

## HYDROCARBON DEW POINT MEASUREMENT IN NATURAL GAS

ANDY BENTON  
TECHNICAL CONSULTANT  
MICHELL INSTRUMENTS LIMITED  
PROCESS SENSING TECHNOLOGIES (PST)



### Introduction

Hydrocarbon dew point (HCDP) in natural gas is an important quality parameter, stipulated in tariff specifications and enforced throughout the supply chain, from processors through transmission and distribution companies to final end-users. Accurately monitoring hydrocarbon dew point temperature in natural gas is vital if the integrity of pipeline infrastructure and quality of the gas are to be maintained, in compliance with contractual agreements.

### Hydrocarbon Dew Point Definition

API measurement standards define hydrocarbon dew point as the temperature at a given pressure at which hydrocarbon vapor condensation begins<sup>1</sup>. This is not very workable since it could identify the temperature when the first two molecules find it irresistible to stay apart and connect to form a microdroplet of liquid that no longer obeys the gas laws which moments before governed their behaviour.

Experience in the field proves this is not a practical definition for HCDP. The theoretical conditions above will not necessarily have an adverse effect on the operation of a gas turbine or create liquid drop-out in a pipeline that could restrict flow capacity, increase differential pressure or lead to

impact damage to turbine compressors. A more workable definition, and one generally practiced in North America, is the temperature when the first visible droplets of liquid hydrocarbon form on a surface at a defined pressure. Under currently approved practices, the pressure for this measurement is the contract pressure. The de facto industry standard for observing the appearance of these droplets and measuring the temperature when it occurs is the Bureau of Mines Dew-Point Apparatus operated in accordance with ASTM D1142.

Hydrocarbon dew point is dependent on pressure, temperature and the composition of the gas. The heavier compounds will condense at higher temperatures. As a very rough rule of thumb, the higher the BTU content the higher the HCDP. The pressure and temperature pairs can be plotted where HCDP occurs for a specific gas sample. The resulting curve, called the phase envelope, can be used to understand the behaviour of the gas under specific conditions. Figure 1 illustrates the phase behaviour of a typical transmission quality natural gas. The HC dew point curve indicates variation with temperature and pressure in phase change from wholly vaporous to mixed condensate in gas phases.

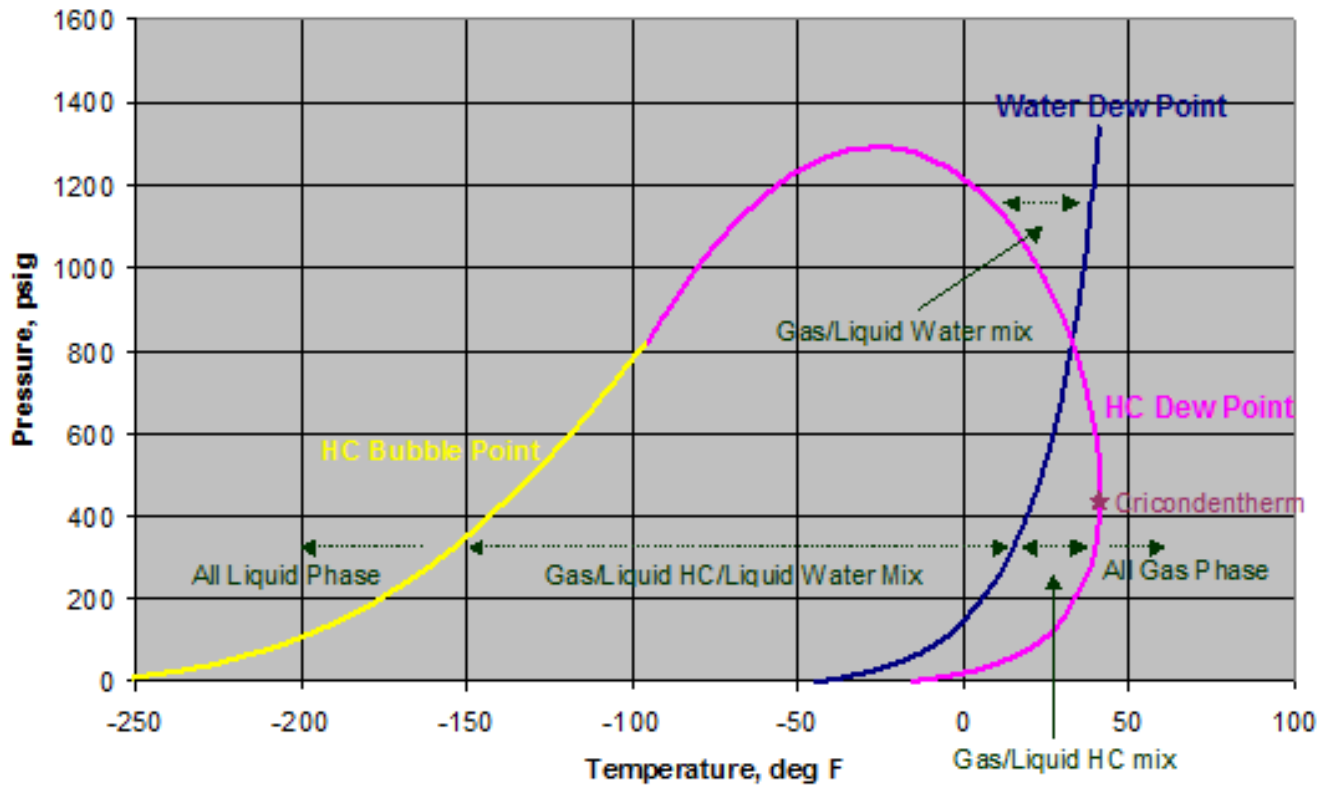


Figure 1 - Typical retrograde phase envelope for natural gas. Note: The cricondentherm represents the highest temperature at which the vapor-liquid equilibrium may be present.

One point on the phase envelope for a given gas is called the cricondentherm. The derivation of the word cricondentherm is critical condensation thermal point and can be shown on the phase envelope curve. The cricondentherm is the maximum temperature where hydrocarbons can condense in that specific gas mixture at any pressure. This key point can tell us how the gas will behave as the pressure is let-down at the processor or end-user's location. Measuring the HCDP at this point can provide valuable information about the gas.

Avoiding the formation of such liquids in natural gas is of critical importance throughout midstream operations. In gas pipeline transmission the presence of liquid hydrocarbons can result in

impact damage to compressors whilst collection of liquid in low points in the pipeline can restrict gas flow capacity.

Electricity power stations have critical requirements with respect to hydrocarbon dew point. Natural gas fuelled turbines designed for low NOX emissions require at least 50°F of 'superheat' - the differential between dew point temperature and the delivery temperature of the gas on entry to the fuel gas/air pre-mixing system. If this is not achieved then the cooling effect of the expansion of large flows of fuel gas can cause liquid to be formed, resulting in possible flashback of the flame from the ignition nozzle into the mixing chamber. The cost repercussions of such a problem can be serious given the resultant sudden

interruption to electricity generation, potential damage to the mixing/burner system and increased maintenance downtime to the power station.

Figure 2 below is a typical phase envelope for natural gas showing three HCDP curves at different stages of processing and one of water dew point (following glycol dehydration during upstream gas production). The three cricondetherm points are identified on the respective hydrocarbon dew point curves. Every field and producer/processors' gas will have a different curve due to differences in composition.

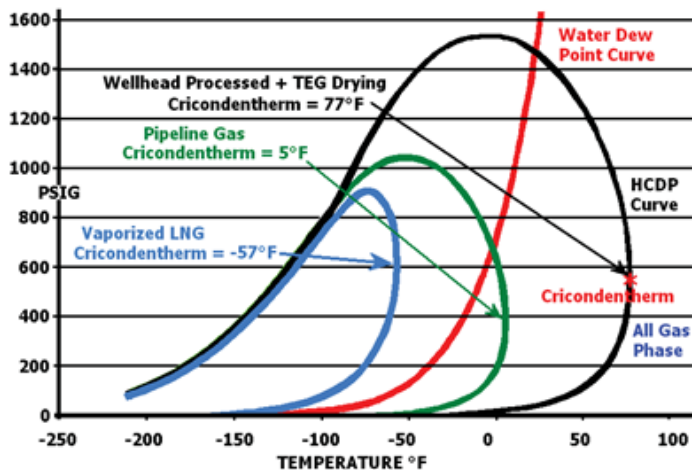


Figure 2 – Phase envelopes at stages of processing

### Hydrocarbon Dew Point Measurement Methods

There are three primary methods used in North America:

- Manual visual dew point method
- Equations of state (EOS) method using gas chromatograph (GC) analysis
- Automatic optical condensation dew point method.

Each of these methods are described below with their advantages and disadvantages.

### Manual, visual technique with chilled mirror dewpointmeter

This is the traditional method for measuring HCDP and can also be used to measure water dew point (WDP) in natural gas. The Bureau of Mines device has been used since the 1930s to provide manual dew point measurements. This method is used for “spot-checking” the dew point of a sample as extracted from a tap on the pipeline from any location in a gas processing facility or point of use. It allows a trained operator to detect the dew point visually and interpret that image as a HCDP or a WDP or a contaminated dew point. It requires patience and training to be able to operate this instrument properly.

There are two chambers within the instrument. One is the sample chamber that is suitable for pipeline operating pressures, containing a mirror visible through a window. There is also a method for measuring the temperature of the mirror. A second chamber allows a coolant to be conducted across the back of the mirror.

The operator connects the sample to the inlet port and begins purging the chamber with a flow of sample. A coolant, typically an expandable gas like liquid propane or carbon dioxide is connected to the coolant inlet. The operator then throttles the coolant through a valve, cooling the polished mirror in contact with the sample gas until the dew point is observed. This image is indicated by the first appearance of very small droplets of hydrocarbon condensate appearing on the mirror. The temperature is immediately read, and the value noted.

Since the operator must interpret the image seen on the mirror, there will always be some subjectivity in this method. The proper procedure is described

in ASTM D1142, but operator experience is critical for best accuracy. The condensate is a shiny, transparent coating that requires training to distinguish and interpret the image on the mirror.

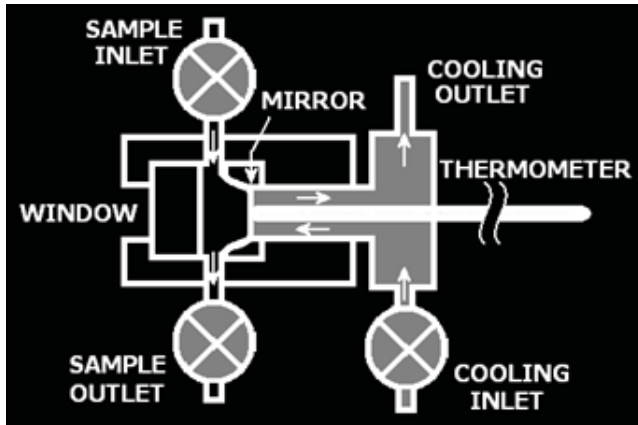


Figure 3 - Bureau of Mines Apparatus Schematic



Figure 4 – Bureau of Mines Dew Point Tester<sup>2</sup>

The latest dew point tester design utilizes a thermoelectric cooler (TEC) to achieve the required

mirror temperature and is powered by a rechargeable battery as a self-contained portable instrument with Ex certification for Class I Division 1 hazardous area operation. No ancillary coolant supply or cylinder gas is required. Digital camera technology captures a high-definition mirror image which is displayed on a large full-color LCD in real time throughout the measurement cycle.



Figure 5 – Example of contemporary dew point tester

Two mirror illumination modes assist the operator to clearly observe the dew point and positively identify the form of condensation, be that frost/ice/water or HC condensate. Visible red light projected onto the mirror at an acute angle provides the clearest image of high surface-tension water dew droplets/mist or frost. Alternatively, a white light beam perpendicular to the mirror in the same orientation as the camera enables thin, low surface-tension HC condensate to be observed and identified by the operator viewing the LCD.



Water/ice is not clearly visible under vertical white light whilst HC condensate does not show under the red illumination, enabling the user through changing between light sources to verify the form of dew observed and identify combined dew formation of water and HC simultaneously, should that occur.

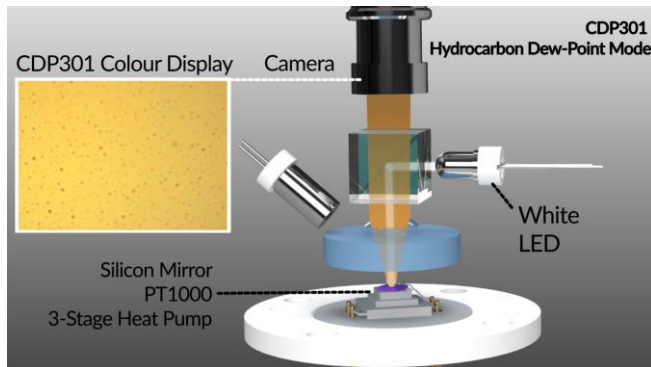


Figure 6 – HC dew point principle for contemporary dew point tester

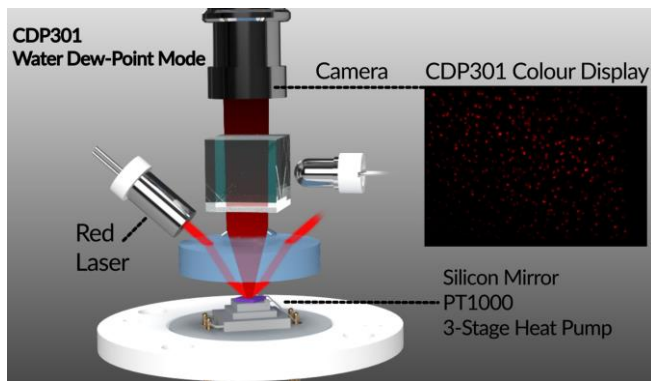


Figure 7 – Water dew point principle for contemporary dew point tester

Mirror temperature is controlled via the by the measurement inface operated by the user. The operator can select manual cooling increments of typically 1 to 5°C to obtain swiftest measurement results. For highest precision such an instrument offers automatic mirror cooling control at rates down to 1°F/minute in accordance with ASTM D1142. It is normal for a sequence of measurements to be made, firstly using manual cooling increments for a swift estimation followed

by a more accurate measurement achieved using the automatic cooling control through the critical temperature region. As required by the ASTM, temperature of dew formation (during cooling) and evaporation (during subsequent warming) are captured through the operator interface, and the average calculated as the measured dew point. Following each measurement, heated mirror recovery to >120°F with continued sample purge cleans the mirror between measurements.

In addition to logging measurement data, such a recent instrument design allows the operator to record the whole measurement as video or capture still images of the mirror with dew formation present. Such content can be exported to PC for later review or form a measurement archive.

*Advantages of the Manual Visual Method:*

- Direct first principles dew point measurement
- Potential to measure both HCDP and WDP, depending on gas characteristics
- Considered the de facto standard for hydrocarbon dew point measurement

*Weaknesses of the Manual Visual Method:*

- Periodic spot checking only
- Older Bureau of Mines devices require cylinder gas for cooling and measurements made considered 'Subjective' operator dependant

**Equation of state calculation method from GC analysis**

Gas is sold based on its heating value and GC analysis is primarily used to determine that value. Since fiscal reporting is based on this heating value, there is a large installed base of field GCs in North America. Most of these chromatographs generally analyze only through C6+ with a few analyzing through C9+ on pipeline gas and in end-user installations. Both buyers and sellers verify the heating content of the gas they are

buying/selling but the sample used for analysis by the GC needs to be handled with care. Should the sample be allowed to cool below the HCDP, the measurement of the heating value would come under question.

Many users are now applying equations of state (EOS) to this data to calculate the HCDP value to ensure the sample lines are maintained above this temperature. Equations of state predict the HCDP of the gas sample, but are they really up to the task? Hydrocarbon dew point is mainly influenced by hydrocarbons above C6, so here are a few comments:

- “the traditional C6 plus analysis provides insufficient data for a valid hydrocarbon dew point calculation.”<sup>4</sup>
- “Based on comparisons to date, however, the C9+ characterization most often appears to predict measured dew points only to within  $\pm 25^{\circ}\text{F}$ .”<sup>5</sup>

This alert gives rise to the idea of designing any sample system for any calculation-based method of detection of HCDP to maintain a temperature of at least  $30^{\circ}\text{F}$  above the highest projected dew point to prevent premature condensation and the errors that would result.

Standards have been written suggesting minimum requirements for producing good data including ISO23874 (2006) ‘*Natural Gas – Gas Chromatographic requirements for hydrocarbon dew point calculation*’. This standard states that the GC system requirements for analysis of higher hydrocarbons includes:

- “be capable of measuring alkanes up to and including n-dodecane;” (C<sub>12</sub>)
- “be capable of measuring individual alkanes at a concentration of 0.000 0001 mole fraction (0,1 ppm1) or less;” (0.1ppmV ed.)
- “be able to distinguish and measure benzene, toluene, cyclohexane and methylcyclohexane as individual components”

- “measure all hydrocarbons in the range C<sub>5</sub> to C<sub>12</sub>”.

A major turbine manufacturer went a step further with this statement. “Small quantities of heavy hydrocarbons above C6 raise the dew point significantly. Using a standard analysis can result in an artificially low dew point determination. Instead, an extended analysis should be used except where no C6+ compounds are present. (An extended gas analysis to C14) checks for the presence of the heavy hydrocarbons and quantifies their amounts to the level of C14. The extended analysis is more complicated and expensive than the standard analysis, and not all laboratories can provide this service. It is, however, the only type of analysis that will result in an accurate dew point determination. An analysis procedure for C1 through C14 is described in GPA 2286-95.”<sup>6</sup>

GCs designed to meet this set of specifications are laboratory GCs, not yet adapted for field installation and are prohibitive in cost for custody transfer points and processing plants. The calibration gases are also very costly to properly operate such a GC. It should be noted that such a system will produce much better HCDP data than the C9+ characterization.

The reason is simple. The equations of state need information that simply cannot be provided by the field GCs in the currently installed base. Table 1 illustrates why. The heavier components in the Standard Analysis to C6+ have been simply lumped together as would be done by the field GC. The results speak for themselves with over a  $115^{\circ}\text{F}$  difference for the same gas.

The difference is that even small quantities of heavier hydrocarbons strongly influence this calculation. These heavier components induce the formation of the HC condensates that cause problems inside the pipeline too. While it may be of interest to know the concentration of liquids from assumptions from the data above, the HCDP

is generally the parameter given in most tariffs and contracts. Due to the large total volumes of gas transmitted in a pipeline and the variation in the topography along its route, any liquid will gather at the lowest points and can cause serious transmission problems.

*Advantages of using EOS from GC data:*

- Potential to combine several gas quality/fiscal metering parameters into one analyzer
- Possibility to provide a theoretical phase envelope curve
- Adding HCDP calculation software to an existing measurement technology may have a lower installation cost.
- The components contributing to a high dew point level may be identified and help to determine the reason or source of these components.

*Weaknesses of using EOS from GC data:*

- It is an indirect method relying on the correct application and suitability of the equation of state being used.
- The accuracy of extended analysis is dependent on correct and regular use of special reference gases.
- The limit of analysis sensitivity and compositional changes especially of aromatics, e.g. benzene and toluene, can produce large measurement errors.
- Staff specialists are required to operate/maintain the instrument performance
- There is a high initial outlay for a GC with C9 capability, installation costs (analyzer house) and operating costs (personnel and reference gases).
- When extended analysis cannot be performed on-site and samples must be sent to a laboratory, the added uncertainty in the results can reduce the confidence in this data.

Component			C <sub>6+</sub>	C <sub>6+</sub> 60/30/10 split	C <sub>9+</sub>	C <sub>9+</sub> 60/30/10 split	C <sub>12+</sub>	C <sub>14</sub>	C <sub>16</sub>
Helium	mol	He	0.0137	0.0137	0.0137	0.0137	0.0137	0.0137	0.0137
Carbon dioxide		CO <sub>2</sub>	0.1532	0.1532	0.1532	0.1532	0.1532	0.1532	0.1532
Nitrogen		N <sub>2</sub>	0.8418	0.8418	0.8418	0.8418	0.8418	0.8418	0.8418
Oxygen		O <sub>2</sub>	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Argon		Ar	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Hydrogen		H <sub>2</sub>	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Methane		C <sub>1</sub>	97.4699	97.4699	97.4699	97.4699	97.4699	97.4699	97.4699
Ethane		C <sub>2</sub>	1.0471	1.0471	1.0471	1.0471	1.0471	1.0471	1.0471
Propane		C <sub>3</sub>	0.3291	0.3291	0.3291	0.3291	0.3291	0.3291	0.3291
iso-Butane		iC <sub>4</sub>	0.0487	0.0487	0.0487	0.0487	0.0487	0.0487	0.0487
Butane		C <sub>4</sub>	0.0535	0.0535	0.0535	0.0535	0.0535	0.0535	0.0535
neo-Pentane		nC <sub>5</sub>	0.001	0.001	0.001	0.001	0.001	0.001	0.001
iso-Pentane		iC <sub>5</sub>	0.0107	0.0107	0.0107	0.0107	0.0107	0.0107	0.0107
Pentane		C <sub>5</sub>	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081
Hexane		C <sub>6</sub>	0.0117	0.00702	0.006	0.006	0.006	0.006	0.006
Benzene		C <sub>6</sub> H <sub>6</sub>		0.00351	0.0004	0.0004	0.0004	0.0004	0.0004
Heptane		C <sub>7</sub>		0.00117	0.0035	0.0035	0.0035	0.0035	0.0035
Toluene		C <sub>7</sub> H <sub>8</sub>			0.0003	0.0003	0.0003	0.0003	0.0003
Octane		C <sub>8</sub>			0.0007	0.0007	0.0007	0.0007	0.0007
m-Xylene		mC <sub>8</sub> H <sub>10</sub>			0.0001	0.0001	0.0001	0.0001	0.0001
Nonane		C <sub>9</sub>			0.0007	0.00042	0.0003	0.0003	0.0003
Decane		C <sub>10</sub>				0.00021	0.0001059	0.0001059	0.0001059
Undecane		C <sub>11</sub>				0.00007	0.0001099	0.0001099	0.0001099
Dodecane		C <sub>12</sub>					0.0001842	0.0000902	0.0000902
Tridecane		C <sub>13</sub>						0.0000551	0.0000551
Tetradecane		C <sub>14</sub>						0.0000252	0.0000252
Pentadecane		C <sub>15</sub>							0.0000105
Hexadecane		C <sub>16</sub>							0.0000032
Pressure	PSIG		400	400	400	400	400	400	400
°F HCDP @ Cricondentherm			-66.5	-60.3	-24.1	-7.8	20.3	36.5	49.1
			C <sub>6+</sub>	C <sub>6+</sub> split	C <sub>9+</sub>	C <sub>9+</sub> split	C <sub>12+</sub>	C <sub>14</sub>	C <sub>16</sub>

Table 1 - HCDP values calculated by Equation of State on 1020 BTU Gas

### Automatic, optical condensation method

A number of automatic, optical condensation dew-point instruments have been designed for on-line hydrocarbon dew point measurement over the past forty years. All these instruments function on the fundamental principle of direct measurement of the temperature at which hydrocarbon liquids start to form on a chilled surface exposed to the gas sample

to be measured – by definition, the hydrocarbon dew point. These instruments function on a cyclic basis, up to six measurement cycles per hour.

An optical surface is chilled until a thin layer of condensate forms on that surface. Measuring the surface temperature when that occurs gives the HCDP temperature. Automatic Dew Point Analyzers are not influenced by individual



operators and include all gas constituents in their analysis. They are available in field installable units that can be mounted very near the sample tap, providing a fast response to any change in the properties of the gas.

The dew point method of chilling a mirror until the condensate formation is observed is the longest established method of measuring HCDP (manual visual method) accurately and is also the oldest method for measuring water dew point (WDP). Automation of the detection and operating methods would eliminate the subjectivity of the original Bureau of Mines device. The benefit would be on-line measurements with increased accuracy and repeatability. But hydrocarbon condensates do not behave as water condensates do.

Water condensates disturb a light path in both the liquid and solid phases. Because of refractive properties they can be seen, for example, as dew or frost on the windshield of a car when the ambient conditions are right. This is due to the unique high surface tension of water - a single molecule with very well documented characteristics. Hydrocarbon condensates only marginally disturb a light beam due to their low surface tension and transparency. This makes it difficult to see the first formation of the condensate on a chilled mirror. The very low surface tension of these HC condensates is also affected by the fact that natural gas is a mixture of compounds. Because the mixture of components cascade sequentially on a surface as it is chilled, the HC condensate film will occur gradually across a small range of temperatures. This is one reason that automating the manual method dew point technique needed a new approach.

Since the 1980's, researchers have devised a number of opto-electronic methods to detect the formation of HC condensates on a cooling mirror surface. The latest innovation is based on digital camera technology.

Using a contemporary design of manual dew point tester (as described previously in this paper) as a research platform, a novel method detects and identifies the formation of condensation occurring on the cooling mirror surface. Algorithms interpret RGB (red, blue, green) color band intensity changes of the sensor mirror image captured by the digital camera CCD sensor.

Research tests show that mirror illumination with perpendicular projection white or acute incidence visible red light improves specificity and signal response to individual forms of condensation. Different forms of condensation exhibit unique changes in the relative intensity of RGB colour segments. HC condensate and water/ice exhibit distinct RGB signal change 'signatures', positively identifying the form of dew point being detected during each measurement cycle.

Detection sensitivity of thin HC condensate film is enhanced using a silicon mirror with proprietary surface finish. White light perpendicular to the mirror provides the strongest change in RGB intensities for HCDP measurements (Figure 8).

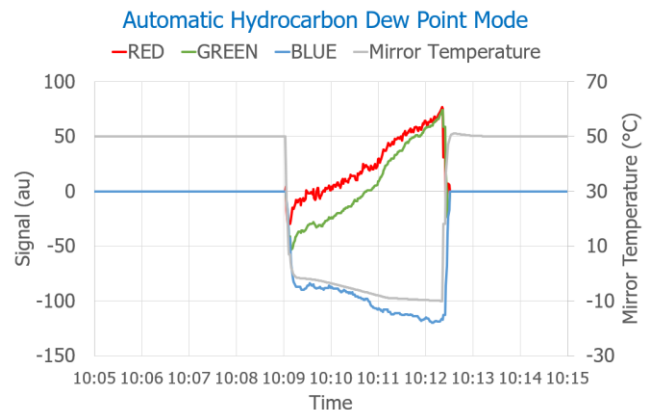


Figure 8 – RGB signal changes for HC dew point under perpendicular white light (measurement cooling cycle from 10:09 to 10:12, -10°C HCDP)

In WDP measurement mode using side angle projection of red light, a PID control loop stabilises the mirror temperature at the equilibrium condition

with a fine water mist or frost layer on the mirror. An equilibrium of constant evaporation and condensate rates is achieved, which is only possible due to the distinct nature of water vapour as an individual component in the gas composition. A defined and constant increase in red light intensity captured through the camera triggers the reading of WDP temperature (Figure 9). The operation of PID control loop is analogous with the ASTM D-1142 test method, whereby successive dew formation and evaporation is detected in order to determine the measured WDP.

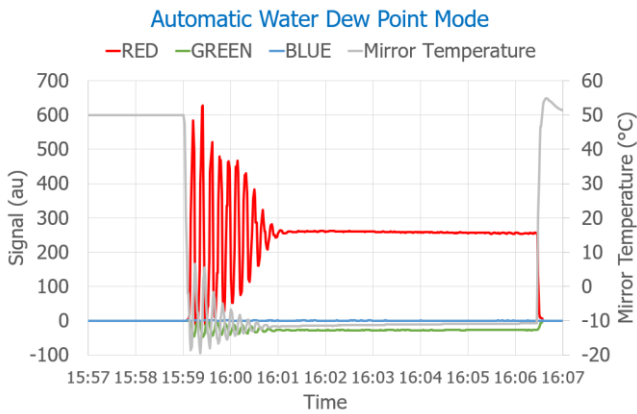


Figure 9 – RGB intensity changes for WDP in acute incidence visible red light (measurement cooling cycle 15:59 to 16:06, -10°C WDP)

In the event that water condenses before HC condensate during a measurement cooling cycle in HCdp mode with white illumination, an unique RGB ‘signature’ identifies that condition (Figure 10). A status message alerts the user to that erroneous condition and an optional analyzer setting can, if required by the user, automatically switch over to WDP mode to provide a precise measurement of that parameter before returning to HCdp measurement mode.

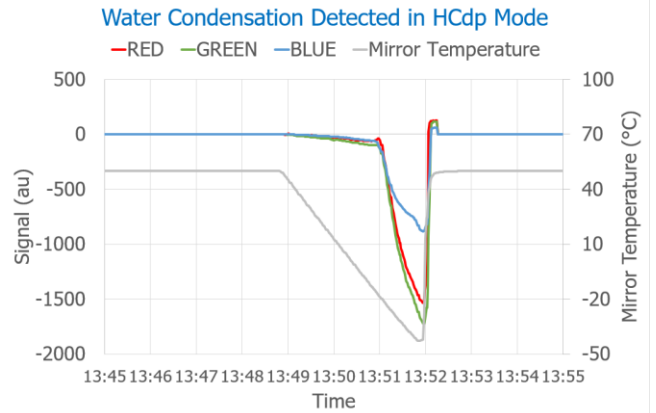


Figure 10 – Water condensation detected in HCdp mode under white light

Testing carried out to date shows that sensitivity of HC dew point measurements can be aligned to less than 5mg/Nm<sup>3</sup> PHLC (potential hydrocarbon liquid content) (Figure 11). The detection sensitivity of such an analyser can be adjusted to conform to individual user application requirements as defined in applicable practice protocols or gas quality specifications. As an example, HCdp measured by an experienced operator with Bureau of Mine tester is likely to align with around 50mg/Nm<sup>3</sup> PHLC. Results of testing with synthesized natural gas mixtures indicate +/-0.5°C accuracy, +/-0.2°C repeatability over the range from -30 to 20°C.

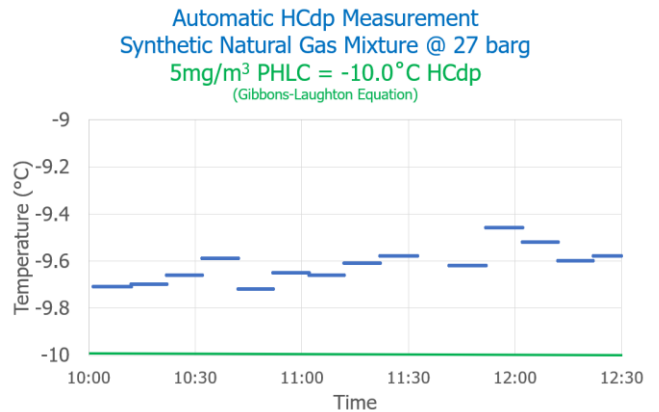
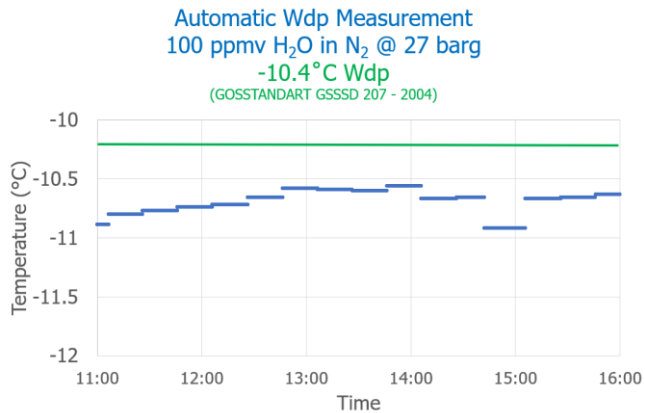


Figure 11 – Example of HCDP measurement results at high detection sensitivity (<math>5\text{mg/m}^3</math> liquid in gas)



- Can produce direct measurement phase envelopes rather than those based on theoretical estimations
- Sensitivity may be harmonized with contractual measurement techniques, practices or historical data
- Analysis at contractual pressure or cricondentherm condition
- Low operating costs.

*Weaknesses of Automatic Optical Condensation Analyzers:*

- High initial investment (but less than a C9+ GC)

Figure 12 – Example of WDP measurement results

A new sensor cell design applying this measurement method significantly reduces sample flow consumption (as low as 0.21 Std ft<sup>3</sup>/hour, 100 Std cc/min) to limit fugitive methane emissions when compared to previous commercially available dew point analysers.

Mirror image during measurement cycles, both live display and recording by the analyser, enables visual validation of measurements by operator review of captured video, either on local display or after file transfer to PC.

*Advantages of Automatic Optical Condensation Analyzers:*

- Provides a direct, fundamental, highly sensitive and repeatable measurement that is objective.
- Requires only AC power and a gaseous sample at line pressure for proper operation
- No specialized training or specific skill requirements for operation and maintenance staff

## **Best Practices For HCDP Measurement**

### *Best Practices - All Measurement Techniques*

In general, methods required to produce good accuracy begin with proper sampling. Proper sampling begins right at the sample tap. The sample should be drawn upwards from a region sufficiently away from the inner walls and five diameters downstream of any components, elbows, valves etc., which might modify the flow profile within the pipeline. This sample must be drawn off through heat traced tubing from the point of extraction through to the analyzer. This is a critical issue since all surfaces contacting the sample gas must be maintained at a temperature higher than any dew point or the accuracy will be compromised. Fast or speed loops should be used for maximum speed of response. Sample filtration must remove all particulates and liquid aerosols. This can sometimes be done as part of the sample extraction probe. However, any required pressure reduction should be taken after the fast loop and before delivery to the measurement section of the analyzer to furnish the analyzer with the freshest possible sample.

### *Best Practices - Manual Visual Analysis*

In addition to the general best practices above, the manual visual method using a Bureau of Mines type device requires a well-trained operator and patience. The mirror surface and optical cell must be clean before starting any measurements. The sample pressure should be at the approximate cricondentherm of the specific gas or the contract pressure. The sample should be allowed to bleed through the device per the ASTM standard D1142. Chill the mirror down gradually until a visible condensate forms on the mirror surface. Once this image is identified as the HCDP, the thermometer should read the HCDP temperature. The mirror

temperature should then be allowed to elevate until the condensate film evaporates and then cooled again to “home in” on the actual reading. These readings should be repeated a minimum of three times with reasonable agreement to qualify as being accurate. To obtain the most precise final measurements, slow cooling rate no greater than 1°F (0.6°C) per minute should apply in the region of interest, per the recommendations of ASTM Standard D1142 (ASTM, 1995)<sup>5</sup>

### *Best Practices - GC Analysis with EOS*

HCDP using EOS calculated from GC analysis best practice includes using a C<sub>9+</sub> GC and then adding data to C<sub>12</sub> from periodic laboratory analysis to improve accuracy of the EOS calculations. These results should periodically be compared to actual manual visual measurements to further enhance predictability. Using multiple EOS may also provide data comparison review over time that will determine the historical significance of one formula over another for a specific field or supplier. Keep in mind that field GC installations may not comply with all the above general best practices and may produce less accurate results. GC samples are analyzed at very low pressures compared to pipeline pressures and are predicting values by measurements at conditions far different from those of the actual pipeline.

### *Best Practices - Automatic Dew Point Analyzers*

An automatic HCDP analyzer must incorporate several elements into the device to be as reliable and repeatable as possible. Below is a list of the critical components and why they need to be part of the analyzer package.

#### 1. Reliable Detection Method

A reliable detector is a given requirement for all instruments. An optical detection method

that positively identifies the form of dew formation, HC or water, provides increased measurement confidence to the user.

## 2. Close Proximity To Pipeline Sample Point

Automatic units should be mounted near the sample tap with internal heaters and insulated housings. Using a sample already piped to an instrument house may be convenient, but the resulting delay in the update may cause serious lag in reaction time for control purposes. Since each manufacturer has different operating temperature specifications, environmental conditions often dictate this choice.

## 3. Controlling Measurement Pressure

Measuring at the cricondetherm has many benefits such as identifying how the pressure can be safely let down to avoid the Joule-Thompson cooling to create condensate. It also has the biggest sweet spot for this measurement and thus is very repeatable. But the measurement pressure is not always driven by what is most useful, but it is always driven by what is in the tariff or contract between the buyer and seller. So, the measurement pressure must be controlled at this specified value.

Many contracts are written with the cricondetherm point as the measuring point for the maximum allowable HCDP in the gas. Contracts written with the reference to the maximum HCDP at any pressure, are describing the same point.

The cricondetherm pressure is not as critical as may be anticipated. Since the profile of this region of the phase envelope curve is nearly vertical, a change of fifty to a hundred psi either way can be shown to produce very little change in the accuracy of the measurement. In the expanded

graph example below (Figure 8), showing a series of direct HCDP measurements by chilled-mirror method, a change of over 100 psi results in influencing the HCDP a maximum of only 2°F. In contrast, just 1 ppm<sub>v</sub> of a C<sub>10</sub> component in the sample can change the HCDP by as much as 10°F! It is however, always good practice for the measurement to be performed at the contract pressure which is often the cricondetherm pressure.

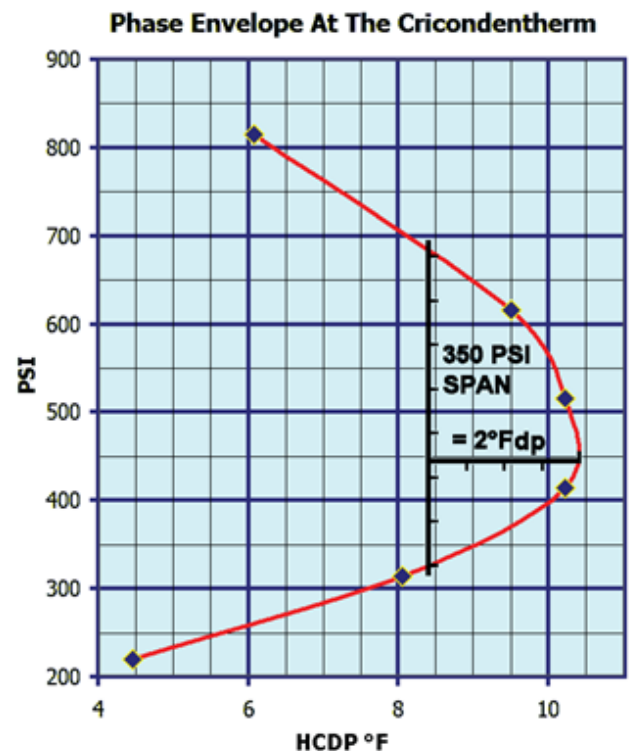


Figure 13 - Series of automatic, chilled-mirror HCDP measurements for a typical transmission quality gas at varying analysis pressure

## 4. Heat The Optical Surface Between Measurements

Heating the optical surface to elevated temperature between measurements aids rapid evaporation of condensates and resists potential contamination build-up of waxes. Without sensor heating the total



cycle time can be three times that of the heated one and result in lower reliability of the measurement.

#### 5. Keep Internal Volumes Small

When the volume of sample in the measuring chamber is reduced, it will speed the measurement and allow faster purging of the measurement chamber even at reduced flow rate.

#### 6. Frequent Sampling

Many of the above practices will allow automatic dew point analyzers to make more frequent measurements. Frequent measurement cycles provide for better response to changes in the gas conditions and allow control functions to be implemented in a timelier fashion.

#### 7. Capability For Aligning With Contract Data

Historically the working definitions of HCDP have been slightly modified and standards have been reviewed with consideration to incorporate them. If this trend will continue and changes come into effect, it is essential to have the ability to adjust the analyzer to align with newly refined standards.

### **What Is At Risk When HCDP Is Not Measured Accurately?**

When measuring the heat content of natural gas that governs all fiscal transactions of gas purchasing, certain practices have become industry accepted for proper sampling and conditioning to ensure accurate measurements. The hydrocarbon dew point is perhaps the single most important property to consider in natural gas sampling. If the sample temperature drops below the hydrocarbon dew point temperature, a significant loss in hydrocarbon content can

occur, resulting in errors in volumetric flow rate, heating value and other gas property calculations.<sup>1</sup> It is of vital concern for all parties to the transaction to follow these same procedures to have the same results and eliminate disputes over billing for gas delivered.

#### End User Risks

Large gas utilities simply cannot tolerate liquid hydrocarbons in their gas. They go to great lengths to prevent liquids from entering their distribution system.

Large natural gas consumers using natural gas for firing aeroderivative turbines are fully aware of the impact they can feel if the HCDP is out of specification. Gas fuelled turbine power generation plants have been hit with high exposure risk of fines for NOX emissions which become excessive due to poor combustion efficiency as the HCDP climbs over the contract limits.

Turbine manufacturers specify a superheat of the gas of 50°F – the operating temperature of the gas supply must be 50°F higher than either the HCDP or the WDP whichever is greater. This is to protect against condensate formation as the pressure is let down from pipeline pressure to burner operating pressure caused by the Joule-Thompson coefficient. If liquid hydrocarbons condense out during the pressure let-down, flashback can occur. “For a GE Frame 7 gas turbine, 50°F of superheat amounts to about 740 kW, which means energy costs can be as high as \$324,120 per year.”<sup>9</sup> If HCDP is maintained at contract levels this parasitic load to heat the gas can be dramatically reduced, increasing the power available for sale.

Excessive HCDP causes turbine flashback where the flame front reverses and moves



toward the source of the gas instead of the turbine. “This is known as flashback and can lead to significant damage to the gas turbine within seconds of it occurring.”<sup>10</sup> Often, the operator must reduce power on the turbine to sustain consistent power output at a lower level or risk continued flashbacks. “Flashback can be a significant issue during combustion turbine operation, as it can reduce combustor life and, in extreme cases, cause combustor damage and extensive repairs.”<sup>11</sup>

Long term effects of high HCDP are excessive maintenance costs as the heavier hydrocarbons damage burner sections and even the turbine blade tips of this expensive equipment. Rebuilding just the burner section is a \$3 million or higher direct cost in addition to lost production for this unscheduled outage. These unbudgeted costs seriously impact the profitability and potentially the viability of these operations. This risk drives this critical gas quality measurement where compliance to the fuel specification is not optional.

#### Pipeline Operator Risks

The demand for quality gas shifts upstream to the pipeline operators who have a custodial function in addition to the transportation function of the gas. Obviously, their delivery of good quality gas is dependent on their receipt of good quality gas. Thus, the responsibility for measuring and recording their receipts are the only way their custodianship can be verified.

If their gas receipts do not comply with the contract, there is a resultant shut-in risk for these operators. They only get paid as long as the gas is moving to the end users.

If this measurement is inaccurate and liquids build up in their pipelines, their investment in turbine compressors is put at risk. Turbine

compressors dedicated to gas operations do not do well with multiphase flow. When liquid in the gas is detected the increased frequency of pigging operations, adds to the cost of moving the gas effectively.

Turbine compressors need good clean fuel to operate reliably. If HCDP is maintained at contract levels this parasitic load to superheat the gas can be dramatically reduced, increasing the gas available for sale.

#### Producer / Processor Risks

Finally, the producer/processor has the initial control over this resource. If they do not comply with the gas contract, they will be shut-in. Their operation comes to an abrupt halt and another vendor will often step in to fill the end users’ demand. In any business, allowing a competitor to fill your customers’ need is a huge risk for that operation to remain viable. More and more, shut-ins carry contractual penalties as the additional cost for changing over to a competitive supplier impacts the end-user as well.

The unprocessed gas also has many recoverable compounds that can bring added income to the producer/processors’ operation. These NGLs currently have significant value to drive their recovery to the limit of the processors’ capability. The economics of their recovery will fluctuate as market conditions change but NGLs will always have value and recovering them adds to the security of not experiencing shut-ins.

Some of the costs are identifiable but impossible to quantify. One example is the legal costs when there is a dispute over shut-ins driven by gas quality measurement by the end user. These can be avoided when the producer/processor and pipeline operator accurately measure the HCDP

along with the water content and encourage their customer to do the same. Accountability is always preferable to litigation.

Some of these costs can be quantified as in the case of the cost of a shut-in as illustrated in Table 2 below:

Shut-in Revenue Loss for 1100 Btu/CF Gas+ NGL Recovery					
Flow	\$4.00/MMBtu			NGL @ \$65/Bbl	
MMcfe/d	One Hour	One Day	One Week	Bbl/Day	One Week
0.25	\$46	\$1,100	\$7,700	10	\$4,550
0.5	\$92	\$2,200	\$15,400	15	\$6,825
1	\$183	\$4,400	\$30,800	25	\$11,375
2	\$367	\$8,800	\$61,600	50	\$22,750
4	\$733	\$17,600	\$123,200	100	\$45,500
8	\$1,467	\$35,200	\$246,400	250	\$113,750
16	\$2,933	\$70,400	\$492,800	500	\$227,500
32	\$5,867	\$140,800	\$985,600	1000	\$455,000
64	\$11,733	\$281,600	\$1,971,200	1500	\$682,500

Table 2

## Conclusion

The natural gas industry continues to diversify to incorporate increasing proportions of non-conventional sources into the established transmission pipeline infrastructure; shale gas, coalbed methane and tight gas. This increased complexity of supply chain heightens the potential risk of non-conforming gas deliveries. For processors and pipeline operators, accurate data is the only enforcement method available for contract quality issues. Accurate on-line instruments are now available that confirm these contractual specifications are met.

In the choice of methods used to measure hydrocarbon dew point, installed cost is an important consideration. Less expensive instrumentation techniques may under-report the dew point risking shut-ins and lost revenue. Even if the installed cost is somewhat higher, choosing an accurate method has been shown to

be a better value. An inaccurate instrument choice can also over-report the dew point temperature which would drive the control system to over-process incoming gas. This would significantly add to the operational cost while cutting profits.

Reliable accurate HCDP instrumentation assists in controlling the gas processing operation thereby enhancing the profitability in this complex business. Likewise, for the transmission pipeline operators, continuous measurement at metering locations assures that gas receipts fulfil contract obligations. Full-featured automatic HCDP analyzers will produce the best results and will often have a ROI that will pay for their installation in just a few months of operation. Should an upset in the gas supply occur, these analyzers will certainly pay for themselves on the first occurrence by alerting operations to such an event in time to prevent a shut-in.

## References

1. “Manual of Petroleum Measurement Standards Chapter 14 – Natural Gas Fluids Measurement, Section 1 – Collecting and Handling of Natural Gas Samples for Custody Transfer”, American Petroleum Institute.
2. “Natural Gas Quality: Hydrocarbon Liquid Drop Out and Interchangeability – An Update on NGC+ Efforts”, Terry Boss – Interstate Natural Gas Association of America, NGC+ Interchangeability Work Group Presentation, February 28, 2005.
3. “Chilled Mirror Device For Water & Hydrocarbon Dew Point Determination”, Eric D. Thompson, Chandler Engineering, AGMSC 2003.
4. “Hydrocarbon Dew Point Monitoring Of Natural Gas Using Field-Mounted On-Line Gas

Chromatographs”, K. Ernst, D. Pettigrew, Emerson Process Management, Pipeline & Gas Journal, July 2005.

5. “The Need for Accurate Hydrocarbon Dew Point Determination”, D. George, Ph.D. et al., Southwest Research Institute, Pipeline & Gas Journal, September 2005.

6. “Gas Fuel Clean-Up System Design Considerations for GE Heavy-Duty Gas Turbines”, C. Wilkes, GE Power Systems, GE Publication GER-3942.

7. “Tests of Instruments for Measuring Hydrocarbon Dew Points in Natural Gas Streams, Phase 1”, Prepared for the Measurement Technical Committee of Pipeline Research Council International, Inc., D. L. George, Ph.D., R. C. Burkey, Southwest Research Institute.

8. Bannell, J. L. K., Dixon A. G. and Davies T. P., “The Monitoring of Hydrocarbon Dewpoint”, paper presented at the International Congress of Gas Quality, Groningen, The Netherlands, 1986.

9. “DLN Combustors Demand Better Fuel-Gas Conditioning”, Power, March / April 2001, Craig Tiras, PE, Flowtronex International.

10. “Utilizing Associated Gas in Industrial Gas Turbines”, Geraldine Roy, Senior Market Analyst, Siemens Industrial Turbomachinery Ltd, Power-Gen Worldwide, Published: Jan 1, 2010.

11. “Flexible Fuel Combustor Design Accommodates LNG”, Pratyush Nag and Ranjeet Vader, Siemens Energy Inc., Power Magazine, August 1, 2009.