Technical Bulletin: Converting dewpoint temperature to PPMv

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The Shaw Aluminium Oxide (Al_2O_3) sensor measures the capacitance between the aluminium core and a gold film deposited on an oxide layer that separates the two electrodes. The capacitance varies according to the water vapor content in the pores of the oxide layer. Essentially, the Shaw sensor is measuring the vapor pressure of water in the sampled gas and the associated Shaw hygrometer expresses this as dewpoint temperature.

The ranges of the Shaw transmitters and hygrometers are expressed as dewpoint temperature (C or F). This is because linearization of the signal output of the sensors during calibration and certification are correlated against chilled mirror hygrometers. Our Chilled Mirror hygrometers are certified by national laboratories. The chilled mirror technique directly measures dew point temperature and is considered a primary standard measurement. However, the relationship between dew point temperature and Parts per Million (PPM) is non-linear. Because of this, expressing dew point temperature as parts per million will require additional math.

Some of Shaw's portable and inline instrumentation incorporate the math required to express the measurement in units of PPMv (Parts Per Million by Volume), PPBv, PPMw, and Lbs for million cubic feet….

With the SDHmini, the engineering units ppmV, g/m^3 and lb/MMSCF are derived from the saturation vapor pressure using the following equations:

$$ppmV = (ew(t) \times 1000000) / 101325 \qquad \text{where } ew(t) \text{ is in pascals (Pa)}$$

$$g/m^3 = (ew(t) \times 18.02) / 2400.344$$

$$lb/MMSCF = g/m^3 \times 62.4219$$

With the SADP, the analog scale shows the correlated, linearized PPMv reading- again assuming the sample pressure is 1 ATM.

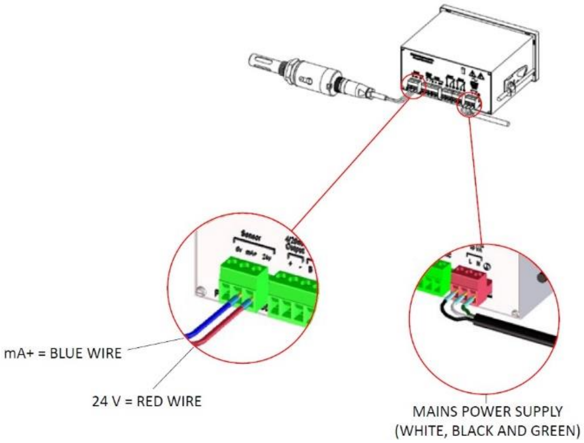
Likewise, the Superdew 3 inline hygrometer can be programmed to express water vapor content of the sampled gas in PPMv- again assuming the sample pressure is 1 ATM.

In contrast, Shaw transmitters (AcuDew and SDTex) can linearize the measured signal from the A2LO3 sensor and provide an output that correlates to dewpoint temperature in degrees C or F. Although the published ranges for both the AcuDew and SDTex transmitters are also expressed in PPMv, the outputs are non-linear for PPMv.

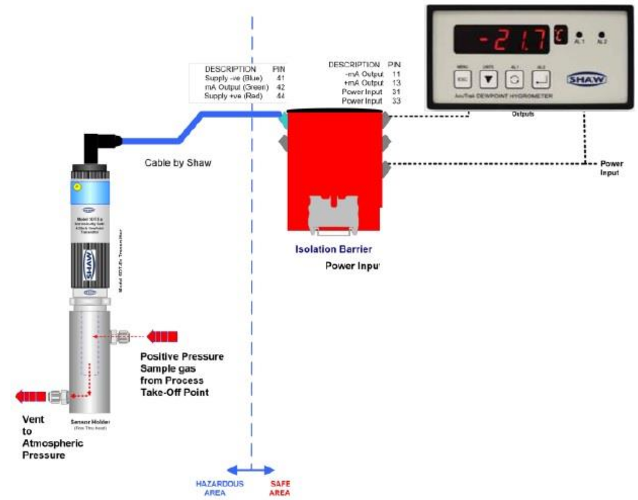
To express dewpoint temperatures as linearized PPMv using the AcuDew or SDTex, you must couple the transmitter 4-20mA outputs to the AcuTrak hygrometer or perform the necessary math within your PLC/ DCS (see the Shaw Bulletin on Pressure Dew point).

The AcuTrak integrates the AcuDew or SDTex signals into a linearized output that can be expressed as PPMv on the AcuTrak display, 4-20mA and RS485.

Other features of the AcuTrak include pressure input (enter the pressure that the transmitter is operating at), sample temperature and background gas type (enter the molecular weight of the background gas).



AcuTrak with the AcuDew Transmitter



AcuTrak with the SDTex transmitter

Following is a chart of Dewpoint temperature vs other units (PPMv) @ 1 ATM

DewPoint		Vapor Pressure (Water/ Ice in Equilibrium) mm Hg	PPM on Volume Basis at 760 mm of Hg pressure	Relative Humidity at 70^{o} F%	PPM on Weight Basis in Air
^{o}C	^{o}F				
-90	-130	0.00007	0.0921	0.00037	0.057
-88	-126	0.00010	0.132	0.00054	0.082
-86	-123	0.00014	0.184	0.00075	0.11
-84	-119	0.00020	0.263	0.000107	0.16
-82	-116	0.00029	0.382	0.00155	0.24
-80	-112	0.00040	0.562	0.00214	0.33
-78	-108	0.00056	0.737	0.00300	0.46
-76	-105	0.00077	1.01	0.00410	0.63
-74	-101	0.00105	1.38	0.00559	0.86
-72	-98	0.00143	1.88	0.00762	1.17
-70	-94	0.00194	2.55	0.0104	1.58
-68	-90	0.00261	3.43	0.0140	2.13
-66	-87	0.00349	4.59	0.0187	2.84
-64	-83	0.00464	6.11	0.0248	3.79
-62	-80	0.00614	8.08	0.0328	5.01
-60	-76	0.00808	10.6	0.0430	6.59
-58	-72	0.0106	13.9	0.0565	8.63
-56	-69	0.0138	18.2	0.0735	11.3
-54	-65	0.0178	23.4	0.0948	14.5
-52	-62	0.0230	30.3	0.123	18.8
-50	-58	0.0295	38.8	0.157	24.1
-48	-54	0.0378	49.7	0.202	30.9
-46	-51	0.0481	63.3	0.257	39.3
-44	-47	0.0609	80	0.325	49.7
-42	-44	0.0768	101	0.410	62.7
-40	-40	0.0966	127	0.516	78.9
-38	-36	0.1209	159	0.644	98.6
-36	-33	0.1507	198	0.804	122.9
-34	-29	0.1873	246	1.00	152
-32	-26	0.2318	305	1.24	189
-30	-22	0.2859	376	1.52	234
-28	-18	0.351	462	1.88	287
-26	-15	0.430	566	2.3	351
-24	-11	0.526	692	2.81	430
-22	-8	0.640	842	3.41	523
-20	-4	0.776	1020	4.13	633
-18	0	0.939	1240	5.00	770
-16	3	1.132	1490	6.03	925
-14	7	1.361	1790	7.25	1110
-12	10	1.632	2150	8.69	1335
-10	14	1.950	2570	10.4	1596
-8	18	2.326	3060	12.4	1900
-6	21	2.765	3640	14.7	2260
-4	25	3.280	4320	17.5	2680
-2	28	3.880	5100	20.7	3170
0	32	4.579	6020	24.4	3640
2	36	5.294	6970	28.2	4330
4	39	6.101	8030	32.5	4990
6	43	7.013	9230	37.4	5730
8	46	8.045	10590	42.9	6580
10	50	9.029	12120	49.1	7530
12	54	10.52	13840	56.1	8600
14	57	11.99	15780	63.9	9800
16	61	13.63	17930	72.6	11140
18	64	15.48	20370	82.5	12650
20	68	17.54	23080	93.5	14330

Additional Comments:

In calculating the relationship between pressure and dewpoint, various approximations are utilised in different methods, leading to variations in the results. Listed below are some of the most popular methods:

1. **Bukacek Method**:
    - This method is based on empirical correlations and is relatively straightforward.
    - It approximates the saturation vapor pressure with the Antoine equation or similar empirical formulas. (Antoine concept too complex for me to either understand or explain to you)
    - The approximation may vary depending on the coefficients used in the equation and the range of temperature and pressure for which it was calibrated.
2. **Magnus Formula**:
    - The Magnus formula is commonly used for estimating the saturation vapor pressure over water or ice.
    - It involves several empirical constants that are determined based on experimental data.
    - The formula may have different versions tailored for specific temperature and pressure ranges, leading to variations in results.
3. **Sonntag/Wexler Equation**:
    - This equation provides a more comprehensive approach by considering both temperature and pressure effects on saturation vapor pressure.
    - It incorporates various coefficients and constants derived from extensive experimental data.
    - However, even with its complexity, it still relies on empirical fits to experimental data, which introduces approximations.

These methods all aim to approximate the relationship between pressure and dewpoint, but they do so through different approaches and levels of complexity. The variations in results stem from differences in the underlying assumptions, empirical fits, and ranges of validity for each method.

Factors contributing to the variations include:

- **Range of Applicability**: Each method may have been calibrated and validated over specific temperature and pressure ranges, leading to discrepancies outside those ranges.
- **Data Quality**: The accuracy of the coefficients and constants used in the equations depends on the quality and quantity of the experimental data used for their determination.
- **Simplifying Assumptions**: Certain simplifications and assumptions are made in each method to make the calculations tractable, which can introduce errors, especially under extreme conditions.

In summary, while these methods provide useful approximations for calculating the pressure-dewpoint relationship, users should be aware of their limitations and potential variations in results, especially when operating outside the ranges for which they were developed.