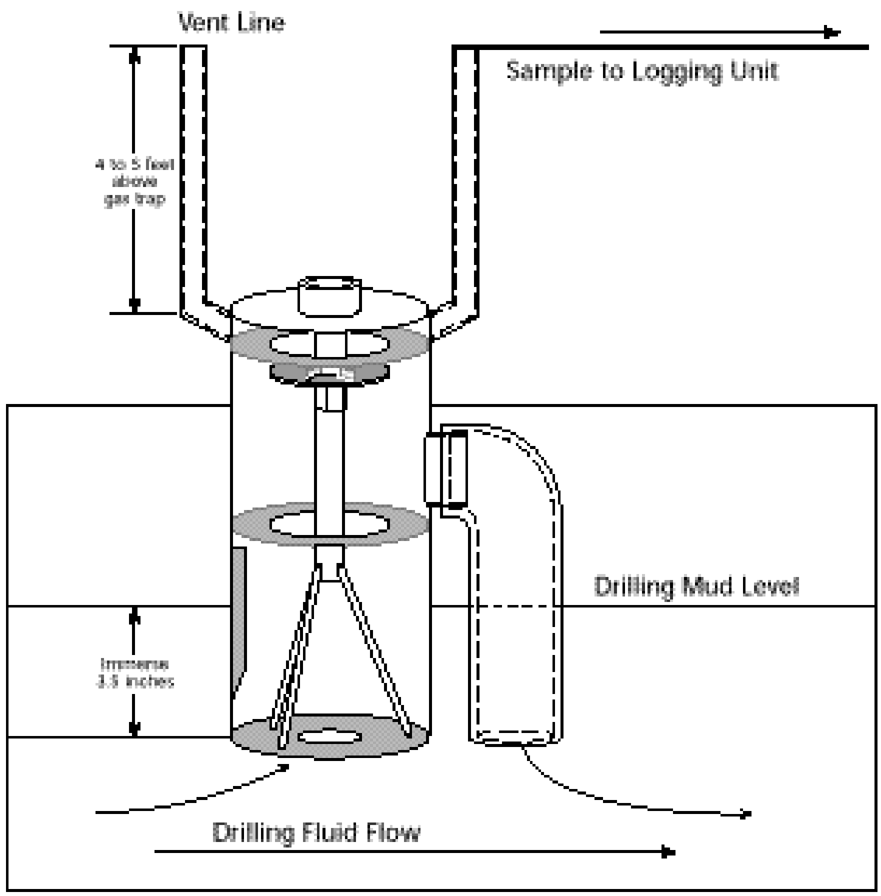

Figure 1: Conventional gas trap for extracting gas from drilling mud.

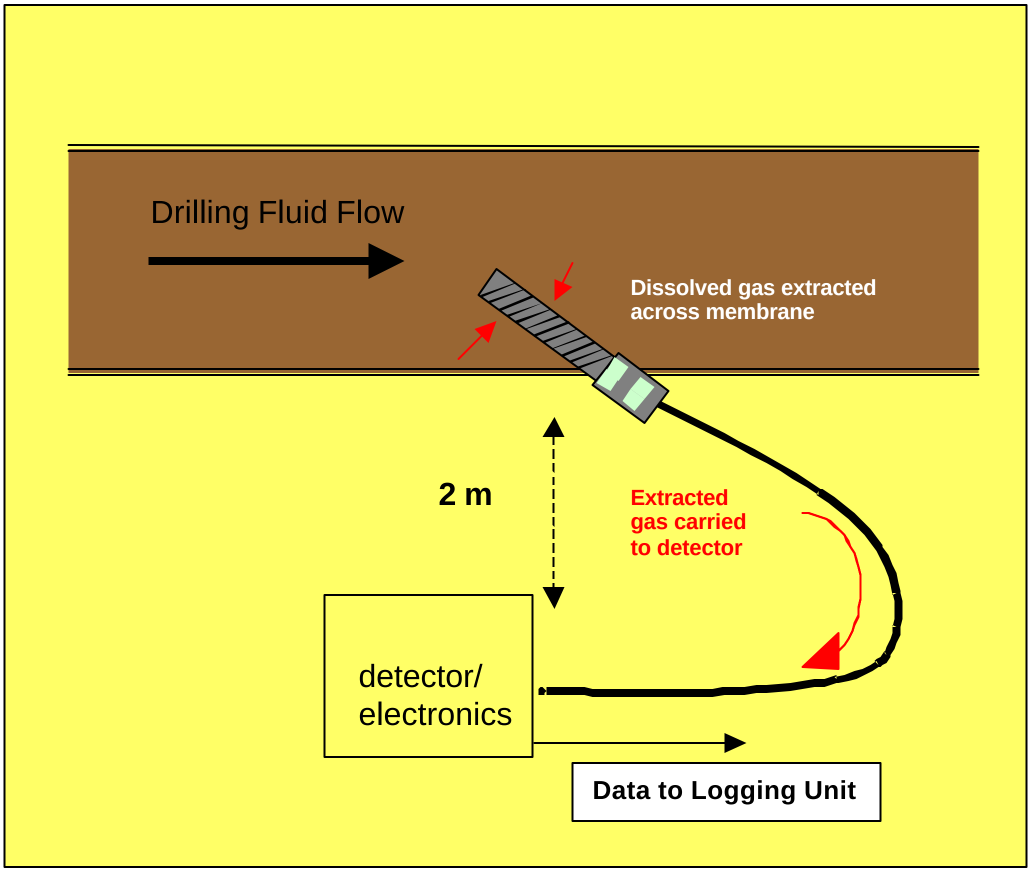

Figure 2-a: Membrane gas extractor positioned in the drilling mud return line.

Figure 2-b: Membrane probe detail.

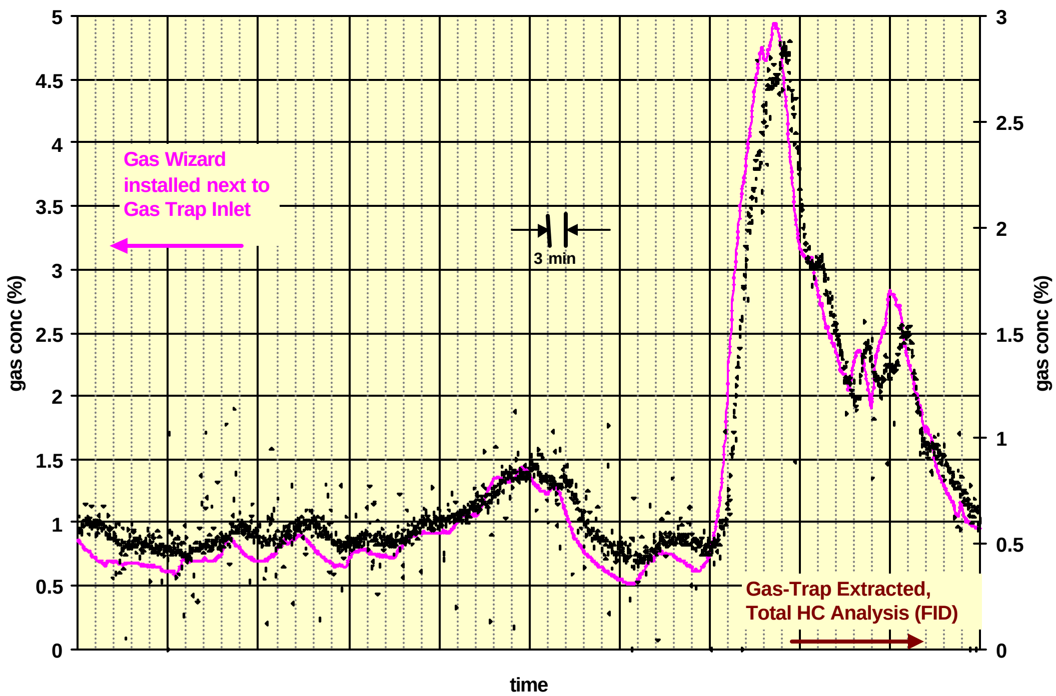

Figure 3: Performance comparison – conventional gas trap and membrane probe. Membrane probe data are the lighter points which fall on a continuous curve. Gas-trap extracted data are the small dots which exhibit a bit more noise.