Application Note

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Rapid Analysis of Mud Logging Well Gas Using the Agilent 990 Micro GC

Author

Jie Zhang
Agilent Technologies, Inc.

Introduction

Mud logging is a process of obtaining information about lithology and fluid content of a drill area. The monitoring of gas, both types and amount, is one of the most critical tasks in mud logging. Accurate gas data recorded during drilling are of great value in proper reservoir evaluation, and may pinpoint potentially overlooked producing zones. Gas chromatography (GC) is the primarily used technique for gas identification and measurement during the mud logging process. The most common component in mud logging well gas is methane; heavier hydrocarbons such as ethane (C_2), propane (C_3), and butane (C_4) may indicate an oil or wet gas zone. Heavier molecules, up to C_7, are also required to be monitored.

The analysis speed is important in the mud logging process, because the more detailed information generated for the unit drilling depth, the more accurate the reservoir evaluation. The Agilent Micro GC is an ideal chromatograph for fast and reliable analysis of well gas. The 990 Micro GC has inherited the characteristics of the previous generation[1]: compactness, energy-friendly, and rapid analysis speed. In addition to the listed features, the 990 Micro GC can deliver a better user experience. The installation of the analytical channel is much easier. It can be done in three steps within several minutes. A full-color touch screen is used to show the status of the instrument and key settings such as network setting, available instrument license, and firmware version. The standard cabinet version can accommodate two analytical channels. The extended cabinet version can easily be made by integrating two standard version mainframes with one main board and one LCD touch screen. Up to four channels can be accommodated in the extended version. The dynamic electronic gas control (DEGC) module has been developed to give pressure control with higher precision, accuracy, and stability.

This study demonstrates the analysis of hydrocarbons in the mud logging process on the 990 Micro GC platform. A standard version equipped with two analytical channels was used for analysis of C_1 to C_5 hydrocarbons. An extended version, configured with three channels, was used for extended mud logging gas analysis of heavier components (up to C_8).

Tables 1 and 2 show the test conditions for each channel. Simulated mud logging well gas was used for configuration verification. Table 3 lists detailed sample information.

Standard mud logging analysis

Hydrocarbons from C_1 to C_5 were analyzed. The 4 m, CP-PoraPLOT Q channel (straight DEGC option, no precolumn backflush) was used for the analysis of propane, butane, isobutane, pentane, and isopentane. The 10 m, CP-PoraPLOT Q channel with backflush option was used for the analysis of C_1 and C_2. The backflush option was deployed to flush the heavier components out from the precolumn before they entered the analytical column. This helped reduce the analysis time, otherwise the analysis would have lasted longer due to the heavier components' late elution on the 10 m PPQ column.

Extended mud logging analysis

Hydrocarbons as high as C_8 were analyzed. The 10 m, CP-PoraPLOT Q channel (backflush DEGC option) was for analysis of C_1 to C_2 hydrocarbons and CO_2; the 4 m, CP-Sil 5CB column with backflush option was for the analysis of C_3 to C_5 hydrocarbons. On this channel, analytes heavier than C_5 were backflushed before they enter the analytical column, which helped guarantee a short analysis time and a clean baseline for the next run. The 4 m, CP-Sil 5CB channel (straight DEGC option) was for the analysis of C_6 to C_8

Instrumentation

Standard Mud Logging		Extended Mud Logging	
Channel Type	Components for Analysis	Channel Type	Components for Analysis
10 m, CP-PoraPLOT Q, backflush	C_1, C_2, and CO_2	10 m, CP-PoraPLOT Q, backflush	C_1, C_2, and CO_2
4 m, CP-PoraPLOT Q, straight	C_3 to C_5	4 m CP-Sil 5CB, backflush	C_3 to C_5
		4 m CP-Sil 5CB, straight	C_6 to C_8

Table 1. Test conditions for standard mug logging well gas analysis.

	Channel Type	
	10 m, CP-PoraPLOT Q, Backflush	4 m, CP-PoraPLOT Q, Straight
Carrier Gas	Helium	Helium
Injector Temperature	110 °C	110 °C
Injection Time	40 ms	40 ms
Column Head Pressure	240 kPa	200 kPa
Column Temperature	60 °C	150 °C
Backflush Time	5.5 seconds	NA

Table 2. Test conditions for extended mug logging well gas analysis.

	Channel Type		
	10 m, CP-PoraPLOT Q, Backflush	4 m, CP-Sil 5CB, Backflush	4 m, CP-Sil 5CB, Straight
Carrier Gas	Helium	Helium	Helium
Injector Temperature	110 °C	110 °C	110 °C
Injection Time	40 ms	80 ms	40 ms
Column Head Pressure	240 kPa	150 kPa	200 kPa
Column Temperature	60 °C	60 °C	120 °C
Backflush Time	5.5 seconds	13 seconds	NA

Table 3. Simulated mud logging well gas.

Compound No.	Compound Name	Concentration (mol/mol)
1	Methane	2.02%
2	Ethane	0.251%
3	Propane	997 ppm
4	Isobutane	495 ppm
5	Butane	300 ppm
6	Isopentane	173 ppm
7	Pentane	204 ppm
8	Hexane	52.6 ppm
9	Methylcyclopentane	50.1 ppm
10	Benzene	49.1 ppm
11	Cyclohexane	47.7 ppm
12	Heptane	49.0 ppm
13	Methylcyclohexane	49.2 ppm
14	Toluene	49.3 ppm
15	Octane	50.4 ppm
16	Nitrogen	Balance

hydrocarbons.

Results and discussion

Figure 1 shows the chromatogram for separation of methane and ethane on the 10 m, CP-PoraPLOT Q backflush channel. There is no CO_2 in simulated mug logging well gas. A natural gas standard with methane, CO_2, and ethane was injected to find the position of the CO_2 peak. The chromatogram in Figure 1B can be used as a reference, if the real mud logging sample contains CO_2. Figure 2 shows the chromatogram of C_3 to C_5 compounds on the 4 m, CP-PoraPLOT Q channel. In the mud logging process, separation speed is a challenge for GC analysis. The 990 Micro GC addresses the separation of the whole sample by analyzing subsets of sample on different channels. The stationary phase type, column head pressure, and column temperature are selected and optimized according to the specific subset of analytes. This analysis approach can help accelerate total analysis speed. The analysis time is determined by the channel on which the separation takes the longest time. In the standard mud logging analysis, the separation on each channel can be completed within 30 seconds. The combination of the analysis results on different channels gives complete

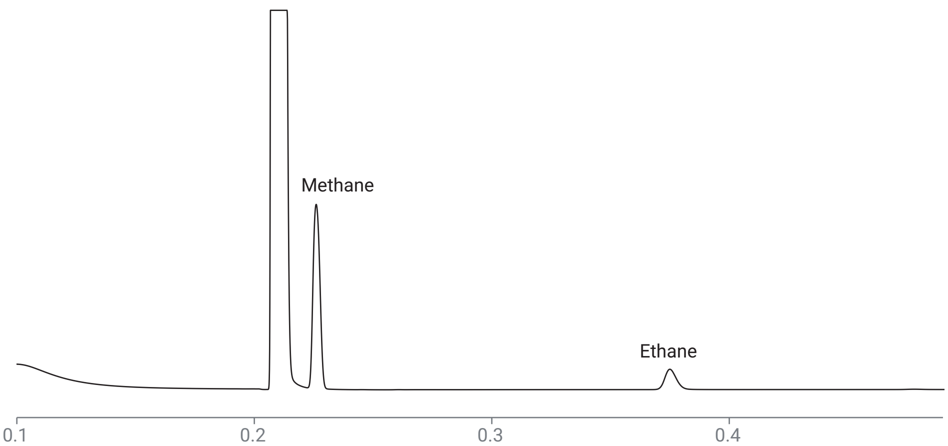

Figure 1A. Standard mud logging analysis, channel 1: methane and ethane analysis on 10 m, CP-PoraPLOT Q, backflush.

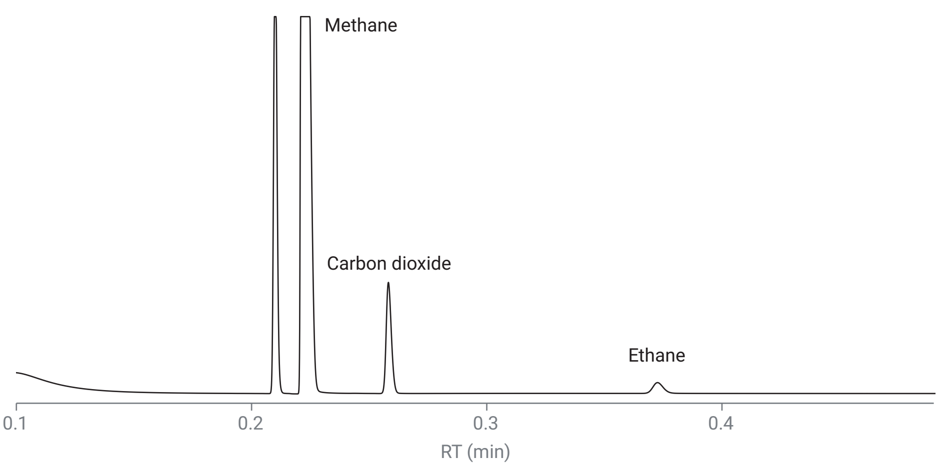

Figure 1B. Standard mud logging analysis, channel 1: CO_2 peak determination by natural gas standard analysis on 10 m, CP-PoraPLOT Q, backflush.

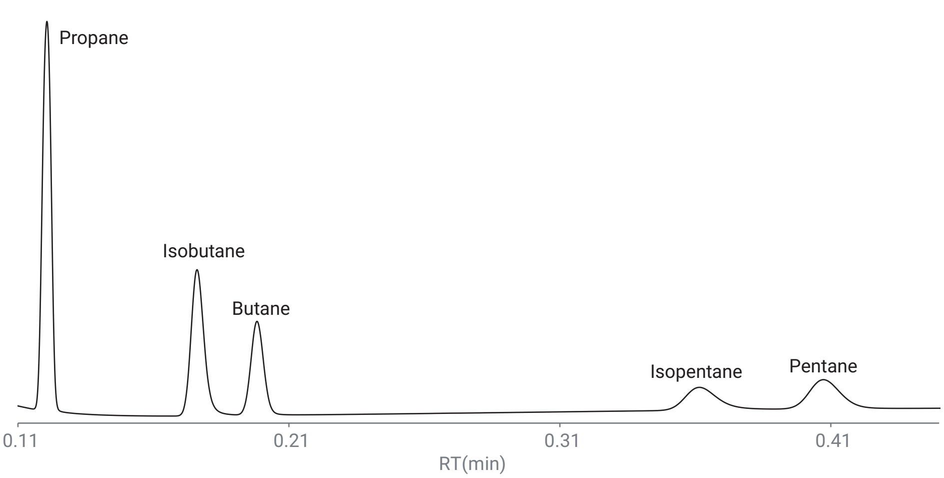

Figure 2. Standard mud logging analysis, channel 2: C_3 to C_5 components analysis on 4 m, CP-PoraPLOT Q, straight.

qualitative and quantitative information on the entire sample.

Tables 4A and 4B show the retention time (RT) and area repeatability for 10 injections. The area RSD% is below 0.2% and RT RSD% is in the range of 0.003% to 0.02%, which demonstrates the excellent performance of the 990 Micro GC and guarantees qualitative

Table 4A. Peak area precision of 10 consecutive injections on the 10 m, CP-PoraPLOT Q and 4 m, CP-PoraPLOT Q channels.

Compound	Methane	Ethane	Propane	Isobutane	Butane	Isopentane	Pentane
Area (mv × s)	8.568	1.585	1.429	0.806	0.512	0.312	0.386
	8.567	1.585	1.429	0.806	0.511	0.312	0.386
	8.566	1.586	1.429	0.806	0.511	0.311	0.386
	8.574	1.586	1.429	0.806	0.512	0.313	0.385
	8.576	1.588	1.430	0.805	0.511	0.312	0.386
	8.576	1.588	1.430	0.806	0.512	0.311	0.386
	8.565	1.587	1.429	0.805	0.511	0.311	0.386
	8.566	1.585	1.430	0.805	0.511	0.312	0.386
	8.581	1.588	1.430	0.805	0.512	0.312	0.386
	8.568	1.587	1.430	0.806	0.511	0.312	0.386
Area RSD%	0.065	0.080	0.037	0.064	0.101	0.203	0.082

Table 4B. RT and RT repeatability of 10 injections on the 10 m, CP-PoraPLOT Q and 4 m, CP-PoraPLOT Q channels.

Compound	Methane	Ethane	Propane	Isobutane	Butane	Isopentane	Pentane
RT (min)	0.224	0.373	0.121	0.176	0.198	0.362	0.407
RT RSD%	0.003	0.004	0.011	0.033	0.006	0.003	0.003

and quantitative results with a high level of confidence.

For extended mud logging analysis, channel 1 is same as the standard version: 10 m, CP-PoraPLOT Q, backflush for methane, CO_2 and ethane analysis. Figure 3 shows the chromatogram of the C_3 to C_5 components on channel 2, the 4 m, CP-Sil 5CB, backflush channel.

Figure 4 shows the chromatogram of the C_6 to C_8 components on channel 3, the 4 m, CP-Sil 5CB, straight channel. The last peak, octane, eluted within 35 seconds. Table 5 shows the RT and area RSD% for the C_3 to C_8 components analyzed on the extended mud logging configuration. The RT RSD% for the C_3 to C_8 components are better than 0.02%, and area RSD% are below 1%, which is

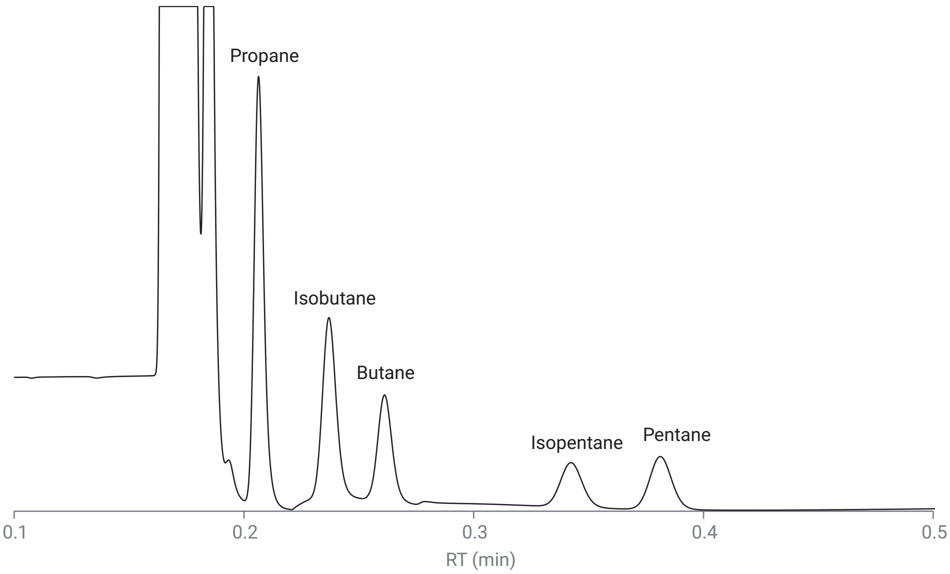

Figure 3. Extended mud logging analysis, channel 2: C_3 to C_5 compounds on 4 m, CP-Sil 5CB, backflush.

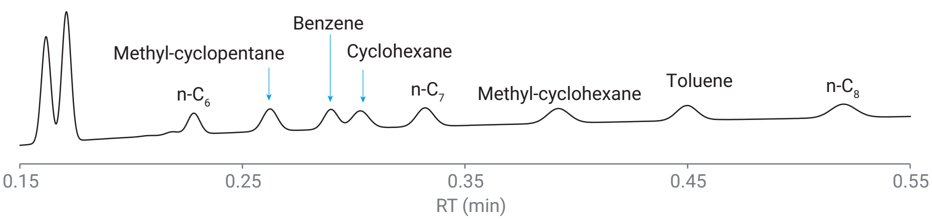

Figure 4. Extended mud logging analysis, channel 3: C_6 to C_8 compounds on 4 m, CP-Sil 5CB, straight.

Table 5. RT and area repeatability for extended mud logging analysis, C_3 to C_5 on the 4 m, CP-Sil 5CB backflush channel, and C_6 to C_8 on the 4 m, CP-Sil 5CB straight channel.

Compound	RT/min	RT RSD%	Area (mv × s)	Area RSD%
Propane	0.206	0.02	0.446	0.144
Isobutane	0.237	0.018	0.294	0.184
Butane	0.261	0.011	0.162	0.060
Isopentane	0.342	0.007	0.104	0.169
Pentane	0.381	0.008	0.125	0.082
Hexane	0.228	0.004	0.051	0.33
Methylcyclopentane	0.262	0.006	0.077	0.571
Benzene	0.290	0.006	0.065	0.219
Cyclohexane	0.303	0.006	0.068	0.221
Heptane	0.332	0.006	0.074	0.547
Methylcyclohexane	0.392	0.009	0.075	0.290
Toluene	0.450	0.007	0.071	1.024
Octane	0.520	0.008	0.078	0.768

proof of the stable pressure and column temperature control, and the repeatable response of the 990 TCD.

Conclusion

This study demonstrates fast analysis of mud logging well gas using an Agilent 990 Micro GC. A two-channel standard configuration and a three-channel extended configuration were used to analyze C_1 to C_5 hydrocarbons and C_1 to C_8 hydrocarbons, respectively. The analysis speed on each channel was optimized to finish within 35 seconds. The RT and area repeatability were excellent, demonstrating that the 990 Micro GC is an ideal platform for fast and reliable mud logging well gas analysis.

Reference

1. Van Loon, R. Mud Logging – Rapid Analyses of Well Gases with an Agilent Micro GC, *Agilent Technologies Application Note*, publication number 5991-2699EN, **2013**.

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