



ADVANCED MICRO INSTRUMENTS

— An ENPRO Company —

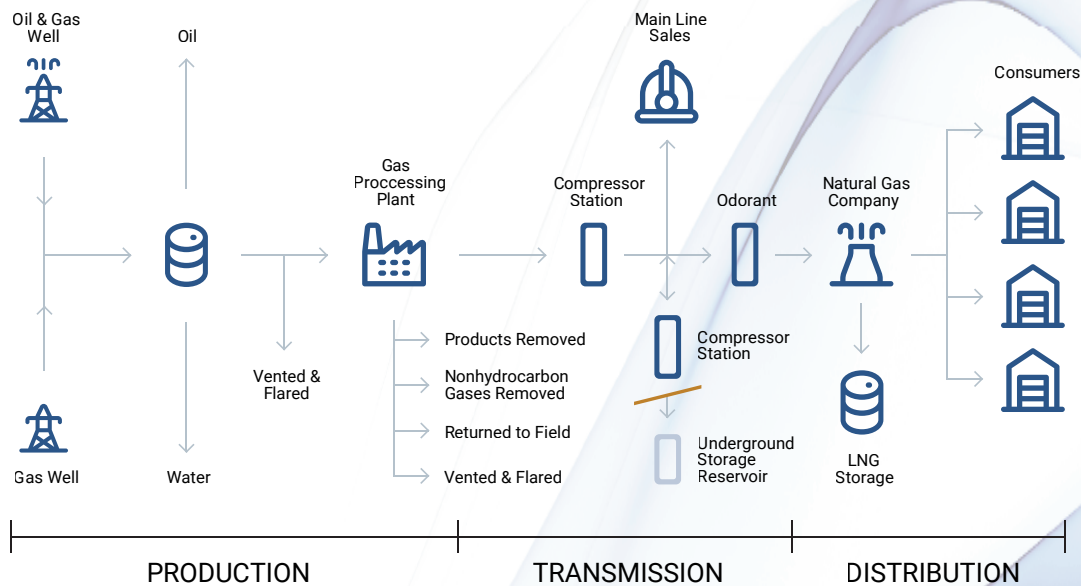


MODEL 4010L **X** TRACE MOISTURE ANALYZER

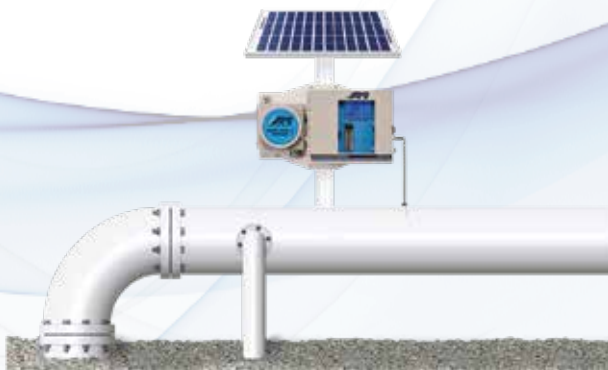
APPLICATION WHITE PAPER:
H₂O DEW POINT MEASUREMENTS

MOISTURE MEASUREMENTS: THE BASICS

NATURAL GAS PRODUCTION & DELIVERY



BACKGROUND



(Remote Installation powered by a standard solar panel)

In the natural gas industry, there are many points in the concentration, production and delivery network that require the measurement of the amount of moisture (H_2O) in the gas or process stream. The limits of contaminants, including moisture, are in place to protect critical pipeline infrastructure from excessive corrosion. It is common that at a custody transfer point in the network the upstream company will perform real time moisture measurement to show the quality of the gas delivered, and the receiving company will also perform real-time measurement to verify the quality of the gas received. AMI's **MODEL 4010LX** TDL Moisture Analyzers are used throughout the gas production, transmission and distribution system to measure the amount of moisture in the gas stream.

EXTRACTION GAS SAMPLING

An extractive Gas Analyzer, like AMI's **MODEL 4010LX**, is installed with a probe and pressure regulator to reduce gas pressure from pipeline pressure (1,000 PSia typical) to analyzer pressure of up to 20 PSig, where a moisture concentration measurement is then performed around atmospheric pressure inside the Analyzer. Depending on the climate temperature and quality of the gas, additional equipment like particle filtration, liquids separation and heat may be used in the transport between the process to the Analyzer to deliver a high-quality, clean, gas phase representative process sample to the instrument.

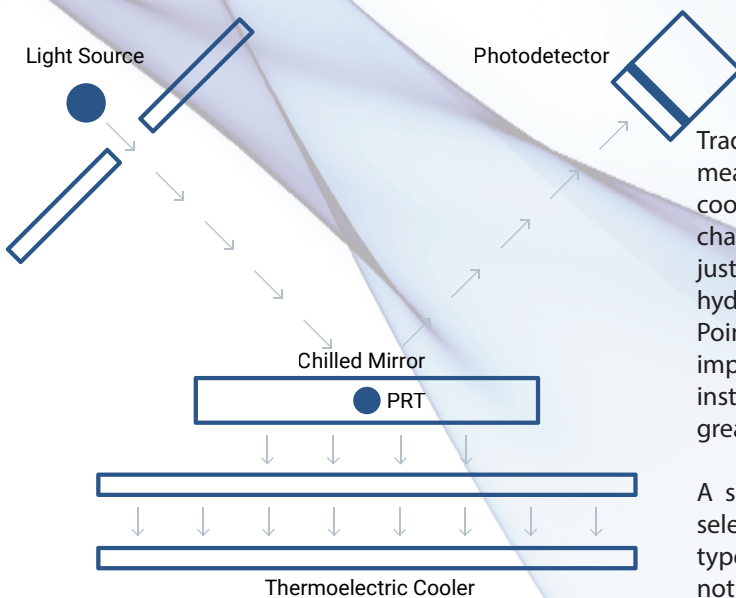
THE TECHNOLOGY FOR MEASUREMENTS

MOISTURE CONCENTRATION vs DEW POINT

Many natural gas operators typically have tariffs and operating requirements for moisture concentrations around 7LBS / MMCF of H₂O or 150 PPMv of H₂O. AMI's **MODEL 4010LX** measures and displays the concentration of moisture in the extracted gas that represents the sample in the process. Other users may have tariffs or operating requirements around how the H₂O concentration behaves inside the pipeline or process at line pressure. One such critical behavior is at when temperature moisture drops out of gas phase to form water droplets and liquid water in the process – called the water Dew Point. This temperature may be used to estimate what is happening inside the pipe (at process pressure) as maintaining the gas phase may be required, depending on the process.



CHILLED MIRRORS FOR DEW POINT



Traditionally, one way to perform a moisture dew point measurement was using a chilled mirror, an optical instrument that cools a mirror or glass and then inspects for liquid formation. One challenge with this method is that in gas streams with more than just pure methane, the mirror is not selective, and other hydrocarbons may drop out and become liquid (Hydrocarbon Dew Point) long before the moisture drops out of gas phase – making it impossible to measure the actual moisture dewpoint with such an instrument when the Hydrocarbon Dew Point temperature is greater than Moisture Dew Point temperature.

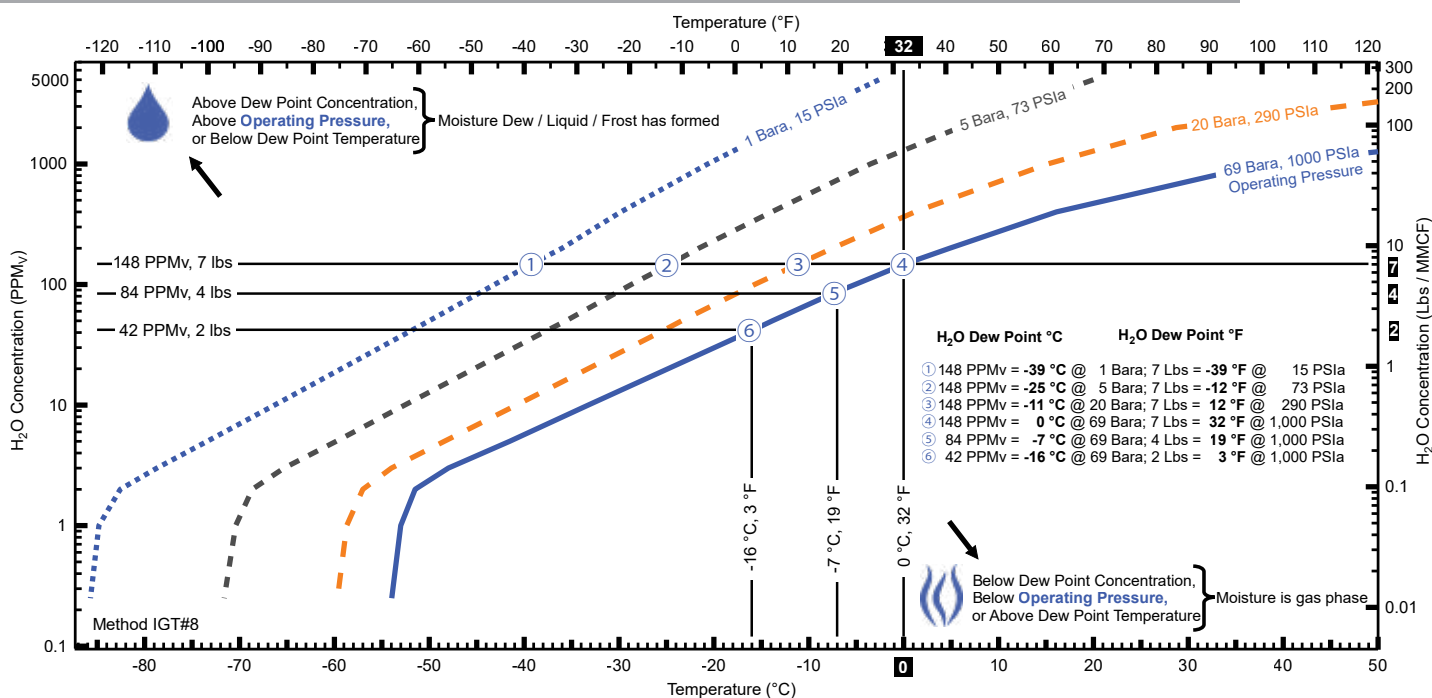
A significant advantage to extractive TDL is that it is a highly selective measurement and can target and measure an exact gas type, like H₂O, regardless of the other gases it is mixed with. It does not require design complexities or energy to reach and operate at very cold temperatures.

CONVERTING MOISTURE CONCENTRATION TO DEW POINT

There are several methods to converting moisture concentration in natural gas to dew point. For over 80 years, the gas industry has used conversion tables that are mathematical methods, based on substantial empirical data, to convert moisture concentration to dew point at line pressure. In more recent years - physical chemistry methods were developed to convert the concentration measurement at Standard Temperature and Pressure (STP), like what is made by the extractive TDL, to predict at what temperature the water would drop from vapor phase to liquid, known as the water/moisture dew point temperature. Knowing this temperature can be useful for regulatory or contractual reasons, but more often is very useful for operating a process with dew point. A process can be controlled to minimize or eliminate moisture condensation by knowing what pressures the process must stay below, or correspondingly, the minimum temperature a gas can reach before moisture condenses.

HOW THE MODEL 4010LX MAKES IT HAPPEN

USING METHOD IGT#8 TO UNDERSTAND BASIC CONVERSION OF MOISTURE CONCENTRATION TO DEW POINT



The IGT#8 is one method to convert moisture to dew point in natural gas. To perform this conversion from concentration PPMv with the **MODEL 4010LX** to dew point temperature in the pipeline, at least 1 additional piece of information is required, the operating pressure of the pipeline or process. The reason for this is that dew point is pressure-dependent. The dew point at atmospheric pressure for any given gas will be much lower than when it is in process. Think of a sponge getting the water rung out of it when it is squeezed – the same happens to the gas at higher pressure. A higher pressure reduces the amount of water vapor that can be suspended and held in gas phase. In a saturated gas stream, the gas can not hold any more water vapor before it condenses out as pressure increases or temperature decreases. If the temperature of the gas increases, the moisture carrying capacity of the gas will also increase. This basic relationship among pressure, concentration and dew point temperature in IGT#8 also exist in more complex methods.

EXAMPLES

- ④ Using the plot above, for a pipeline operating at 1,000 PSia (69 Bara), a moisture concentration of 148 PPMv (7 Lbs / MMCF) from the **MODEL 4010LX** contains a gas where the moisture dew point is 32°F (0°C) when the IGT#8 method is used.
- ③ If this pipeline was instead operated at 290 PSia (20 Bara), the identical sample of 148 PPMv (7 Lbs / MMCF) would then have a moisture dew point in the pipe at 12°F (-11°C).

4010LX AND DEW POINT

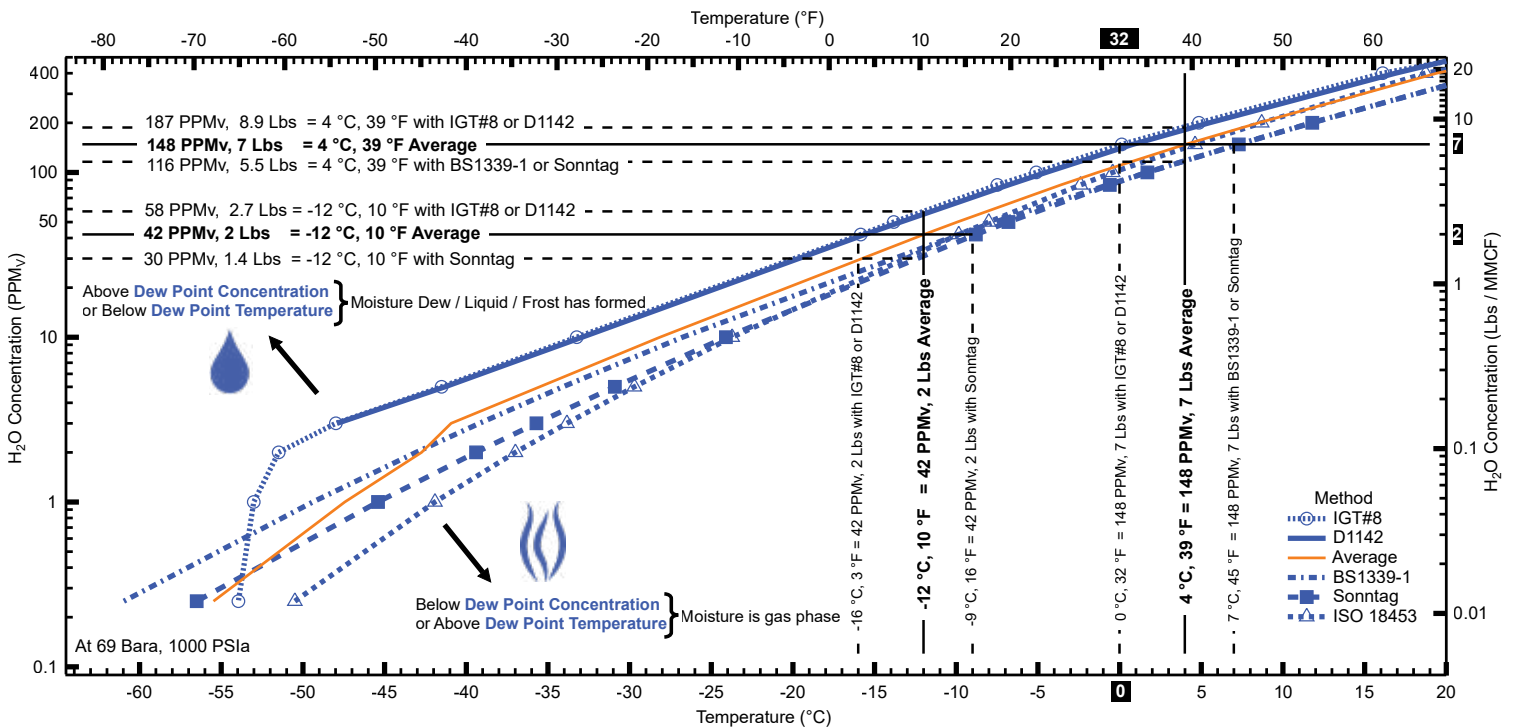
The **MODEL 4010LX** has no built-in method to display or output to dew point. As discussed, however, there are several methods for converting the moisture concentration measurement of the **4010LX** to the process dew point. This conversion must be done external to the **4010LX** analyzer with a separate PLC or computer or directly in a DCS or SCADA control system using the conversion model the operator chooses.

Alternatively, an operator may consider converting the current moisture dew point control values for the process to the equivalent PPMv concentrations. With this approach the operator can utilize the native units output from **4010LX** to control and monitor their process.

Table: Dew Point Temperature of Moisture (H₂O), presented near the end of this paper, shows 5 methods of conversion from moisture concentration of the **MODEL 4010LX**, where the base unit in the **4010LX** is PPMv, with built-in conversion to LBS / MMCF.

COMPLEX METHODS FOR DEW POINT

MOISTURE DEW POINT TEMPERATURE IN NATURAL GAS AT 69 BARA, 1000 PSIA BY METHOD



A comparison of five different methods is shown in the above chart from the example of a typical high pressure pipeline pressure of 69 Bara / 1,000 PSIA. This shows variation of the dew point predicted by each method – and in general the lower the concentration, the more the methods diverge.

For example, at 100 PPMv (4.7 Lbs), the methods show a moisture dew point between -5 to 2°C (23 to 35°F), but the deviation increases as the concentration is lowered to 10 PPMv (0.5 Lbs) to a dew point range of -33 to -24°C (-28 to -11°F). For this reason, it is important an operator understand how the conversion method does or does not account for the specifics of the process and application. The best method to use for each use case will depend on what may be mandated by regulatory or operating procedures or agreements, what is possible by the available instrumentation or exact process operating conditions, and the gas composition and phases.

CONCLUSION

This white paper has discussed basic and complex conversion methods for dew point measurement. More advanced methods will not only take into account the exact surrounding or background gas composition that the moisture is contained in but also how to correct for them. Some enhanced factors can even adjust for how the moisture condenses out of gas phase. In such instances, choose a method or adjust an existing one so that the conversion can differentiate whether moisture is condensing on liquid (dew) or ice (frost) and whether it is precipitating as water (dew) or ice (sublimation), as required by the amount of energy. Be aware that the exact temperature of this phase change will occur at slightly different levels than predicted by simpler methods.

Offline conversion of moisture concentrations given by the **4010LX** to dew point is possible. Conversions will vary depending on the method chosen, the accuracy of the process pressure used, and whether gas composition and other enhancement factors are applied or used by the method.



DEW POINT TEMPERATURE OF MOISTURE (H₂O)

IGT #8
ISO 18453
ASTM D1142
BS1339:1 Dew

Pressure (Bara or PSia) with Result in °C or °F by Method

BS 1339:1 Frost, Sonntag, Buck

Concentration PPMv H ₂ O LBS/MMCF H ₂ O mg/M ³ H ₂ O	1		2		5		10		20		50		69		100		150		200 Bara			
	14.5		29		73		145		290		725		1000		1425		2175		2900 PSia			
	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
5000 PPMv 238 LBS 3800 mg	-3	27	6	43	20	68	37	99	68	155	135	275	181	358	235	455	459	858	462	864		
	-2	28	6	44	20	69	38	100	70	158	150	303	190	375	240	464	493	959	464	867		
	-2	28	7	44	21	69	32	90	44	112	61	143	68	154	75	166	82	180	166	332		
	-3	27	7	44	21	70	33	91	46	114	65	149	72	162	81	178	92	197	178	353		
	-2	28	7	45	21	70	33	91	46	114	65	149	72	162	81	178	92	197	178	353		
2000 PPMv 95 LBS 1520 mg	-13	8	-6	22	6	43	16	61	29	84	56	133	74	165	95	203	179	353	179	353		
	-13	9	-5	22	6	44	17	62	30	86	62	144	48	119	98	209	120	248	134	273		
	-13	9	-5	23	7	44	17	62	28	82	42	108	47	117	53	127	59	139	64	146		
	-14	6	-6	22	7	44	17	63	29	84	46	114	52	126	60	140	69	156	76	168		
	-13	9	-5	23	7	45	18	64	29	84	46	114	52	126	60	140	69	156	76	169		
1000 PPMv 47 LBS 750 mg	-21	-5	-14	8	-4	26	5	42	15	59	30	86	38	100	48	119	85	185	88	191		
	-20	-5	-13	8	-3	27	6	44	16	62	33	91	41	106	51	124	62	144	69	157		
	-20	-5	-13	9	-3	27	6	43	16	60	29	84	34	92	39	101	44	111	48	118		
	-23	-9	-14	6	-3	27	7	45	17	63	33	91	39	102	46	114	54	129	60	140		
	-20	-5	-13	9	-2	28	7	45	18	64	33	91	39	102	46	114	54	129	60	140		
400 PPMv 19 LBS 300 mg	-30	-22	-23	-10	-14	7	-6	20	1	34	13	55	16	61	20	69	29	84	32	90		
	-29	-21	-23	-9	-13	8	-5	22	3	37	15	59	19	66	23	73	28	82	31	87		
	-30	-21	-23	-9	-13	8	-6	21	2	35	13	56	17	62	21	70	26	78	29	83		
	-33	-27	-25	-13	-14	6	-6	22	4	39	17	63	23	73	29	84	36	97	42	107		
	-30	-21	-23	-9	-13	9	-5	23	4	39	18	64	23	73	29	84	36	97	42	107		
200 PPMv 9.5 LBS 150 mg	-36	-33	-30	-23	-22	-7	-14	6	-8	19	2	35	5	41	8	47	12	54	14	58		
	-36	-33	-30	-22	-21	-5	-13	8	-6	22	5	41	9	48	13	55	16	61	18	64		
	-36	-33	-30	-21	-21	-6	-14	7	-7	19	2	36	6	42	9	48	13	55	15	59		
	-40	-39	-33	-27	-23	-9	-14	6	-6	22	7	45	12	53	17	63	24	75	29	84		
	-36	-33	-30	-21	-20	-5	-13	9	-5	23	7	45	12	53	18	64	24	75	29	84		
148 PPMv 7 LBS 112 mg	-39	-39	-33	-28	-25	-12	-18	0	-11	12	-3	27	0	32	3	38	7	44	9	48		
	-39	-37	-33	-27	-24	-11	-16	2	-9	16	1	34	5	40	8	47	12	53	14	57		
	-39	-38	-33	-27	-24	-11	-17	1	-11	13	-2	28	1	33	4	40	8	46	10	49		
	-42	-44	-36	-32	-26	-15	-18	-1	-10	15	3	37	7	45	13	55	19	66	24	75		
	-39	-38	-32	-26	-23	-10	-16	3	-9	17	3	37	7	45	13	55	19	67	24	75		
100 PPMv 4.7 LBS 75 mg	-43	-46	-37	-35	-29	-20	-22	-8	-16	4	-8	18	-5	23	-2	28	0	32	2	36		
	-42	-44	-36	-33	-28	-18	-21	-5	-13	8	-4	25	0	31	3	38	7	44	9	48		
	-42	-44	-36	-33	-28	-18	-21	-5	-15	5	-7	19	-5	24	-2	29	1	34	3	37		
	-46	-51	-40	-39	-30	-22	-23	-9	-14	6	-3	27	2	35	7	45	13	55	17	63		
	-42	-44	-36	-33	-27	-17	-20	-5	-13	9	-2	28	2	35	7	45	13	55	18	64		
84 PPMv 4 LBS 64 mg	-45	-49	-39	-38	-30	-23	-24	-11	-18	0	-10	14	-7	19	-5	23	-2	29	0	31		
	-43	-46	-38	-36	-29	-21	-22	-8	-15	5	-6	22	-2	28	1	34	5	40	7	44		
	-44	-47	-38	-36	-30	-21	-23	-10	-17	1	-9	15	-7	20	-4	24	-2	29	0	32		
	-48	-54	-41	-42	-32	-26	-25	-12	-17	2	-5	23	-1	31	4	40	10	51	15	59		
	-44	-47	-38	-36	-29	-20	-22	-8	-15	5	-4	24	-1	31	5	40	10	51	15	59		
50 PPMv 2.4 LBS 38 mg	-50	-58	-44	-47	-36	-32	-29	-21	-23	-10	-16	3	-14	7	-12	11	-9	15	-7	19		
	-48	-54	-42	-44	-34	-29	-27	-17	-21	-5	-11	12	-8	18	-5	24	-1	29	0	33		
	-48	-55	-42	-44	-35	-30	-29	-20	-23	-9	-16	4	-13	8	-11	12	-9	16	-7	19		
	-52	-62	-46	-51	-37	-35	-30	-22	-23	-9	-12	11	-8	18	-3	27	3	37	7	45		
	-48	-54	-42	-44	-34	-29	-27	-17	-20	-5	-10	13	-7	20	-2	28	3	37	7	45		
42 PPMv 2 LBS 32 mg	-52	-61	-46	-51	-37	-35	-31	-24	-25	-13	-19	-1	-16	3	-14	7	-12	11	-10	13		
	-49	-57	-44	-47	-36	-32	-29	-20	-22	-8	-13	8	-10	14	-6	20	-3	26	-1	29		
	-50	-57	-44	-47	-36	-33	-31	-23	-25	-13	-18	0	-16	4	-13	8	-11	12	-10	14		
	-54	-65	-48	-54	-39	-38	-32	-26	-25	-12	-14	7	-10	14	-5	23	0	33	4	40		
	-49	-57	-44	-47	-36	-32	-29	-20	-22	-8	-12	10	-9	16	-4	24	0	33	5	40		
10 PPMv 0.5 LBS 7.6 mg	-66	-87	-60	-76	-53	-63	-47	-52	-41	-41	-35	-31	-33	-28	-32	-25	-29	-19	-28	-18		
	-60	-77	-55	-68	-48	-54	-42	-44	-36	-32	-27	-17	-24	-11	-20	-4	-17	2	-15	5		
	-61	-77	-56	-69	-49	-57	-45	-48	-40	-40	-35	-30	-33	-27	-31	-25	-30	-22	-29	-21		
	-65	-85	-60	-76	-52	-62	-46	-51	-40	-39	-30	-22	-27	-16	-23	-9	-18	0	-14	6		
	-61	-77	-55	-68	-48	-54	-42	-44	-36	-33	-27	-17	-24	-11	-20	-5	-16	3	-13	9		
5 PPMv 0.24 LBS 3.8 mg	-73	-100	-68	-90	-60	-76	-55	-66	-48	-55	-43	-45	-42	-43	-40	-40	-37	-35	-36	-33		
	-66	-86	-61	-77	-54	-64	-48	-54	-42	-43	-33	-28	-30	-21	-26	-15	-23	-9	-21	-6		
	-66	-86	-62	-79	-56	-69	-52	-61	-47	-53	-43	-45	-41	-42	-40	-40	-39	-38	-38	-37		
	-70	-94	-65	-85	-58	-72	-52	-62	-46	-51	-37	-35	-34	-29	-30	-22	-26	-14	-23	-9		
	-66	-86	-61	-77	-54	-65	-48	-54	-42	-44	-34	-29	-31	-24	-27	-17	-23	-10	-20	-5		
3 PPMv 0.14 LBS 2.3 mg	-79	-110	-73	-100	-65	-86	-60	-76	-54	-65	-49	-57	-48	-54	-47	-52	-44	-47	-44	-46		
	-69	-92	-64	-84	-58	-72	-52	-61	-46	-51	-37	-35	-34	-29	-30	-22	-27	-16	-25	-13		
	-69	-92	-66	-86	-61	-77	-57	-70	-53	-64	-49	-56	-48	-54	-47	-52	-46	-51	-45	-50		
	-74	-101	-69	-92	-62	-80	-57	-70	-51	-59	-42	-44	-39	-39	-36	-32	-31	-24	-28	-19		
	-69	-92	-64	-84	-58	-72	-52	-62	-47	-52	-39	-38	-36	-32	-32	-26	-28	-19	-26	-14		
2 PPMv 0.1 LBS 1.5 mg	-83	-117	-76	-105	-69	-92	-64	-83	-57	-71	-53	-63	-51	-61	-51	-59	-50	-57	-48	-55		
	-72	-97	-67	-89	-61	-77	-55	-67	-49	-57	-41	-41	-37	-35	-33	-27	-30	-22	-28	-18		
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	-77	-106	-72	-97	-65	-85																

SAMPLE READINGS OF TABLE



DEW POINT TEMPERATURE OF MOISTURE (H₂O)

Pressure (Bara or PSia) with Result in °C or °F by Method

IGT #8
ISO 18453
ASTM D1142
BS1339:1 Dew

Concentration PPMv H ₂ O LBS/MMCF H ₂ O mg/M ³ H ₂ O	1 14.5		2 29		5 73		10 145		20 290		50 725		69 1000		100 1425		150 2175		200 Bara 2900 PSia			
	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F		
	BS 1339:1 Frost, Sonntag, Buck																					
148 PPMv 7 LBS 112 mg	-39	-39	-33	-28	-25	-12	-18	0	-11	12	-3	27	0	32	3	38	7	44	9	48		
	-39	-37	-33	-27	-24	-11	-16	2	-9	16	1	34	5	40	8	47	12	53	14	57		
	-39	-38	-33	-27	-24	-11	-17	1	-11	13	-2	28	1	33	4	40	8	46	10	49		
	-42	-44	-36	-32	-26	-15	-18	-1	-10	15	3	37	7	45	13	55	19	66	24	75		
	-39	-38	-32	-26	-23	-10	-16	3	-9	17	3	37	7	45	13	55	19	67	24	75		
100 PPMv 4.7 LBS 75 mg	-43	-46	-37	-35	-29	-20	-22	-8	-16	4	-8	18	-5	23	-2	28	0	32	2	36		
	-42	-44	-36	-33	-28	-18	-21	-5	-13	8	-4	25	0	31	3	38	7	44	9	48		
	-42	-44	-36	-33	-28	-18	-21	-5	-15	5	-7	19	-5	24	-2	29	1	34	3	37		
	-46	-51	-40	-39	-30	-22	-23	-9	-14	6	-3	27	2	35	7	45	13	55	17	63		
	-42	-44	-36	-33	-27	-17	-20	-5	-13	9	-2	28	2	35	7	45	13	55	18	64		
84 PPMv 4 LBS 64 mg	-45	-49	-39	-38	-30	-23	-24	-11	-18	0	-10	14	-7	19	-5	23	-2	29	0	31		
	-43	-46	-38	-36	-29	-21	-22	-8	-15	5	-6	22	-2	28	1	34	5	40	7	44		
	-44	-47	-38	-36	-30	-21	-23	-10	-17	1	-9	15	-7	20	-4	24	-2	29	0	32		
	-48	-54	-41	-42	-32	-26	-25	-12	-17	2	-5	23	-1	31	4	40	10	51	15	59		
	-44	-47	-38	-36	-29	-20	-22	-8	-15	5	-4	24	-1	31	5	40	10	51	15	59		
50 PPMv 2.4 LBS 38 mg	-50	-58	-44	-47	-36	-32	-29	-21	-23	-10	-16	3	-14	7	-12	11	-9	15	-7	19		
	-48	-54	-42	-44	-34	-29	-27	-17	-21	-5	-11	12	-8	18	-5	24	-1	29	0	32		
	-48	-55	-42	-44	-35	-30	-29	-20	-23	-9	-16	4	-13	8	-11	12	-9	16	-7	19		
	-52	-62	-46	-51	-37	-35	-30	-22	-23	-9	-12	11	-8	18	-3	27	3	37	7	45		
	-48	-54	-42	-44	-34	-29	-27	-17	-20	-5	-10	13	-7	20	-2	28	3	37	7	45		
42 PPMv 2 LBS 32 mg	-52	-61	-46	-51	-37	-35	-31	-24	-25	-13	-19	-1	-16	3	-14	7	-12	11	-10	13		
	-49	-57	-44	-47	-36	-32	-29	-20	-22	-8	-13	8	-10	14	-6	20	-3	26	-1	29		
	-50	-57	-44	-47	-36	-33	-31	-23	-25	-13	-18	0	-16	3	-13	8	-11	12	-10	14		
	-54	-65	-48	-54	-39	-38	-32	-26	-25	-12	-14	7	-10	14	-5	23	0	33	4	40		
	-49	-57	-44	-47	-36	-32	-29	-20	-22	-8	-12	10	-9	16	-4	24	0	33	5	40		

- 7 LBS is H₂O dew point 32°F at 1000 PSia with method IGT#8 a typical specification in Southern US where climates are warmer.
- 4 LBS is H₂O dew point 20°F at 1000 PSia with method ASTM D1142 a specification in Northern US regions where climates are cooler.
- 64 mg is H₂O dew point -6°C at 50 Bara with method ISO 18453 an example specification that may be used in France.
- 38 mg is H₂O dew point -8°C at 69 Bara with method BS 1339:1 Dew an example specification in Europe where the CEN is -8°C.
- 32 mg is H₂O dew point -16°C at 69 Bara with method ASTM D1142 a typical upper specification in Canadian regions with colder climates.
- 100 PPMv is H₂O dew point -42°C at 1 Bara with method Sonntag a calibration point of the AMI MODEL 4010LX.