alphasense AMETEK®

NDIR: Determination of Linearisation and Temperature Correction Coefficients

1. Introduction

This Application Note explains how to set the linearisation and temperature correction algorithms in your software when calculating carbon dioxide concentration from the sensor outputs.

Linearisation Coefficients

The absorbance as a function of gas concentration is non-linear and is given by the following equation (see Application Note AAN 204):

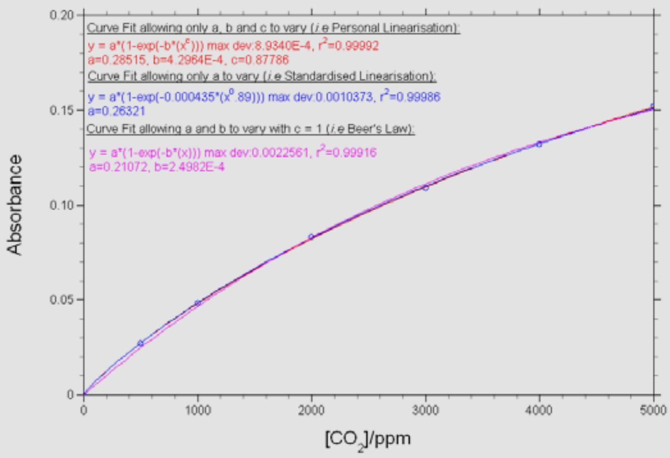
$$ABS = SPAN\left(1 - \exp\left(-bx^{c}\right)\right)$$

where: ABS is the absorbance
SPAN is determined during calibration (see Application Note AAN 201)
x is the gas concentration and
b and c are linearisation coefficients

In practice it is found that this expression does not fit well over the entire concentration range 0 to 100 % volume (i.e. the same linearisation coefficients cannot be used). The values of b and c that should be employed therefore depend on the concentration range of interest. Alphasense publishes coefficients for 0 to 5000 ppm, 0 to 5 %, 0 to 20 % and 0 to 100 % (see Application Note AAN 201). Users should use the coefficients that apply to the range of interest. Note, however that the accuracy decreases as the range increases. If 0 to 100% linearisation is applied and then the sensor is used at say, 1% the accuracy will be very poor. Applying software algorithms such that the linearisation applied depends on the absorbance measured can solve this problem and allow the same IRC-A1 sensor to be used over a wide concentration range. Nevertheless, users interested in other ranges may wish to determine their own linearisation coefficients. Values of b and c can easily be determined by plotting ABS as a function of gas concentration and using curve-fitting software to fit the above equation. Note that b is defined by the units of gas concentration as illustrated in example 1.

Example 1: 0 to 5000 ppm (0 to 0.5 % Volume)

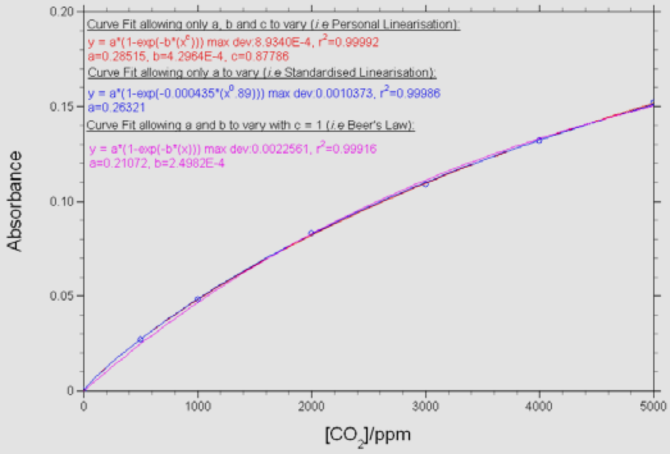
[CO2]/ppm	[CO2]/% Vol	ABS
0	0	0.000
5000	0.5	0.152
4000	0.4	0.132
3000	0.3	0.109
2000	0.2	0.083
1000	0.1	0.048
500	0.05	0.027



In this example the gas concentration has units of either ppm or % Volume. It can be seen that the choice of units effects only the value of the coefficient, b.

In each case three curve fits are shown:

1) Personalised Linearisation. This yields sensor specific linearisation coefficients. In this case b = 4.2964 x 10-4 (using ppm) or 1.334 (using %Volume) and c = 0.878.
2) Standardised Linearisation. These shows the curve fitted to experimental data using Standard Linearisation coefficients (see Table 1 in AAN 201). Note the extremely small error introduced as a result of using standard coefficients rather than sensor specific coefficients.
3) Beer's Law. This shows the fit to Beer's Law (i.e. c = 1).



Example 2: 0 to 5 % Volume

[CO2]/% Vol	ABS
5	0.444
4	0.414
3	0.373
2	0.316
1	0.226
0.5	0.154
0	0

This example shows data in the range 0 to 5 % volume. As is Example 1, three curve fits are shown.

1) Personalised Linearisation (yields b = 0.500 and c = 0.679)
2) Standardised Linearisation
3) Beer's Law

As in Example 1, both the personalised and standardised linearisation coefficients give excellent fits to the data. However, note that over this concentration range the sensor behaviour deviates from Beer's Law, which is reflected in the lower value of c. Deviations from Beer's Law behaviour at higher concentrations are common and are attributed to factors such as increased scattering of light (rather than pure absorption). Note that although the sensor response deviates from Beer's Law-type behaviour, it is highly reproducible.

Temperature Correction Coefficients

There are three coefficients concerned with linear temperature compensation. These are:

β_O SPAN ONLY correction coefficient

α ABS correction coefficient

β_A ABS AND SPAN correction coefficient

Determination of SPAN ONLY correction coefficient

The SPAN ONLY correction coefficient corrects for changes in the SPAN as a function of temperature. These arise due to changes in spectra and filter characteristics with temperature. The SPAN as a function of temperature is given by:

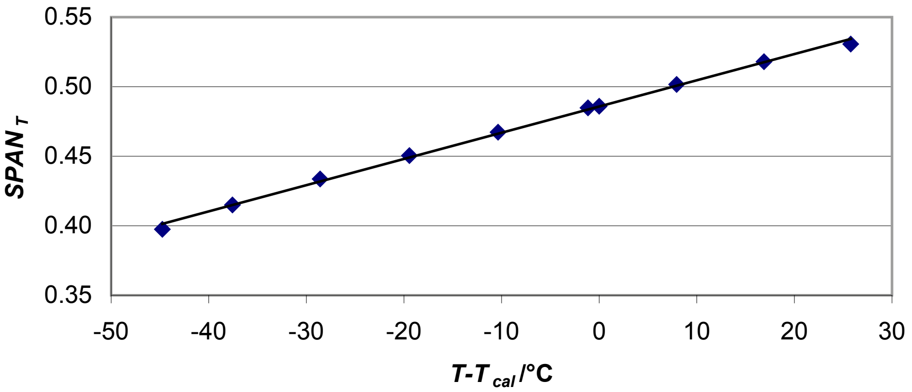
$$SPAN_T = SPAN_{cal} + \beta_o (T - T_{cal})$$

The value of β_O can be determined by plotting $SPAN_T$ as a function of $(T - T_{cal})$. Note that in determining $SPAN_T$ at each temperature the calibration gas concentration must be corrected assuming ideal gas behaviour. The coefficient, β_O is equal to the gradient.

Example:

T/°C	T-Tcal/°C	ABS	T-Tcal/°C	T-Tcal/°C	ABS
24.1	0.0	0.381	5.00	5.00	0.486
-20.7	-44.8	0.324	5.00	5.89	0.397
-13.5	-37.6	0.336	5.00	5.72	0.415
-4.5	-28.6	0.347	5.00	5.53	0.434
4.6	-19.4	0.358	5.00	5.35	0.451
13.7	-10.4	0.368	5.00	5.18	0.467
22.9	-1.1	0.378	5.00	5.02	0.485
32.0	7.9	0.388	5.00	4.87	0.502
41.0	16.9	0.397	5.00	4.73	0.518
49.9	25.8	0.403	5.00	4.60	0.531

β_O = gradient = 0.0019



Determination of ABS and ABS AND SPAN correction coefficient

The ABS correction coefficient, α, accounts for changes in absorbance with temperature. These are caused by factors such as variations in detector sensitivity and filter transmission as a function of temperature. The value of α can be determined by plotting ABS_0 (the absorbance under ZERO gas) as a function of ($T-T_{cal}$). The ABS correction coefficient is equal to the gradient.

Example:

T/°C	$T-T_{cal}$/°C	ABS_0
24.1	0.0	0.000
-14.0	-38.1	-0.029
-5.2	-29.3	-0.020
3.8	-20.2	-0.014
13.0	-11.1	-0.008
31.1	7.1	0.005
40.1	16.0	0.011
49.0	25.0	0.014
26.5	2.4	0.002

The ABS AND SPAN correction coefficient, β_A is used to correct SPAN assuming that ABS has also been corrected. It is determined as for SPAN ONLY, however the SPAN is calculated using corrected absorbance data (see Application Note AAN 201).

Example:

T/°C	T-Tcal/°C	ABS	$ABS_{corrected}$	[CO2]/% Vol.	$[CO2]_{corrected}$/% Vol.	$SPAN_T$
24.1	0.0	0.381	0.381	5.00	5.00	0.489
-20.7	-44.8	0.324	0.346	5.00	5.89	0.425
-13.5	-37.6	0.336	0.354	5.00	5.72	0.438
-4.5	-28.6	0.347	0.361	5.00	5.53	0.451
4.6	-19.4	0.358	0.367	5.00	5.35	0.462
13.7	-10.4	0.368	0.372	5.00	5.18	0.473
22.9	-1.1	0.378	0.378	5.00	5.02	0.485
32.0	7.9	0.388	0.384	5.00	4.87	0.497
41.0	16.9	0.397	0.389	5.00	4.73	0.508
49.9	25.8	0.403	0.392	5.00	4.60	0.516

β_A = gradient = 0.00130