INL/EXT-12-27045

Analysis and Methane Gas Separations Studies for City of Marshing, Idaho

An Idaho National Laboratory Technical Assistance Program Study

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August 2012

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Introduction and Background

Large amounts of methane in well water is a wide spread problem in North America. Methane gas from decaying biomass and oil and gas deposits escape into water wells typically through cracks or faults in otherwise non-porous rock strata producing saturated water systems. This methane saturated water can pose several problems in the delivery of drinking water. The problems range from pumps vapor locking (cavitating), to pump houses exploding. The City of Marsing requested Idaho National Laboratory (INL) to assist with some water analyses as well as to provide some engineering approaches to methane capture through the INL Technical Assistance Program (TAP). There are several engineering approaches to the removal of methane and natural gas from water sources that include gas stripping followed by compression and/or dehydration; membrane gas separators coupled with dehydration processes, membrane water contactors with dehydration processes. Each of these processes will be discussed below.

Methane use facts (DOE Fact Sheet):

- Electrical Generation 10 CF = 1 kwh
- Heat Generation 1 CF = 1000 BTU
- Building Heat Capacity 40 BTU/ ft^2
- Cost of methane 3 to 4$/ 1000 CF
- Barbeque heating 80 BTU/in^2

Separation methods for isolating and drying methane from well water

Membrane separations technology can provide a pathway to turn this "methanated" water into a valuable asset while reducing greenhouse gas emissions. The two main membrane separation techniques that could be implemented to produce clean production quality methane gas from Marsing's water wells are: membrane gas dehydration, and membrane liquid contacting. Membrane dehydration can be used to remove water vapor from the water well vent gas, this will both dry the methane and protect down stream equipment from corrosion. Membrane liquid contacting removes the gas directly from the water and could increase the volume of methane production.

Objectives of the Studies

Marsing, Idaho routinely performs methane removal from their drinking water wells and the city water system with the methane being vented to the atmosphere. The main objective of these studies was to assist the city of Marsing, Idaho with recovery and utilization of the natural gas currently being vented to the atmosphere from the city's water delivery system.

The specific objectives of this work were to:

1) Verify the volume and quality of methane available from the city of Marsing's drinking water wells,

2) Test the viability of membrane processes for both the direct removal of methane from liquid water and dehumidification of the well vent gases.

The INL TAP was requested to perform analyses to validate the gas types and concentrations found in Marsing's well water. Prior INL gas chromatographic (GC) analyses of Marsing well vent gas were provided by INL's Cathy Rae.

Well ID	Methane %
Boost Well	95 %
Test Well #	28 %
Well # 1	93 %
Well #7	0.2 %
Well #8	55 %
Well #9	23 %

A previous study was performed on the City of Marsing's well water system in 2010: "Methane Production and GC Analysis Study." (Provided by John Larsen, City of Marsing)

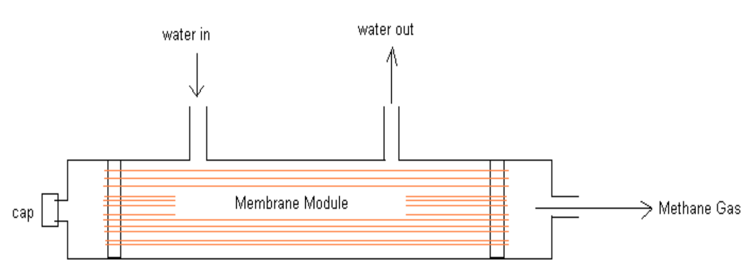
The following is a summary of a 2010 flow rate study and corresponding gas analysis for well #1. Well # 1 was shown to have an average gas production rate of 3 CFM (85 LPM) with surges to 10 CFM (280 LPM). GC analysis was also provided in this report showing data for well # 1 and well #8. Both wells were shown to have 95% CH_4 with very low amounts of contaminants such as CO_2 and sulfides. Using GC analysis, the methane from wells 1 and 8 was found to be clean and useable for most standard natural gas applications.

<u>Membrane Testing</u>

INL's membrane studies focused on two different areas: 1) direct removal of methane from water using membranes as a liquid contactor and 2) membrane dehumidification of the well vent gas.

1) Liquid contacting is the direct extraction of dissolved gases from liquids using a dense polymer membrane. Figure 1 illustrates how a membrane module for liquid contacting is implemented.

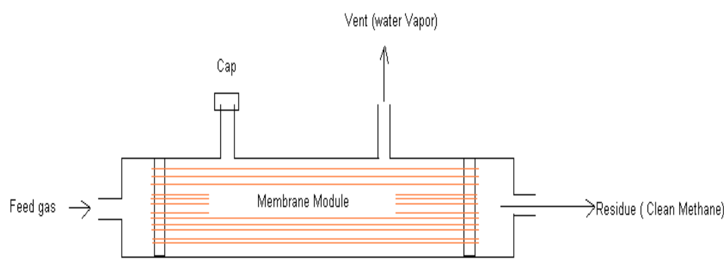
Figure 1. Liquid Contacting Membrane Module



2) Membrane dehumidification. Dense polymer membranes can be used to remove water vapor from gas streams. Because many polymers are highly permeable to water vapor they are very effective at transferring moisture out of gas streams.

Membrane gas dehumidification is achieved as outlined in the Figure 2. The humid gas flows across the surfaces of the membrane and water vapor is transferred across the membrane driven by the higher partial pressure of the water vapor in the humid gas stream compared to the water vapor pressure on the outside the membrane. The extracted moisture is then either condensed or vented to the atmosphere.

Figure 2. Dehumidification Membrane Module.



Both liquid contacting and membrane dehumidification were tested at the City of Marsing's well sites 1 and 8.

Testing details and results are outlined in the following section:

Test 1: Membrane dehumidification of vent gas from well 1 was carried out using two different membrane modules: a 10 m^2 Air Liquide membrane module and a 2500 cm^2 Compact Membrane Systems (CMS) membrane module. The gas source was the vent line from Marsing's "sand tank" connected to well 1, pictured in Figure 3. The total flow from this vent was very hard to measure due to gas leaks around the many PVC fittings. The flow was estimated to be 60-80 LPM. The results of Test 1 are summarized in Table 1.

Figure 3. Well # 1 sand tank and associated PVC plumbing

Table 1. Results of Test 1

CMS Module	20 to 30% Permeate flow	~95% Methane
Air Liquide Module	12 to 40 % Permeate flow	~95% Methane
Residue pressure drop ~1 psi		

Test 2: Liquid contacting experiments were conducted using a Perm Select 1 m^2 area polydimethylsiloxane (PDMS) membrane module. Figure 4 shows the module used for this test. The results of Test 2 are summarized in Table 2.

Figure 4. Membrane module and gas flow meter at well 8 location.

Table 2. Results for Test 2 (Liquid contacting using 1 m^2 Perm Select™ module)

Water flow	Methane Product Flow	Gas Composition
700 ml/min	75 ml/min	95- 98 %
1000 ml/min	88 ml/min	95- 98 %

Test 3: Dehumidification of vent gas from well 8. Both the 10 m^2 Air liquide membrane module and the 2500 cm^2 CMS membrane module were tested. The total flow from well 8 vent line was measured to be 20 to 30 LPM, again gas leaks were present. As pictured in Figure 5 it was necessary to plumb the well 8 vent line to a plastic bucket to remove water droplets that came from this source line. The results of Test 3 are summarized in Table 3.

Figure 5. Experimental set up for gas dehumidification at well 8.

Table 3. Results of Test 3

Module	% permeate flow	Humidity Reduction	Gas Composition
Air liquide module	46 %	42.6 %	95- 98 %
	46 %	42.8 %	95- 98 %
CMS module	24 %	33 %	95- 98 %
	18 %	17.6 %	95- 98 %
	21 %	19.4 %	95- 98 %

Test 4: Liquid contacting was evaluated for methane removal directly from water using a CMS 2500 cm^2 membrane module. Figure 6 shows the module used for this testing. The results of the liquid contacting experiments are summarized in Table 4.

Figure 6. Experimental set up for liquid contacting at well 8

Table 4. Results of of Test 4

Water flow	Methane Product Flow	Gas Composition
700 ml/min	70 ml/min	95%
700 ml/min	90 ml/min	
700 ml/min	69 ml/min	
700 ml/min	70 ml/min	

Conclusions

Methane produced from Marsing city water wells is 93-98% pure saturated in water vapor. Most natural gas wells are 70 -90 % methane and saturated with water vapor, but can have high levels of contaminants such as carbon dioxide (CO_2) and sulfides. As with any Natural gas production in the USA the city of Marsing's methane is saturated with water vapor. However, it lacks any significant concentrations of contaminants. Table 5 compares standard US natural gas well production composition to that found in Marsing.

Table 5. Comparison of typical natural gas compositions with City of Marsing's

	Typical Natural Gas Well	City of Marsings Wells
Methane	70-90 %	93 – 98 %
Nitrogen	5-30 %	<5 %
Carbon Dioxide	1 – 10 %	<1 %
Hydrogen	0 – 4 %	<1 %

Disulfide		
Water Vapor	saturated	~saturated

The City of Marsing has an estimated 3 -10 CFM (from a 2010 study) of 95 to 98 % clean methane per well being produced from their city water well system. Testing performed in these studies showed that the water vapor present in the natural gas can be removed by a membrane dehydration process. Liquid contacting results show that methane production can be taken directly from the well water. Further studies of liquid contacting need to be carried out to determine how much additional natural gas could be recovered from the well water, either at the surface or down well, while gaining a solid understanding of potential for membrane fouling over time.

Recommendations (possible directions forward)

1. Simple compression and storage of methane vent gas (Figure 7). The compression step should remove nearly all liquid water and a majority of the water vapor. This strategy would prepare the methane for use as a heat source by the city or for direct sale to the local gas company.(INL consultation in natural gas handling, Bruce Wilding 208 526 8160, Source of methane compression equipment and possible engineering assistance: Hy-bon.com (hy-bon phone # : 432-697-2292 or 1-800-725-1878)

2. Rough compression of the vent gas combined with a membrane drying process followed by dry compression and storage (Figure 7), this strategy would prepare the methane for use as a heat source and or for electrical generation. (Source of membrane drying cabinets ext. Genron.com, Progen.com, Air Liquide.com) The dry clean natural gas could be sold directly to the gas company.

3. Rough compression to ~10-15 psi and direct delivery to a methane fuel cell skid. The direct methane fuel cell can tolerate up to 100 % humidity and generate electricity as methane is delivered. The electricity could be sold directly to the power company and deducted from the city's power bill. (Source for fuel cell skid, Bloomenergy.com)

4. Rough compression of the vent gas combined with a membrane drying process followed by dry compression and storage. Using this approach additional natural gas could be captured by a combination of liquid contacting both at the surface water and down well. Liquid contacting at the surface could include a liquid and vapor separation step. This strategy would prepare the methane for use as a heat source and/or for electrical generation (Figures 7,8,9,10). (Source for liquid contacting membrane modules, Compactmembranesystems.com)

Figure 7. Compression and storage diagram

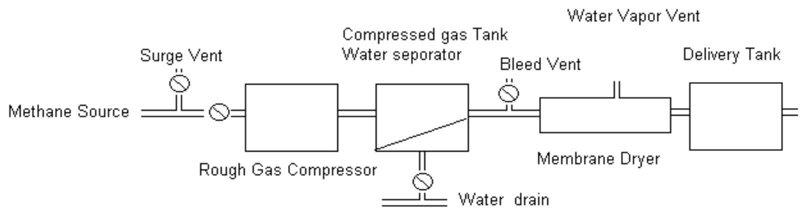


Figure 8. Strategy for using both vent gas and down well liquid contacting

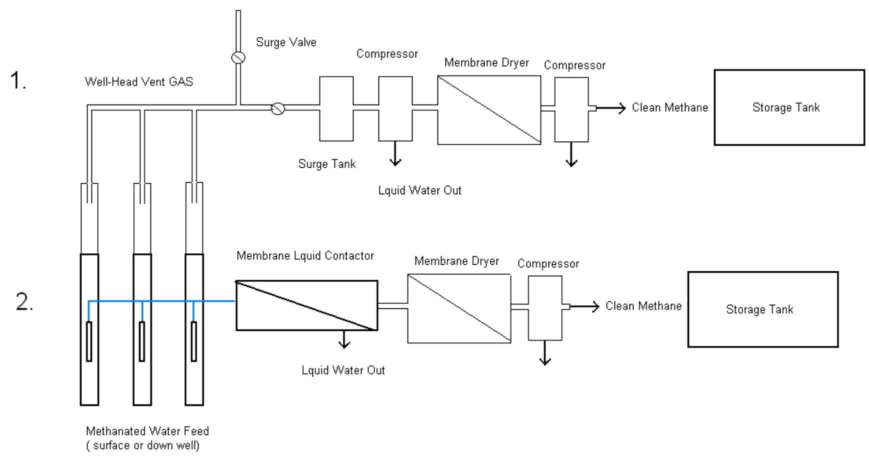


Figure 9. Liquid and vapor separation tank step.

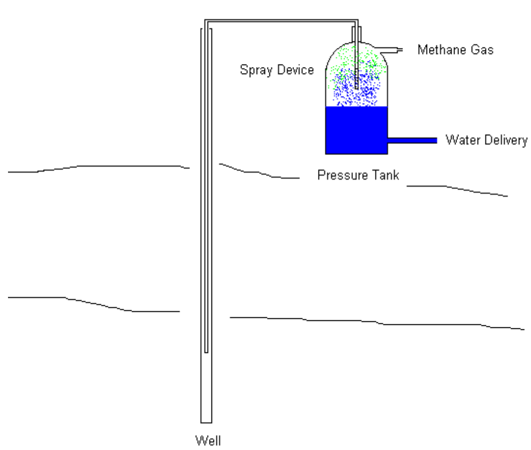


Figure 10. Combined strategies to remove methane from surface water