THE IMPACT OF AND SOLUTION TO ONSITE MISSING WATER CONTENT

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Abstract: In the operation the natural gas production system, the gas composition on dry basis is often updated by a periodic grab sample (usually once a month) or online gas chromatography (GC). Then the composition is used to evaluate the production system performance, such as flow rate calculation. Neglecting the water content of the gas stream will result in a series of inaccuracies, because at processing flowing conditions, most of the gas streams are saturated with water before deep dehydration.

This paper reveals the impact of the missing water content on gas processing and introduces an online solution of recovering the missing water using a modification of gas analysis. This approach has been applied to the online sulphur balance monitoring systems of sour gas plants for more than four years. The discrepancy between the dry basis gas composition from the online GC and the wet reality will be discussed and the modification of the gas composition will be compared with gas analysis of grab samples. The water content changes with the flowing condition, especially for the sour and acid gas which has a specific feature of holding the water over pressure and temperature.

Keywords: water content, gas composition, hydrogen sulphide, carbon dioxide

1. INTRODUCTION

In the operation of a natural gas production system, the gas composition is often updated by a periodic grab sample (usually once a month) or online using gas chromatograph (GC) – both of which are on a dry basis. Then the composition is used to evaluate the production system performance, such as flow rate calculation. Neglecting the water content in gas stream will result in a series of inaccuracies at processing flowing conditions. Most of the gas streams are saturated with water before dehydration.

Acknowledging the correct water content in a gas stream is important in both the design and operation of a natural gas facility. It is a critical factor to decide the operating set points and to achieve the required processing objectives and prevent unexpected events, such as the hydrate formation. In sour and acid gas systems, the capacity of holding water has a different feature then the typical hydrocarbon streams, and there are more concerns related to corrosion and safety.

In the practice of sulphur monitoring system of gas plants (Wang *et al*., 2007), we have an insight view of the system material balance in molecular (component) level which requires a precise and accurate composition from gas analysis. This paper reveals the impact of missing water content on gas processing and introduces an online solution of recovering the water content by using the online AQUAlibrium modification of gas analysis, which has been applied on the online sulphur balance monitoring systems of sour gas plants for more than four years. The discrepancy of gas composition of online GC on dry basis from the wet reality will be discussed and the AQUAlibrium modification result of gas composition will be compared with gas analysis of grab samples. The water content changes with the flowing condition, especially for the sour and acid gas which has a specific feature of holding the water over pressure and temperature.

AQUAlibrium (Flowphase) is a software package designed for acid gas and sour gas mixture and their equilibrium involving water. Therefore it is particularly useful for this application.

2. GAS ANALYSIS AND COMPOSITION

2.1 Typical Gas Analysis Report of Grab Sample and Online GC

Both the GCs and grab samples only give the gas composition on a dry basis, which means that the water is not included. Table 1 comes from gas analysis reports for the samples of different streams grabbed on March 3rd, 2008 at Pouce Coupe Gas Plant in Alberta, Canada. The streams are saturated with water, but no water content was reported on the gas analysis reports. The water content is also excluded from online GCs.

Table 1 Typical Gas Report of Grab Samples

Stream Name	West Doe Inlet	Plant Inlet	Inject 1	Inject 2
Pressure (kPa)	4842	4292	130	126
Temperature (°C)	-14	14	25	25
Component Mole Fraction				
H_2	0.0001	Trace	Trace	Trace
He	0.0027	0.0003	Trace	Trace
N_2	0.0165	0.0031	0.0000	0.0000
CO_2	0.0569	0.0128	0.4791	0.4966
H_2S	0.0065	0.0086	0.5080	0.4752
C_1	0.8991	0.8925	0.0103	0.0150
C_2	0.0135	0.0559	0.0005	0.0095
C_3	0.0014	0.0158	0.0002	0.0003
iC_4	0.0002	0.0026	Trace	0.0010
nC_4	0.0006	0.0040	0.0001	0.0003
iC_5	0.0005	0.0010	Trace	0.0001
nC_5	0.0008	0.0011	Trace	0.0001
C_6^+	0.0012	0.0023	0.0018	0.0019

2.2 Modification of Gas Composition by AQUAlibrium

Neglecting the water content of the streams results in series of calculation discrepancies on important process parameters such as the flow rates, sulphur content and plant sulphur unbalance. The water content of a gas streams depends on the capacity of holding water of each component at the flowing temperature and pressure. Figure 1 shows the water holding capacity of stream Injection 1 as a function of the temperature and the pressure.

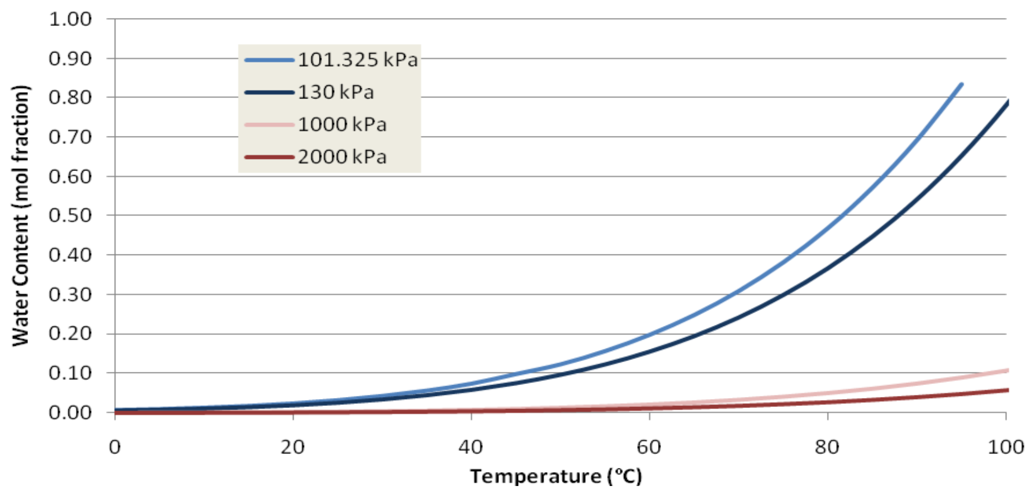

Fig.1. Saturated Water Content of Injection 1 as a Function of the Temperature and Pressure

To find a gas composition with water content present, which is closer to the reality, a phase equilibrium analysis is required. The modification to the mole fraction of each component in the gas stream depends on its capacity of holding water at the sampling condition. Table 2 shows the modified gas composition and gas properties of the streams at the sampling condition by AQUAlibrium (see Carroll, 2002a and Carroll, 2002b).

Table 2 Modification of Gas Composition and Properties

Stream Name	West Doe Inlet		Plant Inlet		Inject 1		Inject 2	
Pressure (kPa)	4842		4292		130		126	
Temperature (°C)	-14		14		25		25	
	Component Mole Fraction							
	Raw	Modified	Raw	Modified	Raw	Modified	Raw	Modified
H_2O	0.0000	6.04E-05	0.0000	0.000460	0.0000	0.024696	0.0000	0.025467
H_2S	0.0065	0.006499	0.0086	0.008596	0.5080	0.495454	0.4752	0.463098
CO_2	0.0569	0.056897	0.0128	0.012794	0.4791	0.467268	0.4966	0.483953
C_1	0.8991	0.901846	0.8925	0.892390	0.0103	0.010046	0.0150	0.014618
C_2	0.0135	0.013499	0.0559	0.055874	0.0005	0.000488	0.0095	0.009258
C_3	0.0014	0.001399	0.0158	0.015793	0.0002	0.000195	0.0003	0.000292
iC_4	0.0002	0.0002	0.0026	0.002599	0.0000	0.0000	0.0010	0.000975
nC_4	0.0006	0.0006	0.0040	0.003998	0.0001	9.75E-05	0.0003	0.000292
iC_5	0.0005	0.0005	0.0010	0.000999	0.0000	0.0000	0.0001	9.75E-05
nC_5	0.0008	0.0008	0.0011	0.001099	0.0000	0.0000	0.0001	9.75E-05
C_6^+	0.0012	0.001199	0.0023	0.002299	0.0018	0.001756	0.0019	0.001852
N_2	0.0165	0.016499	0.0031	0.003099	0.0000	0.0000	0.0000	0.025467
Molecular Weight (kg/kmol)	18.3685	18.3685	18.3774	18.3773	38.7479	38.2358	38.8435	38.313
Z-factor	0.857289	0.857278	0.900188	0.900147	0.991849	0.991705	0.992179	0.992038
Density(kg/m³)	48.1515	48.152	36.7023	36.7036	2.04881	2.02203	1.99	1.96311
Enthalpy(kJ/kmol)	-1750.58	-1750.62	-546.829	-546.959	829.797	827.817	839.32	837.137
Heat Capacity (kJ/kmol.K)	43.5798	43.5803	43.4045	43.4042	36.1427	36.0917	36.4591	36.398
Viscosity(Pa.s)	1.12E-05	1.12E-05	1.13E-05	1.13E-05	1.38E-05	1.37E-05	1.38E-05	1.37E-05
Thermal Conductivity (W/m.K)	0.033452	0.033451	0.037413	0.0374	0.016139	0.016284	0.016302	0.016446
Specific Volume (m³/kg)	0.020768	0.020768	0.027246	0.027245	0.488089	0.494554	0.502512	0.509397

It can be seen that excluding the water has more impact on the stream at higher temperature and lower pressure. And a higher concentration of H_2S and CO_2 will also increase the water content.

The water content modification by AQUAlibrium was verified by its online service in the component material balance monitoring of the gas plants. The daily removed water amount matches very closely the calculated water amount difference between all the inlet streams and outlet streams. The estimated sulphur balance between the input streams and output streams of the gas plants also shows that the AQUAlibrium water content modification improves the gas analysis from the GCs.

Because the gas composition is the fundamental of gas processing, production management and related calculations and most of the processing are related to the water handling, the missing water content has significant impact on the technical and economic evaluation and operation of the gas facilities.

3. FLOW CALCULATION

Flow rates of the streams are collected for both accounting and production purposes in gas plants. The most commonly used flow meters are orifice and vortex. Regardless of the type of flow meter used, the gas composition is required to calculate the flow rates. Instead of the gas composition from grab sample, which is updated periodically (usually once a month), online GC provides another option of updating the gas composition continuously and online. Either way, the water is not included and the absence of water will result in inaccuracy of flow measurement.

The flow differences between raw and modified compositions are listed below:

- West Doe Inlet: 1448.53 X $10^3 m^3/d$ (raw), 1474.11 X $10^3 m^3/d$ (modified), bias rate 1.7659 %
- Injection 1: 13.8942 X $10^3 m^3/d$ (raw), 13.9576 X $10^3 m^3/d$ (modified), bias rate 0.4563 %
- Injection 2: 14.7826 X $10^3 m^3/d$ (raw), 14.9231 X $10^3 m^3/d$ (modified), bias rate 0.95 %

Flow calculation is fundamental and many decisions are based on the results of flow calculations. A calculation bias is caused by the differences of gas properties which is the result of gas composition.

4. HAZARD GAS EMISSION MONITORING

By enforcing the safety and environment protection, H_2S and CO_2 in sour gas facilities are required to be monitored by legislation, such as the mandatory S-30 report in Alberta. The difficulty of monitoring the component balance of a gas plant is due to the fact that the balance is very sensitive to each concentration. A small inaccuracy of the component concentration may result in the balance being outside of the mandatory range. As a result this improper evaluation of the hazard gas balance will result in extra effort and work.

By applying the combination of AQUAlibrium and the online GC gas analysis, a gas composition closer to reality results. This is due to the improved water content in the stream and equilibrium the hazard gas concentration of each stream at its sampling conditions. According to our practice, the compensation of this gas composition modification will improve the monitoring balance by 2% to 5%, as shown in Fig. 2.

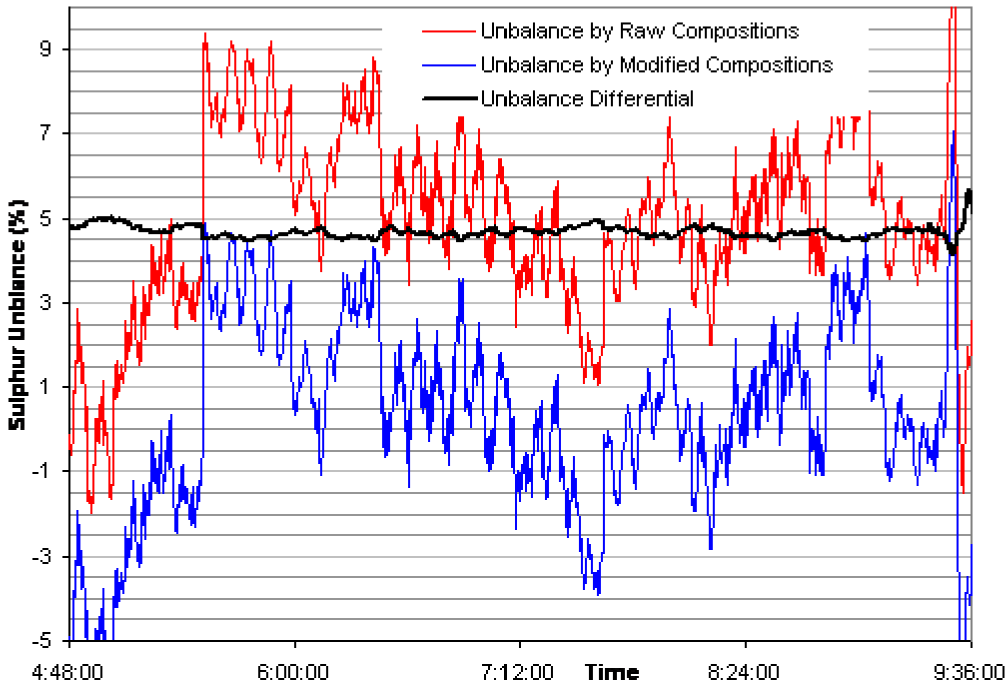

Fig.2. Sulphur Unbalances of Raw and Modified Gas Composition

The impact of excluding water on the evaluation of the hazard gas balance is complex and variable because water concentrations are very different in the inlet streams and outlet streams because of component concentrations, temperatures and pressures. So recovering the water will change the component concentrations of each stream differently based on its dry basis composition and sampling temperature and pressure. The final component balance is estimated by the combination of flow and component concentrations on the revised gas composition.

5. ONLINE APPLICATIONS

The AQUAlibrium water content modification has been used for the online gas plant sulphur variance monitoring system since 2004. It helps the online monitoring system produce more accurate evaluation of the component balances of the gas plants especially for the important components, such as H_2S, CO_2 and water.

In the monitoring system, the online GCs update the real time gas compositions on dry basis. These gas compositions are then modified to include the water concentration using AQUAlibrium phase equilibrium for the flowing temperature and pressure. All the other related calculations are based on the revised gas compositions.

The procedure was easy to be verified with the real time production and processing data. First, the component flow rates of all the inlet and outlet streams must be balanced at normal production state with consideration of plant processing delay of the flow. The removed water amount also matches the difference of calculated water amount between the inlets and outlets.

6. CONCLUSIONS

According to our practice and research in the online monitoring of the gas components in the gas plants, the following conclusions can be drawn:

- Most of the gas streams are saturated with water in the gas processing facilities, at least before deep dehydration. A great portion of the processing effort is related to the water handling. Finding the water concentration in the gas stream is important to processing and production.

- Currently water is not included in the gas analysis either by grab sample or online GC. The missing water makes the reported gas composition different from the reality. As a result, the evaluation and control of the process and production are somewhat inaccurate due to the incomplete gas composition.
- The water content can be recovered online and offline by AQUAlibrium using the phase equilibrium on the dry basis composition and sampling temperature and pressure. The holding water capacity of each component is different and it changes with temperature and pressure. In practice, the AQUAlibirum composition modification matches the reality well in wide range of component concentrations, temperature and pressure.
- As fundamental of analysis, the modified gas composition with water included has great significances to the precise evaluation and optimal operation of the production system because lots of the analysis is based on the gas composition and most of the handling is water related.
- The online real time water awareness will help the precise control and optical operation of the water handling facilities, such as adjusting the rate of hydrate inhibitor online.

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