PREVENTION OF FREEZING IN MEASUREMENT AND REGULATINGSTATIONS

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Introduction

The competitive business environment that exists in the energy industry demands reliable service. Even though it is expensive to change energy companies, customers do have options if they become dissatisfied with their service. Significant money can be lost with trading partners through erroneous data used in establishing the value of the trade. The regulatory environment is becoming more strident in demanding safe, controlled operations. Even minor excursions outside prescribed norms can lead to substantial fines, and worse, years of having regulators going over operations with a fine tooth comb looking for any discrepancy.

Two of the hallmarks of all successful companies involved in the natural gas industry are precise, reliable controls and accurate, repeatable measurement of both volume and BTU value. Freezing is an operational occurrence which frequently affects both control and measurement systems. Freezing can cause control systems to fail by blocking the supply of instrumentation gas to control devices and actuators. Freezing can cause gas volume measurement to be inaccurate by ice build-up on meter tube surfaces, by blocking straightening vanes, and by altering the effective dimensions of orifice plates. A control system failure can cause a power plant to go off-line at a critical time of high demand. A control system failure can cause a plant such as a glass manufacturing facility to shut down while in process. Measurement system failures greatly alter the value of the trade. All of these can be very expensive on many levels. The relatively small cost of freeze prevention is a very good long term investment.

The Problem

Freezing is the result of either ice or hydrate formation within the gas system. Both are dependent on the presence of water in the flow of gas. Modern gas production techniques involve considerable use of water. Water gets into pipelines from other sources such as minor leaks that suck water into the pipe form the formation of venture drafts. Considerable effort and expense is put into removing water from the gas flow at all steps of the process from the well head to consumption. It is, however, very difficult both physically and expense wise to remove all of it. For this reason, typical dry gas standards allow for 7 lbs. of H_2O per one million SCF of gas. Under the right conditions this is more than enough to cause problems.

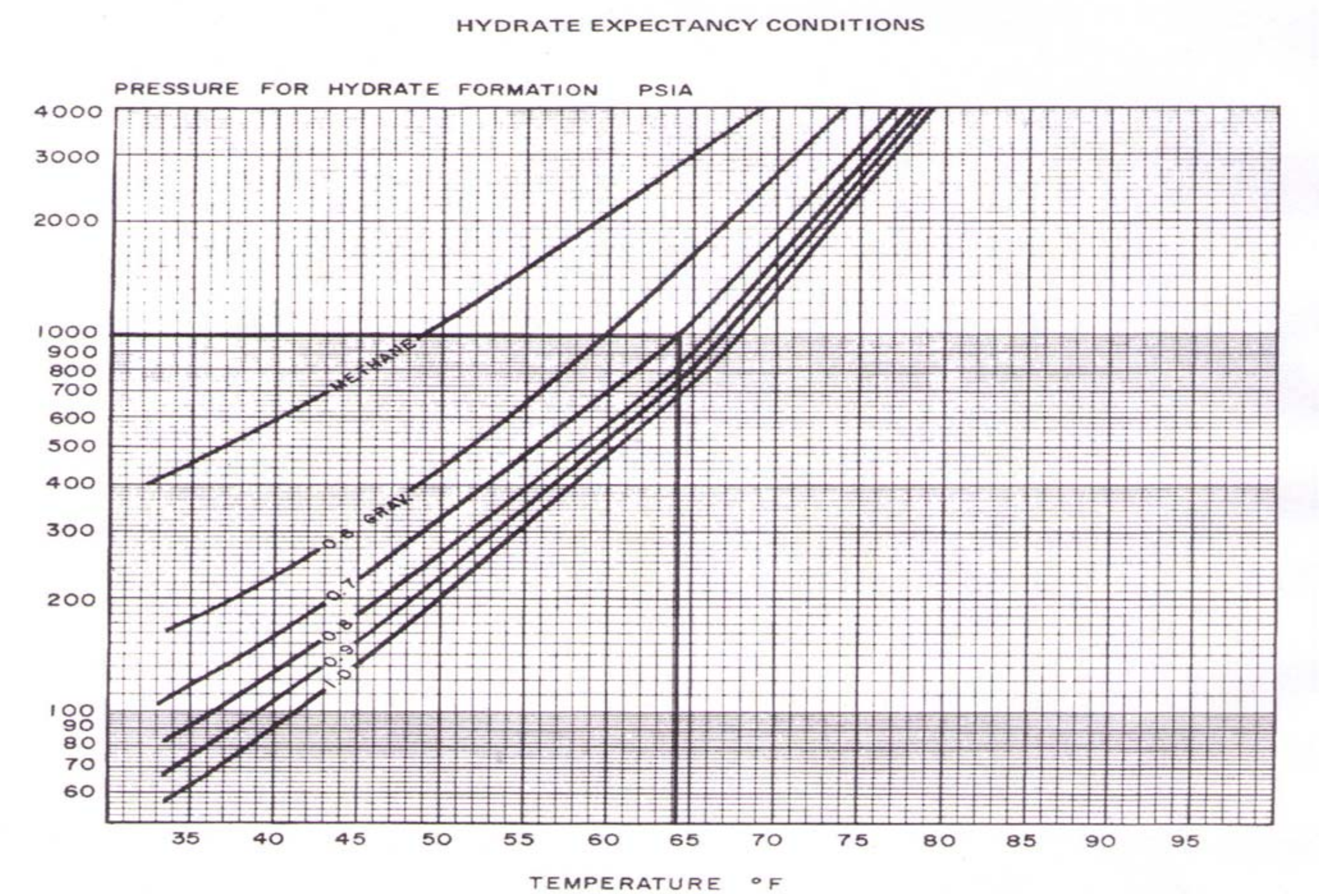
Ice forms when water vapor within the gas stream experiences conditions that cause condensation and freezing to occur. Ice formation occurs at a relative 32°F. The biggest cause of ice formation is a pressure drop and the Joule-Thompson Effect. For every 100 PSI drop in pressure the temperature drops 7°F. If the initial flowing pressure is 950 PSI at a temperature of 50°F and pressure is reduced to 250 PSI, the 700 PSI drop will yield a temperature drop of 49°F. Subtracting the 49° from the 50° gives a new gas temperature of 1°F, well below freezing. This is not an uncommon controlled pressure drop. Some of the other causes of ice formation are turbulence in headers and severe bends, rapid expansion of the gas when moving to a larger pipe diameter, and extreme ambient conditions.

Hydrates are snow-like, complex, crystalline solids that form when water vapor combines with some hydrocarbon gases under the right conditions of temperature and pressure. They are more common in high BTU gas, but, are not limited to it. Figure 1 is a temperature/pressure graph that shows some curves for hydrate formation at different specific gravities plus methane. The rapid process starts with the formation of the first water-hydrocarbon crystal and proceeds like a chain reaction. The initial hydrate formation is dependant on the presence of free water or water vapor. Following are some of the chemical equations for hydrates:

1. Methane $CH_4 \cdot 7H_2O$
2. Ethane $C_2H_6 \cdot 8H_2O$
3. Propane $C_3H_8 \cdot 18H_2O$

As you can see from these equations it usually takes seven or more molecules of water to a single molecule of the hydrocarbon. Hydrates can also form from the combinations of carbon dioxide and hydrogen sulfide with water. These are two very common constituents of natural gas.

Figure 1



Following are some of the conditions that promote hydrate formation:

1. Primary considerations:
   - Gas must be at or below its water dew point with free water present.
   - Low temperature.
   - High pressure.

2. Secondary considerations:
   - High Velocities.
   - Pressure pulsations.
   - Any type of turbulence or agitation.
   - Introduction of a small hydrate crystal.

The Solutions

Freezing problems occur under many different operational conditions. Solutions must be designed for the particular needs at each location. The most important aspect of freeze protection is anticipation. Where conditions such as pressure drops exist in the flow, freezing is possible. An ounce of planning can save a ton of grief. Very close behind anticipation in importance is selecting a method of freeze prevention that is cost effective, will give consistent results, and can be easily maintained. Following are some options available:

1. Glycol Dehydration

One of the most common methods of dehydration for large volumes of gas is glycol absorption. Gas passes through glycol in a vessel called a contactor. The glycol absorbs water from the gas. The glycol is then treated by circulating it through a regenerator and distilling out the water. The reconditioned glycol returned to the contactor and the process is repeated. The objective is to remove the water to a point where the water vapor dew point of the gas will not be obtained at the highest pressure and the lowest temperature of the pipeline. This process can reduce the water dew point to 60-70°F. This system is a low cost continuous operation and has a minimal pressure loss across the unit. The drawbacks are potential glycol carryover or slugs during surges, contamination by solid particles, and inefficiency with fluctuating flow rates.

2. Solid Absorption

A very efficient method of water removal is the dry bed or molecular sieve method. Gas is passed through large towers containing solid particles (molecular sieve) which aggressively absorb the water. Eventually, the sieve becomes saturated and must be regenerated. The gas stream must be switched to a second tower for continuous operation. Hot gas is then passed through the first tower to evaporate the water and dry the sieve. Cool gas is then passed through the sieve reading it for reuse. This cycle is repeated until the sieve has degenerated beyond reuse and must be replaced. This method produces very dry gas across a wide range of flow rates. Its drawbacks are that is is more costly than glycol and more complex to operate.

3. Methanol Injection

Methanol injection is a very common freeze protection practice for smaller systems and locations such as regulator stations at storage facilities. Methanol is injected into the gas flow ahead of a pressure drop or other cause of freezing using a chemical injection pump. Methanol works as an anti-freeze lowering the freezing point of the gas. It also lowers the hydrate formation temperatures. The amount of methanol required is easily calculated using available tables.

This method is also very effective for protecting pneumatic controllers. Pneumatic controllers operate by passing small volumes of gas through small orifices and passages making them very sensitive to freezing. Control gas is passed through a small vessel containing methanol to condition the gas. An in-line filter should be placed between the vessel and the controller to prevent methanol carry-over from reaching the controller. This method is very effective and inexpensive.

4. Heat Application

Heat is a logical solution to freezing. If the temperature of the gas is never allowed to reach freezing temperatures, ice can not form. For large scale operations this method has significant drawbacks. While freezing is eliminated, the water remains in the flow to cause problems downstream. Heat systems are expensive to install and consume large amounts of fuel in operation. The heat rapidly dissipates downstream from the source. It is also a safety concern in that it is an ignition source that requires constant vigilance to prevent disaster.

Heat, however, can be a very effective solution to freezing in specific points of high freeze potential such as instrument regulators. Following are some of the methods available: insulating blanket, electric heat blanket, insulated cabinets with catalytic space heaters, in-line catalytic heaters, and heated regulators. In addition to effective freeze protection, these devices are relatively inexpensive. As with any source of heat, these items still present a possible ignition source and must be properly maintained.

5. System Design

Considerations can be made in designing measurement and regulation systems to reduce or eliminate freezing potential. Piping configurations that allow liquid accumulation should be avoided. Fully ported ball valves and large diameter tubing should be used so that no restrictions are present in the gauge and instrumentation lines. Tubing should be installed so that there are no “traps” present. All tubing should slope upward from the tap to the instrumentation to prevent liquid accumulation in gauge lines. Taps should be installed at least five pipe diameters from any source of turbulence and probes should always be used to collect clean gas from the center of the flow and thus avoiding the “garbage” that flows along the wall of the pipe and can accumulate in the tap. Lastly, the system should be leak free. Some leaks can create a venture draft that draws liquids into the piping. Other leaks can draw liquids in the piping toward the leak. The avoidance of traps and liquid drop out areas in piping design will work to greatly minimize freezing potential.

6. Drip Pots, Coalescers, and Liquid Dumps

Where severe liquid problems or the potential for slugs of liquids exist in gas supply used for instrumentation, drip pots and coalescers can be used to eliminate or minimize the amount of water. Both of the devices work by having the liquid attach to a surface thus separating if from the supply gas. The liquid drains away under its own weight. These devices require routine draining. For extreme cases, automatic liquid dumps can be used collect the liquid and periodically self drain using an internal float valve assembly to release the liquid to a lower pressure point. These devices are particularly useful in measurement flows where you do not want to affect the gas measurement by using filters.

7. Instrument Filters

Probably the most common and most cost effective method of preventing freezing in instrumentation supply is the use of filters and filter/dryers. Not only do these devices protect sensitive instrumentation from freezing, they also protect the instrumentation from particulate matter flowing in the gas stream. In some cases a good linear polyethylene filter will do the job, but, in most the filter/dryer is the best solution. Filter/dryers are designed for high pressure applications and have removable media cartridges. The cartridges typically include a desiccant to remove liquid, activated charcoal to remove odorant and small amounts of H_2S, and filter pads to remove particulate matted down to 2-4 micron. Other media from molecular sieve to special H_2S removal media are available. Filter/dryers are very cost effective freeze protection and only require periodic cartridge replacement to remain effective.

For critical locations where shutting down the instrument piping is not an option, two filter/dryers can be combined into a dehydration system with two offset regulators to provide continuous operation. One regulator is set 10 PSI higher that the other. The gas will follow this path until the desiccant in that filter/dryer becomes saturated causing the regulator to freeze. The gas will automatically switch to the lower pressure regulator maintaining gas supply. The cartridge can be changed on the frozen side. Readjustment of the regulators to change the high/low pressure orientation keeps the gas flowing through the second regulator and then first regulator with the fresh cartridge waits its turn. For extreme conditions, the dehydration unit can be configured with an in-line catalytic heater.

Another option is to combine the filter/dryer and catalytic heater into a multi-chambered devise called an instrument column. The entire column is heated with a catalytic heater. Instrumentation supply gas comes into the bottom chamber. A pressure cut is taken on the outlet of the chamber to feed higher pressure requirements for instrumentation gas and to feed the second chamber. A pressure cut is taken on the outlet of the second chamber to feed lower pressure requirements and the third chamber. A pressure cut is taken on the outlet of this chamber to feed the lowest pressure requirements and the catalytic heater. This devise has two things working for it: heated gas and smaller pressure cuts to minimize Joule-Thompson affect.

Conclusion

Freezing is a major issue in any natural gas system from the mainstream pipeline flow to the low pressure measurement and control stations. With thorough evaluation and careful planning of each application, proper selection of available options, and a good routine maintenance program freezing problems can be controlled and minimized. If these issues are ignored, the cost of fixing the resulting problems is almost always significantly more expensive than the cost of the preventive action not taken. At the low end of this, not replacing a $50.00 filter cartridge can cause the loss of a $3,000.00 pneumatic controller that can in turn cause a power plant to shut down at peak demand. Depending on contractual considerations this single event can cost in the hundreds of thousands of dollars and put not only the system at risk but people that depend on the electricity at risk. Avoiding freezing issues is a good investment that adds to the profitability of your company, and, is the responsible thing to do.

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