

## **DESIGN AND OPERATION OF MUDLOGGING EQUIPMENT**

CEARLEY, J.DOUGLAS, Cearley Technology, Graham, TX

### **ABSTRACT**

Hydrocarbon well log analysis instrumentation typically consists of a hotwire, or total gas detector, and a gas chromatograph. Commercial brands of logging systems include Analytical, Aztec, Core Lab, Lee, Roach, Tooke, and Midland Instruments. These systems share a basic flow system design and most utilize a filament type gas sensor.

Gas contained in the porosity of the rock is entrained in the mud flow along with the drill cuttings. Only in the case of underbalance does other formation gas enter the annulus; this may presage a well control problem. Some extremely permeable or fractured formations may instantly flush, if overbalanced, and yield only a very mild gas increase, although they might produce a flowing drill-stem test.

Gas is separated from the mud at the shale shaker by an agitator. The eggbeater action of this device is retarded by high mud viscosity, and less gas may be removed from the mud stream. Flow from the trap to the instruments is typically through 1/4" outside diameter poly tubing; use of 3/8" tubing greatly facilitates system reliability.

A new type of ceramic bead filament allows measurement of gas at levels which previously demanded air dilution of the sample. This filament has a very long working life.

Hotwires are calibrated with 1% methane test gas. Gas from a BIC brand cigarette lighter, which is 100% isobutane, can substitute if diluted and if calculations for the difference in BTU (about 3 to 1) are applied.

### **INTRODUCTION**

Mudlogging equipment has been in use since before World War II; it is a system whereby gas is removed from the drilling mud return and measured in order evaluate the hydrocarbon content of formations. In 1997, a mudlogging unit is a durable travel trailer or skid mounted unit containing a hotwire, or total gas detector, a gas chromatograph, a rate of penetration recorder, and living quarters for a well-site geologist. Other equipment may include pump stroke counters, pit volume indicators, carbon dioxide detectors, and mud resistivity recorders. Toxic gas monitoring is best left to the excellent companies which

specialize in its control. Since the geological staff reduction of oil companies after the last boom, the mudlogger may typically be the only geologist physically present during the drilling of a well.

## **PRINCIPLES**

Gas entering the mud (EXLOG , 1985) is:

$$G=(d/24)^2 * ((\pi*R)/60) * P * S * 7.48$$

Where

G=rate of gas entering the mudstream at reservoir pressure

(gallons/minute)

d=hole diameter (inches)

R=rate of penetration (feet/hour)

P=porosity (decimal)

S=gas saturation (decimal)

To convert to atmospheric pressure take the calculated G from above, multiply by the reservoir pressure (pounds/square inch) and divide the product by 14.7.

When the mud system is balanced, the only gas reaching the surface is from the porosity within the well cuttings. When underbalanced, or near balanced, however, gas may enter the annulus from the undrilled formation. Connection gas occurs in the near balanced situation. When the pump is kicked out, annular friction pressure is lost, reducing the Equivalent Circulating Density of the mud. Also, the swabbing action as the drill string is picked up lowers the E.C.D. The contribution of the swabbing action is on the same order as the loss of annular friction pressure (EXLOG, 1984). To determine the pressure loss during connection, double the calculated annular friction pressure. The swab action during a trip is, of course, much more pronounced, and although it is less when a bit screen rather than a float is used, it is greater and acts over a longer time than

the swab action during a connection. It is for this reason that trip gases are higher than connection gases. Both high trip and high connection gas, together with a general increase in background gas, are precursors to taking a kick. Both the driller and the company representative should be notified immediately if they are present.

## **THE AGITATOR**

Gas flow to the instruments begins at the agitator, or trap, which is suspended in the possum belly of the shale shaker. An electric or air motor turns an eggbeater like attachment which whips the gas from the returning mud. A vacuum line transports this gas, along with air, to the mudlogging unit. Texaco in cooperation with the Gas Research Institute (Wright, et. al., 1993) has developed a new trap design which has had considerable exposure. Some features of this device, i.e. the vent and seal, are similar to the classic Analytical Logging trap, which has been in service for twenty years or more. The port down-comer and the interior baffles are new. In the Analytical trap, the baffle function is performed by a steel riser, which also provides room for moisture fall back and a distance factor in case the agitator mount fails or the mud level rises. A pyramidal agitator is used, which is demonstrated to have a more even return in different viscosity muds than the double C shaped Analytical beater, against which it was tested. The test reveals, however, that the Analytical output is greater under certain conditions. The Texaco device provides a standard output which is desirable for in-field drilling in shale-sand sequences; correlative gas measurement is important in this type drilling. For carbonate reservoirs, particularly those which must be only scratched in order to avoid an oil-water contact, such as the Chappel , Devonian, or Goen Reef, require that the least presence of gas be detected, since it signals that it is time to stop drilling and test

or set pipe. Knowing that Total Depth is near, toolpushers will often raise the viscosity, regardless of instructions on the prognosis. This high viscosity makes it extremely difficult to separate the gas from the mud; typically about 75 Marsh funnel seconds is a cut-off point. This problem is aggravated in a fractured reservoir, since even a slight overbalance may flush the fractures and gas may not be present in the rock matrix. Cearley Technology recommends the use of a drywall compound stirrer, available at any lumber yard, for a beater. This apparatus has a double set of petal shaped plates which are designed to separate air bubbles from sheet rock mud. It has a 3/8" inch shaft, and a stainless steel changeover should be machined in order to connect it to the 1/2" electric motor shaft.

## **FLOW SYSTEM**

Ninety percent of problems with a mudlogging unit occur with the flow system. It is not true that equipment only breaks down when a possible show is drilled. Failure has already occurred; it is then perceived at the crucial moment. It is extremely important to understand the flow design of the mudlogging unit. An ideal system will be discussed, although there is much diversity even among same brand equipment. Flow begins at the trap. The trap must be kept clean, for since it is in direct contact with the mud, plugging is more likely to occur there. The Texaco trap needs refinement with regard to ease of cleaning; the easier it is to perform maintenance, the more probable is that maintenance will be performed. The riser of the Analytical trap should be equipped with a quick coupling connection so that the vacuum line can be removed and water flushed through the trap riser and canister (with agitator power off). This also facilitates frequent butane checks.

A diaphragm type vacuum pump provides flow from the trap to the unit. Flow from the trap to the pump is typically through 1/4" poly tubing, which is highly subject to plugging and kinking. Substitution of 3/8" poly tubing yields excellent results, with Cearley Technology reporting fifty jobs with no plugging. This line should be inspected at the beginning of each job and discarded if any interior discoloration is observed, particularly in winter. A bubble jar filled with ethylene glycol may be installed at the trap in winter, or a small amount of ethylene glycol may be allowed to flow through the poly tubing every few days in order to scrub it of water. Inside the unit, between the poly tubing and the main supply pump, there should be a float type check flow stop, so that if mud does enter the unit, it will not reach the pumps or instruments. A one liter bubble jar filled with 250 milliliters of ethylene glycol should be installed between the fluid stop and the pump. If H<sub>2</sub>S is present, an H<sub>2</sub>S scrubber should be present between the fluid stop and the bubble jar. H<sub>2</sub>S levels should be measured by the safety company that deals with them, but if the clear ethylene glycol turns black, H<sub>2</sub>S is present in the gas flow. Mudlogging instrumentation and personnel have a very short life in its presence.

The pressure side of the main supply pump should be attached to a 10 cubic feet per hour flowrater and through it to an expansion chamber with an outside exhaust. The expansion chamber is necessary because the hotwire and chromatograph do not require all the supply gas delivered by the main sample pump. The expansion chamber should lead to a "Dryrite" column. "Dryrite" is ground anhydrite; some is treated with an indicator that turns from blue to pink when saturated with water, some is in its natural white state. Either type may be reactivated by baking at 150<sup>o</sup>F until dehydrated. It is essential that no water vapor reach the chromatograph column; it is less crucial to the total gas detector.

From this point, there are several different ways to plumb the flow system. The flow system of Midland Instruments equipment is used as an example. The sample gas pump is of the same type as the main supply pump. Its suction side is connected directly to the hot wire filament chamber, and pulls sample gas across the filament, which is enclosed by a diffusion sleeve, from the 4 cubic foot per hour sample flowrater. In parallel with the sample flowrater is an air flowrater of the same capacity. This air flowrater can admit air in order to dilute the sample when high gas levels are encountered, but it is closed in normal operation. The sample flowrater is connected to an air bleed valve which can be operated for butane test or zeroing purposes when needed. If this valve is not present, the lid of the interior bubble jar must be removed to zero the instruments. Downstream from the bleed valve is the main sample "Dririte" column. This completes the hotwire flow circuit.

The chromatograph sample valve taps into the flow circuit between the scrubber and the bleed valve. The carrier air to the chromatograph is generated by a pump of the same type. Its flow is continuous through the chromatograph column, and its suction side is attached to a separate "Dririte" column. Carrier air should be taken from inside the unit in order to maintain a constant temperature. It is essential that there should be no smoking inside the unit while the instruments and pumps are turned on. Tar from the cigarette smoke coats the hexadecane crystals in the chromatograph column and quickly renders it inoperable.

### **TOTAL GAS DETECTOR**

The core of the total gas detector, or hot wire, is the wheatstone bridge. Always referred to as "the filament", the filament is actually two platinum filaments with a common node. One filament is sealed; this is the reference

filament. The other is open to the flow of gas across it when fitted into the filament chamber. Two ten ohm fixed resistors with a common node have their open ends attached the open end of each filament. A variable resistor completes the wheatstone bridge. A potential of from 2.2 to 3.0 volts is applied across the two junctions. Potential across the filament junction and the resistor junction is in series with a fixed resistor attenuator switch. This output voltage has a span of from 0 to 5 millivolts and is inputted to a chart recorder. Oxidation of gas passing across the reader filament balances the bridge and provides the gas level information. The choice of flow rates is essential to maximum gas measurement and may change from job to job. Air cooling of the filament may attenuate the output from oxidation of the natural gas.

Sometimes negative gas kicks are observed. These may result from nitrogen or carbon dioxide in the formation. Platinum filaments become saturated at a concentration of 12.5% methane in air (Core Lab, 1980). It is then that the air flowrate must be used to dilute the sample.

## **CHROMATOGRAPH**

The gas chromatograph is composed of a timer, a sampling valve, an oven, a chromatographic column, a carrier air supply, and a filament bridge. At all times, carrier air passes through a column of hexadecane catalyst, which is enclosed in a heated chamber. Triggered by a high signal from the hot wire, by a footage interval switch, or simply left on all the time, the timer opens and closes a sample valve, which injects a volume of gas from the sample gas supply into the carrier air flowing through the column. Methane comes out of the column first and is measured as a pulse across the filament bridge. It is followed by ethane, propane, isobutane, and normal butane in order of ascending molecular weight. The acetylene produced by the carbide lag bomb is seen as propane by the

device. This knowledge is useful when a drilling break occurs right after the bomb has been dropped. The gases must be heated by the oven in order for separation to occur. When outside temperatures are very low, passing the gas sample through a one hundred foot coil of poly tubing inside the unit may preheat the gas sufficiently for the oven to raise it to separation temperatures. Gases come out of the column at a specified time; this is determined by calibration with standard test gas composed of equal parts methane, ethane, propane, isobutane, and normal butane. Calibration factors are taken from the test gas results and applied to the formation gas observations to obtain quantitative proportions. Readings taken directly from the chromatograph chart recorder do not reveal the true ratio of gases to one another without these calculations being performed. When standard test gas has a methane response of greater peak amplitude than its ethane pulse, it is time to replace the column.

### **FILAMENTS**

Platinum filaments are destroyed quickly at high gas levels. Service life can be measure in days rather than weeks. The ceramic bead filament, surrounded by a diffusion shield similar to a gasoline filter, has an extremely long life. Cearley Technology has one which has been in service for over three years, and Permian Basin Instruments has observed one with a service life of over ten years. A new solid state device is now commercially available which promises great sensitivity and indefinite service life.

### **DEPTH COUNTER**

A rotary switch or microswitch is attached to the drilling rig's rate of penetration recorder. When one foot is penetrated, a relay is closed inside the unit and an event pen is actuated on one or both of the chart recorders.

## **CHART RECORDERS**

Chart recorders are complex, expensive devices . The type used in mudlogging operations is the process control recorder. Molytec and Honeywell recorders are the most common. The Honeywell recorder has an extremely long life if left in one place, as on a factory production line. When hauled from location to location , it is subject to trauma failures; broken wires and cold solder joints can become very expensive. Molytec recorders are of lesser initial cost, but of lesser initial quality. Mice can enter the front of a Molytec recorder and destroy it rapidly. Honeywell recorders are sealed from rodent entry. Tooke recorders require thermal paper, but travel very well. Often a little sandpaper applied to the scribe of a Tooke and to its electrical contacts will restore function when lost. Any type of chart recorder with a 0-5 millivolt input range can be used when necessary.

## **THE UNIT**

The most common question oil operators ask about mudlogging is "How much gas does a unit represent?" Tooke, Analytical, and most Roach hot wires are calibrated so that 1% methane test gas yields a deflection of 100 units. Some Roaches are calibrated with 1% methane gas producing 50 units. Core Lab instruments are set so that 1% methane gives a 20 unit response. Midland Instruments are set so that 1% methane gives either a 25 or 30 unit reading; they also feature a divide by setting for calibration at other sensitivities. A chromatographic analysis of common cigarette lighters, confirmed by the BIC company in Connecticut, shows that BIC brand lighters contain pure isobutane. When diluted by syringe or flowmeter ratios, this gas can be used for comparison

purposes, after applying calculations for the approximately 3 to 1 BTU difference between isobutane and methane.

## **CONCLUSIONS**

Mudlogging units consist of a trap, a flow system, a hotwire, a chromatograph, an footage marker, and chart recorders to process the information from them. The flow system is most prone to trouble. A drywall compound stirrer is a good choice for a beater to separate the gas from the mud. Ceramic bead filaments are a great improvement over the old platinum filament. The unit is defined as 10,000 ppm methane for calibrated Analytical, Roach, and Tooke units; 20,000 ppm methane for other Roaches; 50,000 ppm methane for Core Lab instruments; and 33,000 or 40,000 ppm methane for Midland instruments, with other settings available by switch.

## REFERENCES CITED

Core Laboratories, Inc., 1980, Technical Grading System for Well Logging Personnel, Dallas, Texas, 347 p.

EXLOG, 1985, Theory and Evaluation of Formation Pressures: A Pressure Detection Reference Handbook, Alun Whittaker, ed., International Human Resources Development Corporation, Boston, Massachusetts, 231 p.

Exploration Services, Inc., Operations and Maintenance Handbook, 1977, Midland, Texas, 89 p.

Wright, A.C., Hanson, S.A., and DeLaune, P.L., 1993, A New Quantitative Technique for Surface Gas Measurements: Transactions of the Society of Professional Well Log Analysts 34th Annual Logging Symposium.