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Best Measurement Practices

## Hydrocarbon Dew Point Is A Critical Consideration For Pipeline Operations

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**H**ydrocarbon dew point (HCDP) in natural gas has always been operationally important. More frequently, it is being written into tariffs as a quality parameter and this trend is likely to continue into the foreseeable future. This requirement begins with the customer who wants a quality product and may be at risk of losing his or her operating capacity if the gas quality slips. For example, gas turbine generator plants have a written requirement in their warranties that the fuel gas must be totally gaseous.

To comply, the gas is superheated to a minimum of 50°F above the highest dew point of the gas at the pressure regulators located ahead of the burner section. All turbine manufacturers require this. This quality requirement then works its way up the supply chain. Pipeline operators find good gas is also a benefit to them since it saves their system and ultimately the quality requirement becomes the responsibility of the seller (producer/processor) to provide this market driven product — clean, dry gas.

Accurate HCDP data will assist in controlling gas processing. Good processing will prevent shut-ins, help to maintain pipeline integrity and prevent hydrate formation which could damage in-stream devices such as compressors, valves, sample probes and orifice plates.

A formal definition of HCDP can be stated as the temperature at which hydrocarbon condensates

first begin to form when natural gas is cooled at a constant pressure. Experience tells us that this is not a workable definition. A working definition is the temperature at which hydrocarbon condensates first begin to form a visible deposit on a surface, when the gas is cooled at a constant pressure.

This relationship is complicated by the nature of natural gas itself since it cannot be described by one chemical name and in fact has many chemical fractions and an infinite blend of these components. It is this blend that will produce dew points that vary widely at the same pressure from one sample to another. One thing that is consistent is that the heavier components will condense out first. Large measurement errors will occur if these components are not accurately taken into account.

When a rich gas field is developed the gas must be processed before it is ready to be sold as pipeline gas. The competitive producer/processor must remove the heavier components in order to supply high quality gas to the market. The graph above shows the cricondenthem dew point reduction after processing. A common way to remove heavy gas components is to chill the gas so the heavy components condense and drain away. This is a costly process since chilling large quantities of gas requires energy. A likely undesirable result is a lower Btu product which can reduce the market value for their customer. The producer/processor must meet the tariff while

making a profit and it is this fine line that makes monitoring the HCDP so essential.

In today's economy this tight operating regime is also driven by world markets with interconnectedness and LNG supplies from sources where the gas is easier to produce. This puts increasing price pressures on the producer/processor to trim the efficiencies of their process while producing a quality product. The major companies recognize the problem and have jointly funded research projects to test available measurement technologies. Everyone wants to find the best way of monitoring HCDP under all types of conditions.

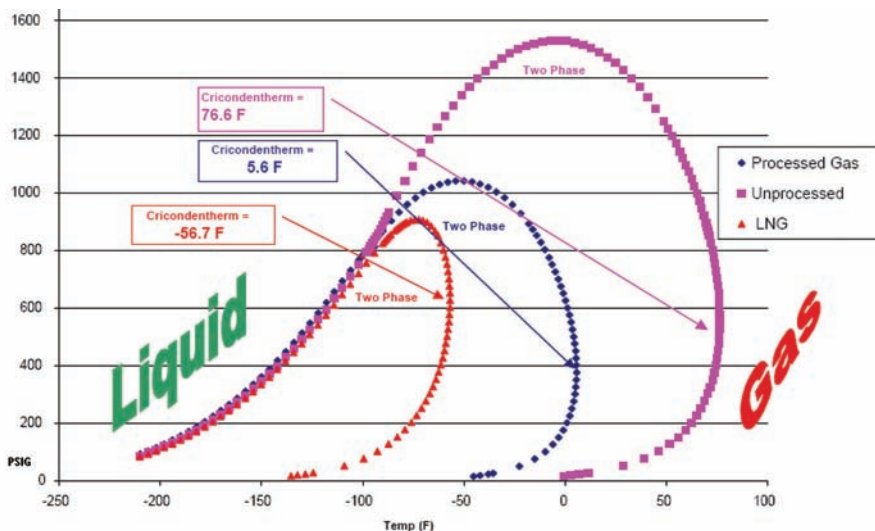
### Measurement Methods

The manual visual dew point method is the simplest and most widely used method for measuring both HCDP and water dew point (WDP) in natural gas. This Bureau of Mines device has been used since the 1930s to provide manual dew point measurements. The proper use of this device is considered by many as the de facto standard in the industry. 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 pressures to 5,000 psig, containing a mirror that is visible through an eyepiece. A second chamber allows the coolant to be conducted to the back of the mirror. There is also a method for measuring the temperature of the mirror.

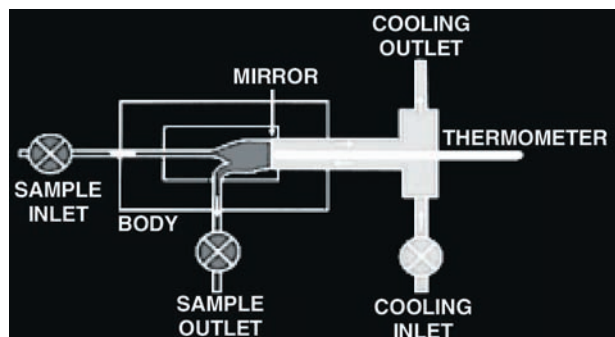
The operator connects the sample to the sample inlet port and begins purging of the chamber with a flow of sample. A coolant, typically an expandable gas like carbon dioxide or propane is connected to the coolant inlet. The operator then throttles the coolant through a valve cooling the polished mirror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

Because the operator must interpret the image seen on the mirror, there will always be some subjectivity in this method. The proper proce-



Typical retrograde phase envelope for natural gas.<sup>1</sup>

ture 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.



Bureau of Mines Device Schematic.<sup>2</sup>



Bureau of Mines Dew Point Tester.<sup>2</sup>

Strengths of this method: the most widely used measurement technique, some models are intrinsically safe, considered the de facto standard for hydrocarbon dew point measurement and low capital investment — Instrument costs \$5,000-10,000.

Weaknesses of this method: periodic spot checking only, “Subjective” (operator dependant measurement), and labor intensive.

The EOS method using GC analysis is found where 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 analyzers are generally C<sub>6</sub>+ and a few are C<sub>9</sub>+ analyzers on pipeline gas and in end-user installations. Both ends of the transaction are verifying the heating content of the gas they are selling/buying. Many users are now applying equations of state to this data to calculate the HCDP value.

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 C<sub>6</sub> and above. Therefore, the traditional C<sub>6</sub>+ analysis provides insufficient data for a valid hydrocarbon dew point calculation.<sup>3</sup> Based on comparisons to date, however, the C<sub>9</sub>+ characterization most often appears to predict measured dew points to within ±25°F.<sup>4</sup>

More research is being done on this method for predicting HCDP of the natural gas sample

using this method. Standards have been written suggesting minimum requirements for producing good data. Recently ISO published their standard 23874 (2006) “Natural Gas — Gas Chromatographic requirements for hydrocarbon dew point calculation.” This standard states that the GC system requirement for analysis of higher hydrocarbons includes that it: be capable of measuring alkenes up to and including dodecane, be capable of measuring individual alkenes at a concentration of 0.000 000 1% (0.1 ppmv); be able to distinguish and measure benzene, toluene, cyclohexane and methycyclohexane as individual components; and measure all hydrocarbons in the range C<sub>5</sub> to C<sub>12</sub>.

Analyzers designed to meet this set of specifications are laboratory devices, not suited for field installation and are prohibitive in cost for custody transfer points and processing plants. It should be noted that such a system will produce much more accurate data for HCDP calculations than the C<sub>9</sub>+ characterization.

The information required by the equations of state to perform an accurate calculation of HCDP simply cannot be provided by the field GCs in the currently installed base. The table illustrates why. Starting in the left-hand data column, we have an extended laboratory analysis of a rich gas from a mature gas field. All the data in the subsequent columns has been derived from this base line of the extended laboratory analy-

sis. The heavier components have been simply lumped together as would be done by the field GC. Some columns show a split similar to using a company, contract or historical characterization assumption. The results speak for themselves. This method requires adjustments and a minimum of a C<sub>9</sub>+ GC to start. Even with a C<sub>9</sub>+ with a 60-30-10 split, the HCDP value is underestimated by nearly 29°F at 400 psig.

Although the gas shown above is the same and the calculations are done at the same conditions, the results vary by over 100°F. The difference is that even small quantities of heavier compounds strongly influence this calculation. These heavier components are the ones that cause problems inside the pipeline too.

Strengths of this method: potential to combine a number of gas quality/fiscal metering parameters into one analyzer, possibility to provide a theoretical phase envelope curve, adding software to an existing measurement technology may have a lower installation cost, and 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 this method: accuracy of extended analysis, dependent on correct and regular use of special reference gases; an indirect method relying on the correct application and suitability of the equation of state being used; susceptible to measurement errors due to limit of analysis sensitivity and composition changes (presence of aromatics: benzene and toluene); specialist staff required to operate/maintain performance and high initial outlay for a GC with C<sub>12</sub> capability, installation costs (analyzer house) and operating costs (personnel and reference gases) and EOS Software.

Component		C14 Extended	C9+ split 60/30/10	C9+	C6+ split 60/30/10	C6+
helium	mol	He	4.9807	4.9807	4.9807	4.9807
hydrogen		H <sub>2</sub>	0.9961	0.9961	0.9961	0.9961
nitrogen		N <sub>2</sub>	183.2910	183.2910	183.2910	183.2910
carbon dioxide		CO <sub>2</sub>	67.7380	67.7380	67.7380	67.7380
Methane		C <sub>1</sub>	9298.0325	9298.0325	9298.0325	9298.0325
Ethane		C <sub>2</sub>	283.9018	283.9018	283.9018	283.9018
Propane		C <sub>3</sub>	80.6879	80.6879	80.6879	80.6879
i-butane		iC <sub>4</sub>	12.9499	12.9499	12.9499	12.9499
n-butane		nC <sub>4</sub>	15.9383	15.9383	15.9383	15.9383
i-pentane		iC <sub>5</sub>	3.9846	3.9846	3.9846	3.9846
n-pentane		nC <sub>5</sub>	2.9884	2.9884	2.9884	2.9884
cyclopentane		C <sub>5</sub> H <sub>10</sub>	0.2391	0.2391	0.2391	0.2391
n-hexane		nC <sub>6</sub>	2.7892	2.7892	2.7892	3.41274
cyclohexane		C <sub>6</sub> H <sub>12</sub>	0.1992	0.1992	0.1992	
benzene		C <sub>6</sub> H <sub>6</sub>	0.1692	0.1692	0.1692	
n-heptane		nC <sub>7</sub>	0.8965	0.8965	0.8965	1.70637
toluene		C <sub>7</sub> H <sub>8</sub>	0.0598	0.0598	0.0598	
n-octane		nC <sub>8</sub>	0.7471	0.7471	0.7471	0.56879
p-xylene		C <sub>8</sub> H <sub>10</sub>	0.0100	0.0100	0.0100	
n-nonane		nC <sub>9</sub>	0.3287	0.4901	0.8169	
n-decane		nC <sub>10</sub>	0.2889	0.2451		
n-undecane		nC <sub>11</sub>	0.1096	0.0817		
n-dodecane		cC <sub>12</sub>	0.0598			
n-tridecane		nC <sub>13</sub>	0.0199			
n-tetradecane		nC <sub>14</sub>	0.0100			
Temperature	°F		60.0000	60.0000	60.0000	60.0000
Pressure	psig		400.0000	400.0000	400.0000	400.0000
	HCDP		85.7°F	56.9°F	38.6°F	8.7°F
	Press	PSIG	400	400	400	400

Table 1: Hydrocarbon Dew Point values calculated by SRK EOS at 400 psig of a fairly rich gas sample

The automatic optical condensation method uses analyzers that have been in commercial use for over 20 years. Independent laboratory testing has shown them to have very good accuracies to better than  $\pm 1^{\circ}\text{F}^5$  when compared to the Bureau of Mines manual dew point method. They can also provide the user with up to six measurement cycles per hour. An optical detector is chilled until a layer of condensate forms on that surface. Measuring the detector 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 principle is one of the oldest methods of measuring WDP accurately and is also the oldest method for measuring HCDP (manual method). It has long been thought that the same technique could be automated to eliminate the subjectivity of the manual method. The benefit would be an increase in accuracy and repeatability. But hydrocarbon condensates do not behave as water condensates do.

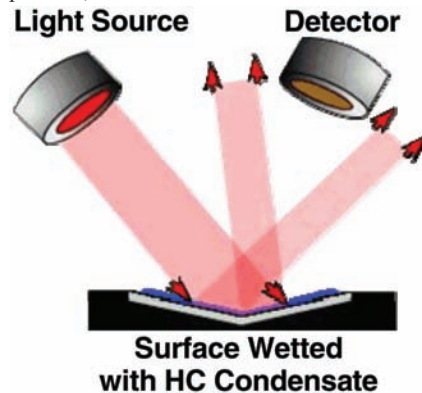
Water condensates in both the liquid and solid phases disturb a light path where hydrocarbon condensates do not. This is due to the unique high surface tension of water. It is a single molecule with very well documented characteristics.

Hydrocarbon condensates in natural gas have a very low surface tension and the issue is further complicated by the fact that they are a mix of related compounds. Because the mixture of components cascade sequentially on a surface as it is chilled, the HCDP will occur gradually across a small range of temperatures. This is the reason that the old dew point technique needed a new approach.

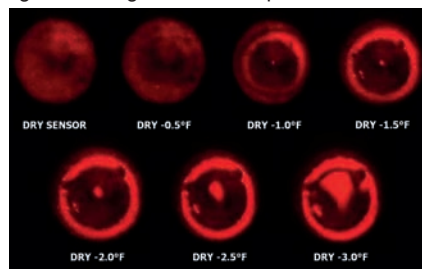
In the mid-1980s, researchers found that since hydrocarbon condensates have a very low surface tension and were shiny, they could be used as the mirror in an automatic system. A chemically etched dry sensor, with a strong light illuminating it, would diffuse the light instead of reflecting it. Then condensing a hydrocarbon dew layer onto the surface by cooling it focuses the reflected light producing a strong image that can be detected easily. It was also discovered that a conical depression on the optical surface dramatically improved the repeatability.

The detection of the image is very sensitive allowing the sensor to "see" an image of the

HCDP as it begins to condense. This same image quality can be repeated over and over again, eliminating the subjectivity of an operator. A detector signal with this wide sensitivity can be adjusted to harmonize with the currently accepted industry practices, contractual or historical data.



The Detector "sees" an image of focused light as a ring with a dark spot in the middle.



Actual "Dark Spot" optical surface images.

In addition, since the heavier components do indeed condense out first, it is important that another feature be modified from the traditional WDP analyzer. The sample being measured must be trapped within the measurement chamber. This blocking-in of the sample prevents an over-reporting of HCDP caused by continued build up of the heavy components of a continuously flowing sample.

Slow cooling, analogous to the best practices for manual visual chilled mirror method is also desirable. The condensate requires some time to form and be identified by the detector. So this needs to occur with care in order to identify the first temperature when the "dew" formation appears. This slow cooling does not have to impact the duration of a measurement cycle significantly. With PLC control and digital memory, the automatic HCDP analyzer should have the ability to mimic the operator of a manual dew scope. It should ramp the optical surface temperature down rapidly to within a few degrees of the previously measured dew point temperature, then slow the cooling rate to achieve the final dew point.

Heating the optical surface between measurements is also desirable. If the optical surface is heated after each measurement, it forces the evaporation of all condensate and prepares the surface for the next measurement cycle. Thermoelectric coolers are quite capable of performing this task by simply reversing the current to the device. Heating the optical surface while the fresh sample is purging the measurement chamber in preparation for the next cycle provides a stable optical baseline. A combination of the PLC control of the cooling rate and the heating between measurements shortens the

measurement cycle to as little as 10 minutes.

Strengths of this method: 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 skill requirements for operation and maintenance staff; 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; and low operating costs.

The weakness of this method is the initial minimum investment of \$35,000. (See Best Practices Sidebar)

## Conclusion

Gas contracts are more restrictive as market demands continue to tighten. Accurate on-line instruments are now available that confirm these contractual specifications are met. In any case, accurate data is the only enforcement method available for contract quality issues. 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. But, even when 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.

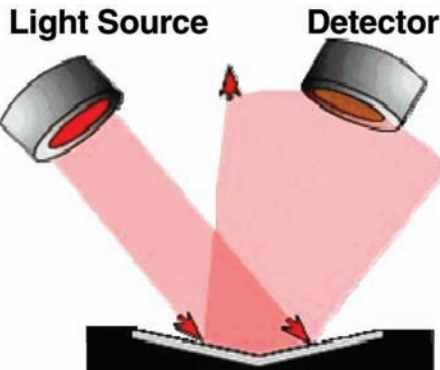
Reliable accurate HCDP instrumentation assists in controlling the gas processing operation enhancing the profitability in this complex business. Full-featured automatic HCDP analyzers will produce the best results and will often have a ROI that will pay for their installation in just a few months of operation. Should an upset in the gas supply occur, these analyzers will certainly pay for themselves on the first occurrence by alerting operators to such an event in time to prevent a shut-in. **PE&GJ**



**The author: Jack Herring** has been in the moisture/dew point measurement industry since 1979. He has published several articles and co-authored the *Moisture Measurement section of the "Industrial Instruments & Controls Handbook"* by McGraw Hill (1999). He can be contacted through [www.michell.com/us](http://www.michell.com/us).

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Dry Optical Surface

The dry detector "sees" an image of diffused light.

# Best Practices

**For All Measurement Techniques** — The 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 and valves, 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 immediately before delivery to the measurement section of the analyzer.

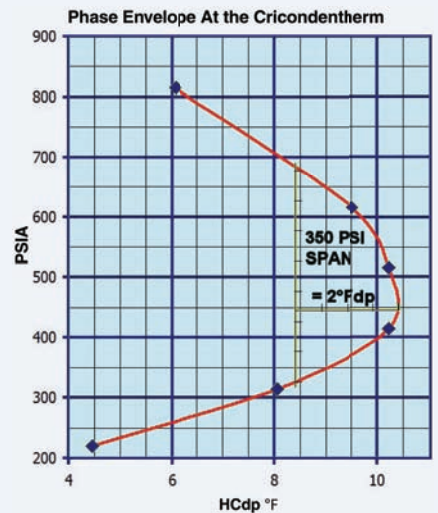
**Best Practices for the Manual Visual Analysis Method** — In addition to the general best practices, this method requires a well-trained operator and patience. The optical device must be clean before starting any measurements. The sample pressure should be at the approximate cricondentherm of the specific 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 at a rate no greater than 1°F (0.6°C) per minute, per the recommendations of ASTM Standard D1142 (ASTM, 1995) until a visible condensate forms on the optical 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 slightly and then be 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.

**Best Practices for the Gas Chromatograph (GC) Analysis with EOS Method** — GC best practices include 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 of 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 for the method using Automatic Dew Point Analyzers

- **Reliable Detection Method** — A reliable detector is a given for all instruments. Rough or etched surfaces will be able to discriminate the HCDP because the condensate will make the optical surface more reflective and the image easier to detect.
- **Close Proximity to Pipeline Sample Point** — Automatic units should be able to 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.
- **Trap the Sample during the Measurement** — A sample that is allowed to flow continuously creates an abnormal build up of the heavier hydrocarbons on the optical surface. Blocking in the sample during the measurement cycle will produce more accurate readings.
- **Controlling Measurement Pressure** — The derivation of the word cricondentherm is critical condensation thermal curve — also called the “phase envelope.” The cricondentherm is the point on this curve where pressure and temperature indicate that the maximum HCDP is to be found (diagram).

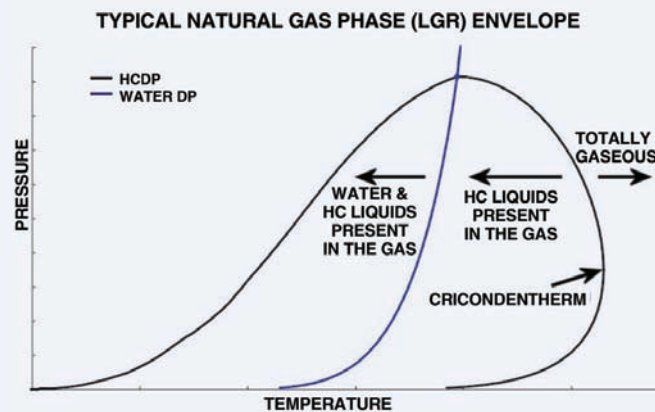


In this expanded graph example, a change of 100 psi results in influencing the HCDP a maximum of only 2°F. In contrast, missing just 1 ppmv of a C<sub>10</sub> component in the sample can change the HCDP by as much as 10°F. It is however, always good practice for the measurement to be performed at the contract pressure which is often the cricondentherm pressure.

can be shown to produce very little change in the accuracy of the measurement. In the expanded graph example, a change of 100 psi results in influencing the HCDP a maximum of only 2°F. In contrast, missing just 1 ppmv 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 cricondentherm pressure.

- **Heat the Optical Surface Between Measurements** — Without sensor heating the total cycle time can be three times that of the heated one and result in less reliability of the measurement.
- **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.
- **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 more timely fashion.

- **Capability for Harmonizing With Contract Data** — Historically the working definitions of HCDP have been slightly modified and standards have been rewritten to incorporate them. If this trend continues and changes come into effect, it is essential to have the ability to adjust the analyzer to align with newly refined standards. *P&GJ*



Critical condensation thermal curve (cricondentherm) diagram.

Many tariffs are written with this point as the measuring point for the maximum allowable HCDP in the gas. Tariffs written with the reference to the maximum HCDP at any pressure, are describing the same point. The cricondentherm pressure is not as critical as may be anticipated. Since the profile of this region of the curve is nearly vertical, a change of fifty to a hundred psi either way