

## **OPTIMIZING METHANOL USAGE FOR HYDRATE INHIBITION IN A GAS GATHERING SYSTEM**

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### **ABSTRACT**

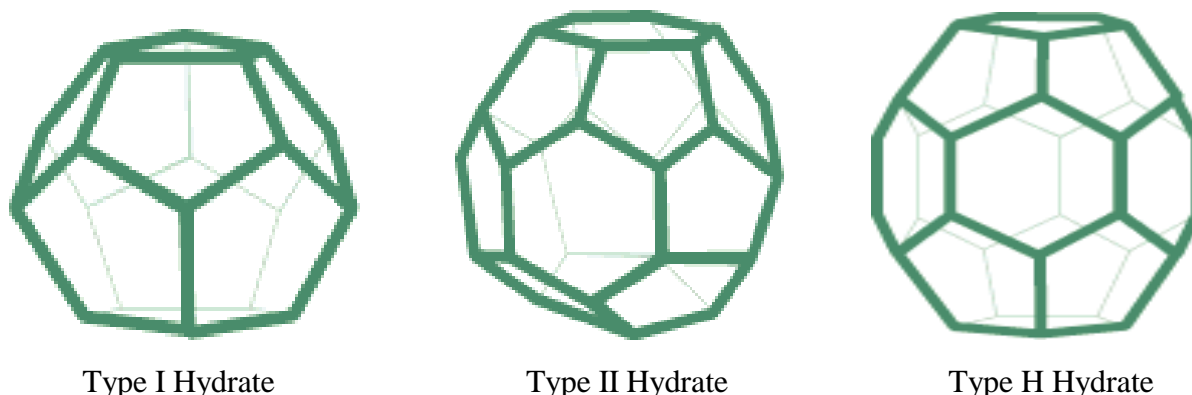
Hydrate inhibition with methanol continues to play a critical role in many operations. Numerous opportunities exist for optimizing methanol usage based on the operating conditions, seasonal variations in temperature, and accurate prediction of the hydrate formation temperature. To properly predict the requirements, the distribution of methanol between the gas and liquid phases is of key importance. These opportunities for optimization have been made possible primarily through research data from the GPA.

## OPTIMIZING METHANOL USAGE FOR HYDRATE INHIBITION IN A GAS GATHERING SYSTEM

### BACKGROUND

The formation of hydrates in natural gas systems has been a problem to the gas processing industry for nearly a century (Hammerschmidt<sup>1</sup>). Gas hydrates are “ice-like” crystals composed of natural gas molecules that glue themselves inside symmetrical cages of water molecules. Gas hydrates occur naturally in deep water and polar environments with structures similar to Figure 1. Their formation in gas and/or NGL systems can plug pipelines, equipment, and instruments restricting or interrupting flow. The two most common forms of hydrates are Type I and Type II. Type I hydrate crystals form cages around small molecules such as methane, ethane, carbon dioxide and hydrogen sulfides.

Type II hydrate crystals are more complex structures which encapsulate the relatively larger propane and butane molecules. Around 1990, the existence of a third hydrate structure, Type H, was recognized (Englezos<sup>2</sup>). Type H crystal structures are so large they can encapsulate iso-pentane molecules.



**Figure 1 - Typical Hydrate Structures**

Methanol has been recognized and used as a hydrate inhibitor for nearly as long as the hydrate problem has existed (Hammerschmidt<sup>3</sup>). In many cases, methanol continues to be the most simple and cost effective method of treating hydrate problems compared to other forms of inhibition such as glycol injection or dehydration of the gas (Esteban, et al.<sup>4</sup>, Covington, et al.<sup>5</sup>). The first widely recognized method for calculating the methanol requirements for hydrate inhibition was proposed by Hammerschmidt<sup>3</sup> in 1939. Since that time, a number of research projects have been undertaken to increase the understanding of this complex and costly problem. At least 15 major research projects related to hydrates have been under the sponsorship of the Gas Processors Association (GPA)<sup>6</sup> from 1974 to the present. These projects have led to significant extensions in the range of application by providing fundamental data for the industry.

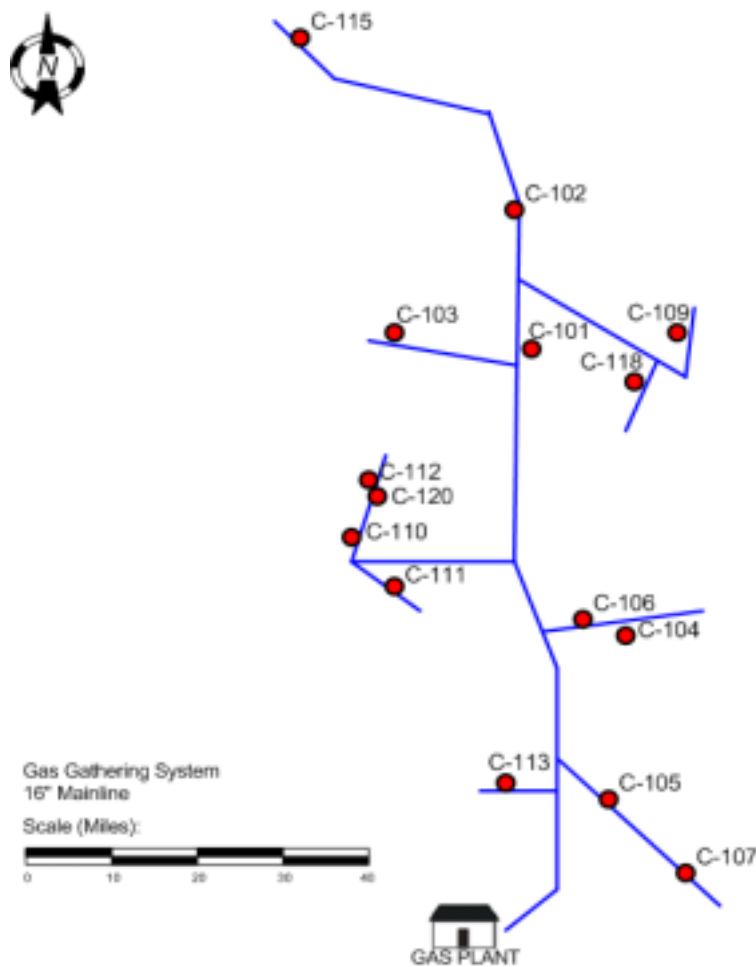
In addition to Hammerschmidt's original equation, a number of published methods are currently available for calculating methanol requirements including: (1) the K-chart method as given in the GPSA Engineering Data Book<sup>7</sup>, (2) the equations and refinements by Nielsen and Bucklin<sup>8</sup>, (3) a

graphical procedure by Maddox<sup>9</sup> and (4) the widely recognized CSMHYD method by Sloan<sup>10</sup>. These methods and others are reviewed and discussed in recent papers on hydrate suppression, Esteban, et al.<sup>4</sup> and Covington, et al.<sup>5</sup>.

The research data taken by GPA and others has served as the foundation for the development of accurate and reliable methodologies for calculating hydrate formation, freeze points, water content and hydrate inhibition which apply over wide ranges of temperature, pressure and composition. These methods have been implemented in process simulation software such as ProMax<sup>®</sup> with TSWEET<sup>®</sup> and PROSIM<sup>®11</sup>. Process simulators have the advantage of a full thermodynamic property package for use in the calculations and help reduce error tendencies from manual calculations. Without the research data, this level of accuracy, reliability and range of applicability would not have been possible.

## THE GATHERING SYSTEM

The gathering system for this study spans approximately 125 miles and collects gas from wells using a local low pressure system as shown in Figure 2. The gas is then compressed with a local booster compressor. At each booster station, the gas is compressed using three stages with interstage and final stage cooling. Depending on location in the gathering system, a pressure ranging from 600 to 800 psia is required to enter the high pressure portion of the gathering system.



**Figure 2** – Map of Gas Gathering System

As shown in Table 1, the gas has typical values and ranges as follows:

**Table 1 - Typical Gas Composition for Gathering System**

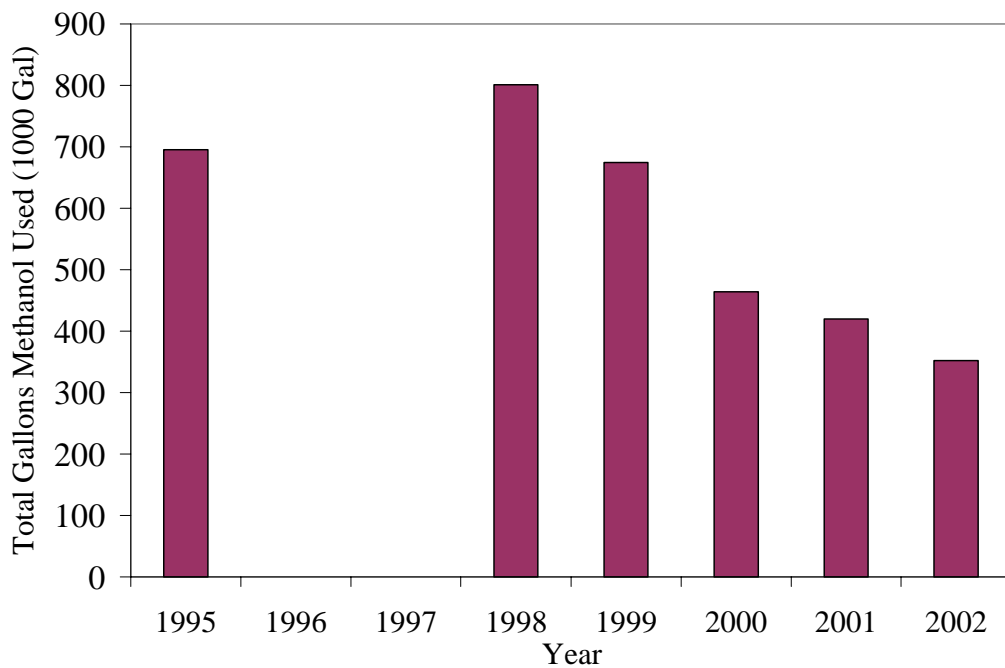
Component	Typical (mol %)	Range (mol %)
N <sub>2</sub>	1.68	0.5 - 3.7
CO <sub>2</sub>	1.2	0.3 - 3.1
C <sub>1</sub>	71.9	59 - 85
C <sub>2</sub>	11.8	2 - 16
C <sub>3</sub>	7.7	2 - 13
i-C <sub>4</sub>	1.2	0.3 - 2.3
n-C <sub>4</sub>	2.5	0.8 - 5.2
i-C <sub>5</sub>	0.7	0.3 - 2.3
n-C <sub>5</sub>	0.7	0.2 - 1.9
C <sub>6+</sub>	0.6	0.1 - 1.1
He	0.02	0 - 0.04
C <sub>1</sub> +C <sub>2</sub>	74	65 - 90
C <sub>3</sub> +C <sub>4</sub>	12	4 - 9
MBTU/SCF	1.3	1.1 - 1.6

The C<sub>3</sub> and C<sub>4</sub> content are noteworthy with the typical values of 8% for C<sub>3</sub> and 3% for C<sub>4</sub> since there is a possibility for significant Type II hydrate formation.

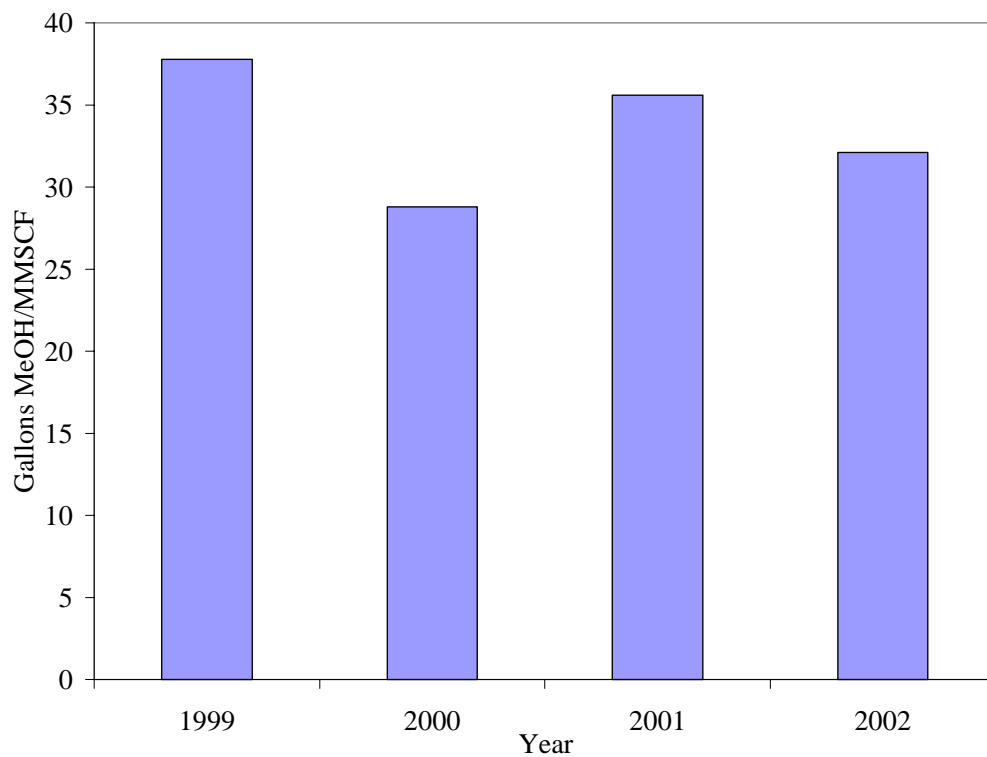
The gathering system is a wet gas system designed for hydrate inhibition with methanol. At each booster compressor station, methanol is injected with periodic rate adjustments based on the gas flow through each station. Experience has shown that the system must be inhibited down to a temperature of about 20°F in winter and about 40°F in summer and include a reasonable margin of safety. In this paper, the hydrate formation and inhibition in the gathering system is studied and the system is analyzed in an effort to further optimize the methanol usage.

## HYDRATE FORMATION AND INHIBITION IN THE GATHERING SYSTEM

Historically, this particular gathering system had a methanol recovery unit and the operating staff had not been overly concerned with high injection rates. However, in 2001, the methanol recovery unit developed operational problems which would have required a major rework of the unit. A cost analysis was performed and the decision was made to shut down the recovery unit and proceed with more conservative injection rates. The historical total methanol usage for the gathering system including both the wellheads and booster stations is shown in Figure 3. This shows that the yearly usage has declined each year since 1999. However, when calculated on a normalized basis, the combined wellhead and booster station usage has remained relatively constant in the range of about 30 to 35 gal/MMSCF as shown in Figure 4. As a result, this system provides an excellent opportunity for optimization of its current operations.



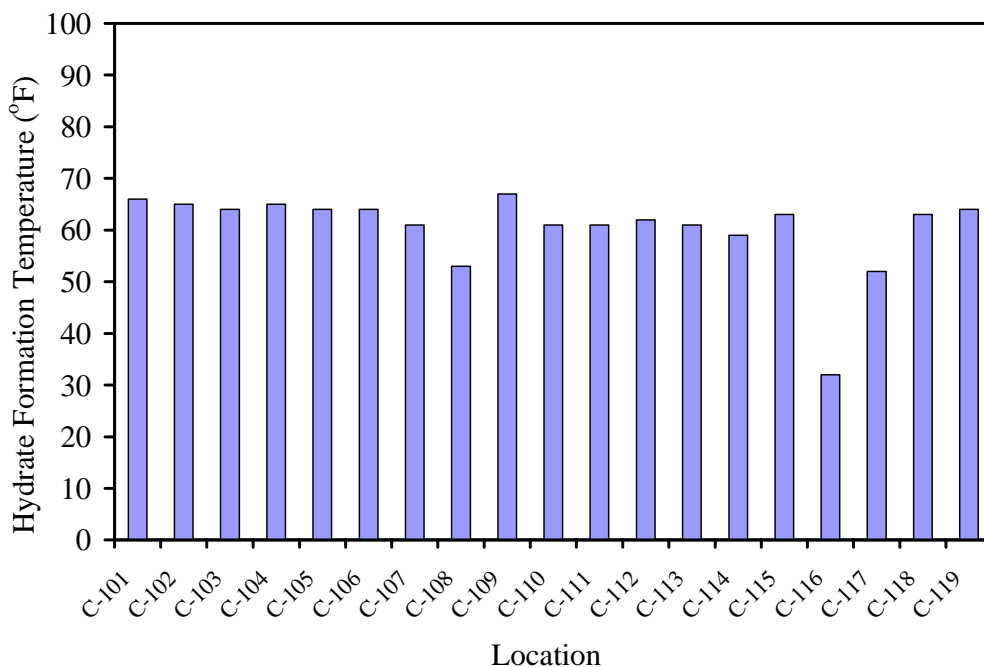
**Figure 3** – Historic Methanol Usage in the Gathering System (Wellheads plus Booster Stations)



**Figure 4** – Historic Methanol Usage in the Gathering System (Wellheads plus Booster Stations)

## Hydrate Formation Temperatures

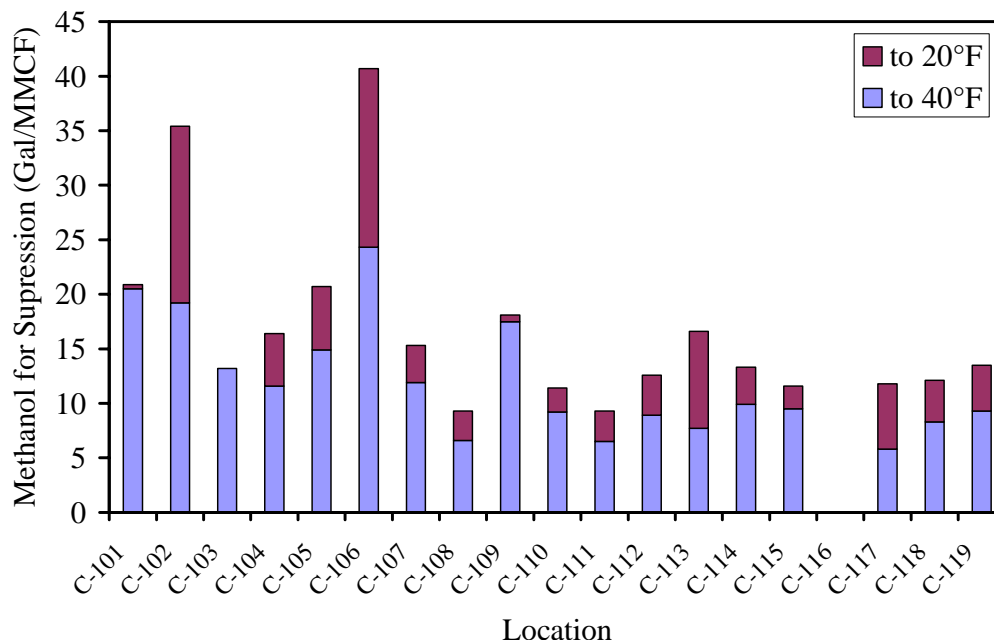
Based on the current operating conditions of feed gas composition, temperature and pressure, the hydrate formation temperatures were calculated for each booster station and the results are shown in Figure 5 and Tables 2a and 2b. As can be seen from these plots, the hydrate formation temperature is about 61 to 65°F for almost every station. Thus, this gathering system has the distinct honor of having hydrates form at almost the maximum temperature possible. In addition, Type II hydrates are the first to form at all stations due to the high C<sub>3</sub> and C<sub>4</sub> content of the gas as shown in Table 1.



**Figure 5** – Hydrate Formation Temperature at Each Booster Station

## Current Methanol Requirements

The required methanol injection rates were calculated for both summer (inhibition to 40°F) and winter (inhibition to 20°F) scenarios for each booster station. Detailed results along with the total daily requirements are presented in Tables 2a and 2b for the summer/winter scenarios. The normalized methanol requirements are also presented graphically for each booster station in Figure 6 and can be noted to vary from about 6 gal/MMSCF to as high as 41 gal/MMSCF depending on the booster station and the summer/winter scenario. As noted previously in Figure 5, the hydrate formation temperature was near constant at almost every station. The pressure in the system varies from about 600 to 800 psig depending on the location and thus would not be expected to cause the major differences in the injection requirements from station to station. Figure 6 and Tables 2a and 2b also include the final cooler temperature for each booster station. The final cooler temperature varied widely from station to station and also from summer to winter at the same station.



**Figure 6** – Methanol Usage at Each Booster Station for Summer/Winter Scenarios

**Table 2a** – Gathering Information and Methanol Required for Suppression to 40°F Summer Scenario

Location	August-2003			H <sub>2</sub> O Content (lb H <sub>2</sub> O/MMSCF)	Raw Stream Hydrate Temperature	gal/MMCF for Suppression to 40°F
	Flowrate (MCFD)	Temp.(°F)	(Psig)			
C-101	987	123	639	146.6	66	20.5
C-102	2,462	137	663	194.5	65	19.2
C-103	379	112	688	102	64	13.2
C-104	317	109	667	96.4	65	11.6
C-105	924	127	611	160	64	14.9
C-106	637	166	652	351.4	64	24.3
C-107	1,518	129	677	154.8	61	11.9
C-108	6,722	123	618	140.3	53	6.6
C-109	908	139	745	184.9	67	17.5
C-110	1,746	116	782	103	61	9.2
C-111	427	91	793	52.4	61	6.5
C-112	1,223	109	778	86.6	62	8.9
C-113	757	92	659	60.9	61	7.7
C-114	3,453	120	620	132.7	59	9.9
C-115	2,572	113	840	91.5	63	9.5
C-116	4	73	5.7	501.3	32	0
C-117	2,734	79	335	69.7	52	5.8
C-118	648	85	650	50.9	63	8.3
C-119	706	85	650	51.1	64	9.3
<b>TOTAL</b>	<b>29,124</b>				<b>Volume Average Composite:</b>	<b>10.5</b>

**Table 2b** – Gathering Information and Methanol Required for Suppression to 20°F Winter Scenario

Location	January-2003			H <sub>2</sub> O Content (lb H <sub>2</sub> O/MMSCF)	Raw Stream Hydrate Temperature	Gal/MMCF for Suppression to 20°F
	Flowrate (MCFD)	Temp (°F)	(Psig)			
C-101	930	77	640	39.2	66	20.9
C-102	3,045	145	678	228.5	65	35.4
C-103	---	---	---	---	---	---
C-104	428	104	678	83.6	65	16.4
C-105	914	117	615	125.1	64	20.7
C-106	619	161	649	319.9	64	40.7
C-107	1,309	111	680	99.3	61	15.3
C-108	7,291	98	623	73.7	53	9.3
C-109	953	110	768	90.1	67	18.1
C-110	1,767	98	756	66.1	61	11.4
C-111	678	90	812	50.1	62	9.3
C-112	1,477	102	803	70.6	63	12.6
C-113	762	114	652	110.1	61	16.6
C-114	3,688	104	640	86.5	59	13.3
C-115	2,942	96	858	57.7	63	11.6
C-116	134	46	25	151.5	32	0
C-117	3,044	83	336	78.3	52	11.8
C-118	616	85	650	50.9	63	12.1
C-119	564	85	650	51.1	64	13.5
<b>TOTAL</b>	<b>31,161</b>	<b>Volume Average Composite:</b>				<b>15.3</b>

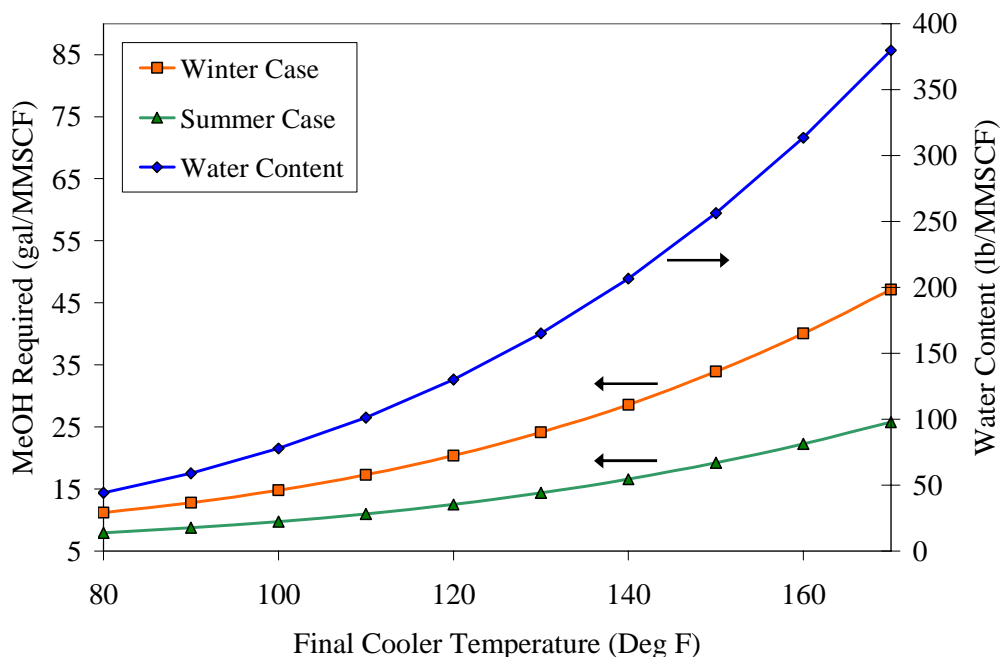
The wide range in injection rates noted in Figure 6 are primarily caused by the variation in water content and methanol vaporization to the gas phase resulting from the variations in the final cooler temperature. This impact is further illustrated in Figure 7 where the influence of the final cooler temperature on the water content and methanol requirement is presented for compressor station C-106.

As can be seen from Tables 2a and 2b, the normalized injection rate for the current gathering system (booster stations only) is about 10 and 15 gal/MMSCF for the summer/winter scenarios, respectively.

### Factor of Safety for Methanol Injection Rates

It is common practice to include a ‘reasonable’ safety factor into the methanol injection rates to diminish the likelihood of hydrate formation due to upsets or changes in the system. A common fluctuation is the cyclical nature of the gas temperature from day/night ambient changes. One of the most widespread practices is to inject a percentage excess of methanol into the system based on prior experience. An alternative method is to create a graph similar to Figure 7 and investigate the methanol requirements with the final gas temperature. In Figure 7, the line for the winter case represents the amount of methanol required to suppress the hydrate formation temperature to 20 °F. If one expects an average final cooler temperature of 100 °F, then the slope of the line for the winter case at 100 °F can be used to help determine the amount of excess methanol required. If the slope is steep in the vicinity of the normal operating temperature, a large factor of safety is probably needed to maintain inhibition. If the slope is relatively flat such as the summer case in Figure 7 in the vicinity of 100 °F, then the factor of safety is not as critical.





**Figure 7** – Methanol Requirements and Water Content versus Final Cooler Temperatures for a Booster Station

### Optimization

As shown in Figure 7, the primary factor impacting the methanol requirements at each booster station for this system is the final cooler temperature. Higher temperatures result in greater methanol vaporization into the gas as well as increased amounts of liquid water which must maintain a minimum methanol content. Thus, as illustrated in Figure 7, the methanol requirements at each booster station can be reduced by lowering the final cooler temperature. Since the hydrate formation temperature is about 60 to 65 °F, the lower limit on the final cooler temperature is about 75 to 80 °F. For example at booster station C-106, if the final cooler temperature was reduced from 160 °F to 80 °F the methanol requirement for the winter case would be reduced from 40 to 11 gal/MMSCF.

As seen in Figure 6, the methanol requirements for the summer scenario is only about two thirds that of winter. Thus, significant savings can also be realized by seasonally adjusting the injection rates.

## CONCLUSIONS

The usage of methanol for hydrate inhibition in a gas gathering system can be revealed and optimized by considering a number of factors. The most important factor is condensing and removing as much water as possible prior to injecting methanol. Reasonable safety factors can be utilized by determining the slope of the methanol required vs. temperature similar to Figure 7. In many cases, the overall methanol usage may also be reduced by seasonal adjustments. In this particular gathering system, adjusting for summer temperatures reduces the required methanol rate by about one third.

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