PHASE DYNAMICS

Automatic Computer Density Correction of the Phase Dynamics

Phase Dynamics calibrates at the factory with an oil of approximately 865 kg/m^3. For this density of oil you do not need any "Cal Factor" in the analyzer and the display should be correct with a sample that you analyze. Any measurement using electric dipole moment physics (capacitance, RF and microwave) as the basis of measurement looks at the polar moment of the molecule. Oil has very low polarity and water has a high polarity. When the density increases there are more molecules per unit area. Therefore a change in density to a heavier crude makes an analyzer show increased water content when it is really a change in density.

If the density changes to 846 kg/m^3 , then a "Cal Factor" is required that is equal to approximately:

Cal Factor = - 0.217 x density + (2.3557e -4) x Density^^{2} - (9.6447e -8) x density^^{3} + 73.72 =

$$[-0.217 \times 846] + [2.3557 \times 10^{-4} \times (846)^2] - 9.6447 \times 10^{-8} \times (846)^3 + 73.72 = +0.34$$

which would be added to the Phase Dynamics water cut. For lighter oil the density is less, less molecules per unit area means water cut offset needs to be added to the calculated water cut.

If the water cut was actually zero for a 846 kg/m^3 crude then Phase Dynamics would calculate a negative number = – 0.34% water cut (if the "Cal Factor" = 0). Since a negative water cut is not displayed the analyzer would read zero. To obtain a number from the Phase Dynamics unit, a +0.34% must be entered into the "Cal Factor" in the Phase Dynamics unit (see the instruction manual).

If the oil density changes to a 924 kg/m^3 then this heavier oil looks like there is water in the oil when there is not. The 924 kg/m^3 density oil would require that a "Cal Factor" of -1.76% be entered to make the 924 kg/m^3 oil with no water appear as zero on the Phase Dynamics unit. This means that the heavier oil density makes it look like there is +1.76% water there when there is none (and the Cal Factor = 0). To implement correction for a heavy oil a negative "Cal Factor" must be placed into the Phase Dynamics.

The density correction equation for the Phase Dynamics Analyzer is:

Corrected W/C = [Measured Water Cut - PDI Cal Factor + Flow Computer Offset] +
- 0.217 x density + 2.3557e-4 x Density^^{2} - 9.6447e-8 x density^^{3} + 73.72

Where: **Measured Water** = the 4-20 mA value, Modbus or other water cut value read from the PDI unit.
PDI Cal Factor = "Cal Factor" entered into the Phase Dynamics unit to assure greater than zero water cut.
Flow Computer Offset = A value entered into the flow computer (PLC) to correct the final water cut
Density = FLOWING density (not temperature corrected) from a densitometer

In the earlier text where the density goes from 846 to 924 kg/m^3 the steps to correct across this range are described as follows: NOTE: You MUST USE UNCORRECTED DENSITY. The density which must be used is AT FLOWING TEMPERATURE AND PRESSURE.

1.) Calculate the "Cal Factor" required to make the water cut always read above zero: Use the minimum density (846 kg/m^3) that will be seen to calculate:

Cal Factor = $- 0.217 \times 846 + 2.3557 \times 10^{-4} \times (846)^2 - 9.6447 \times 10^{-8}$ **$\times (846)^3 + 73.72 = + 0.34$ %**

Since this is the minimum required to make the measurement always above zero, a larger number would be recommended. Arbitrarily use a 0.50% Cal Factor.

2.) The effect of the heaviest crude would be to have water appear on the display when there is not any. +1.76% would be seen on the Analyzer's display with zero water cut in a 924 kg/m^3 oil.

EXAMPLES

EXAMPLE 1:

PDI Water cut Display = 1.35% PDI Cal Factor = + 0.5% Flow Computer Offset = - 0.30
Density = 846 kg/m^3 Actual Water Cut From Lab Analysis = 0.89%

$$\text{Corrected W/C} = [1.35 - (+0.5) + (-0.3)] - 0.217 \times 846 + 2.3557 \times 10^{-4} \times (846)^2 - 9.6447 \times 10^{-8} \times (846)^3 + 73.72 = 0.55 + 0.34 = 0.89\ \%$$

NOTE: The Flow Computer Offset (-0.30) was determined by taking a resulting Corrected W/C and correcting it against the Lab Analysis for several samples.

EXAMPLE 2: PDI Water cut =3.32% PDI Cal Factor = + 0.5% Flow Computer Offset = - 0.30
Density = 924 kg/m^3 Actual Water Cut From Lab Analysis = 0.76%

$$\text{Corrected W/C} = [3.32 - (+0.5) + (-0.3)] - 0.217 \times 924 + 2.3557 \times 10^{-4} \times (924)^2 - 9.6447 \times 10^{-8} \times (924)^3 + 73.72 = 2.52 - 1.76 = 0.76\ \%$$

NOTE: The same Flow Computer Offset (-0.30) was maintained since this was derived from prior data.

EXAMPLE 3: PDI Water cut =4.00% PDI Cal Factor = + 0.5% Flow Computer Offset = - 0.30
Density = 924 kg/m^3 Actual Water Cut From Lab Analysis = 1.44%

$$\text{Corrected W/C} = [4.00 - (+0.5) + (-0.3)] - 1.76 = 3.2 - 1.76 = 1.44\ \%$$

NOTE: If this was a 0-4% analyzer then the output would be 20 mA for this example. This means that you could not have greater than 1.44% water cut for the 924 kg/m^3 oil and still be able to read it. The solution would be to have a 0-10% range analyzer instead of the 0-4%.

EXAMPLE: For An Analyzer with a 0.00% to 4.00% Range - 4% limits ability to correct density

Density kg/m^3	Actual Water Cut (%)	Density Offset Calculation (%)	PDI "Cal Factor" (%)	PDI Internal Calculation Plus "Cal Factor" (%)	PDI Display, Digital or Analog Output (%)	Flow Computer Offset (%)	Corrected Water Cut Using Equation (%)
930	0.00	-1.92	+5.00	7.44	4.00	-0.52	-3.44 (NG)
902	0.00	-1.12	+5.00	6.66	4.00	-0.52	-2.64 (NG)
890	0.00	-0.80	+5.00	6.32	4.00	-0.52	-2.32 (NG)
872	0.00	-0.32	+5.00	5.84	4.00	-0.52	-1.84 (NG)
859	0.00	+0.00	+5.00	5.52	4.00	-0.52	-1.52 (NG)
809	0.00	+1.28	+5.00	4.24	4.00	-0.52	-0.24 (NG)
747	0.00	+2.88	+5.00	2.64	2.64	-0.52	0.00
689	0.00	+4.48	+5.00	0.52	0.52	-0.52	0.00

EXAMPLE: For An Analyzer with a 0.00% to 10.00% Range - all values are valid for no water.

Density kg/m^3	Actual Water Cut (%)	Shift Due to Density (%)	PDI "Cal Factor" (%)	PDI Internal Calculation Plus "Cal Factor" (%)	PDI Display, Digital or Analog Output (%)	Flow Computer Offset (%)	Corrected Water Cut Using Equation (%)
930	0.00	-1.92	+5.00	7.44	7.44	-0.52	0.00
902	0.00	-1.12	+5.00	6.66	6.66	-0.52	0.00
890	0.00	-0.80	+5.00	6.32	6.32	-0.52	0.00
872	0.00	-0.32	+5.00	5.84	5.84	-0.52	0.00
859	0.00	-0.00	+5.00	5.52	5.52	-0.52	0.00
809	0.00	+1.28	+5.00	4.24	4.24	-0.52	0.00
747	0.00	+2.88	+5.00	2.64	2.64	-0.52	0.00
689	0.00	+4.48	+5.00	0.52	0.52	-0.52	0.00

EXAMPLE: 0-10% Range Analyzer with varying density and water cut: large density swing limits high end.

Density kg/m^3	Actual Water Cut (%)	Shift Due to Density (%)	PDI "Cal Factor" (%)	PDI Internal Calculation Plus "Cal Factor" (%)	PDI Display, Digital or Analog Output (%)	Flow Computer Offset (%)	Corrected Water Cut Using Equation (%)
930	0.00	-1.92	+5.00	7.44	7.44	-0.52	0.00
930	1.00	-1.92	+5.00	8.44	8.44	-0.52	1.00
930	4.00	-1.92	+5.00	11.44	10.00	-0.52	2.56 (NG)
689	0.00	+4.48	+5.00	0.52	0.52	-0.52	0.00
689	1.00	+4.48	+5.00	1.52	1.52	-0.52	1.00
689	4.00	+4.48	+5.00	4.52	4.52	-0.52	4.00
689	10.00	+4.48	+5.00	10.52	10.00	-0.52	8.96 (NG)

NOTE: (NG) = not a good number

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Effect of Density Adjustment on Instrument Range (0-4% or 0-10%)

A 4-20 mA signal scaled from zero to four percent Water Cut is used to send the uncorrected water cut to the PLC. Since this number is uncorrected, the actual water cut range of the 4-20 mA is limited to the zero point of the heavier crude density water cut offset as the table below shows.

Actual W/C %	Displayed W/C Including a **"Cal Factor" = 0.5%**		
	Density = 924	Density = 859	Density =846
0.0	1.77+0.5=**2.23**	0.0+0.5=**0.50**	-0.32+0.5=**0.18**
0.4	2.17+0.5=**2.63**	0.4+0.5=**0.90**	0.08+0.5=**0.58**
1.0	2.77+0.5=**3.23**	1.0+0.5=**1.50**	0.68+0.5=**1.18**
2.0	**4.00 Overrange** (4.23)	2.0+0.5=**2.50**	1.68+0.5=**2.18**
3.0	**4.00 Overrange** (5.23)	3.0+0.5=**3.50**	2.68+0.5=**3.18**
4.0	**4.00 Overrange** (6.23)	**4.00 Overrange** (4.5)	**4.00 Overrange** (4.18)

Therefore, the heavier crude limits the water cut obtainable with a 0-4% ranged instrument to a range of actual water cuts:

from	0.0% Real W/C	(2.27% on display)
to	4.00% - 2.27% = 1.73%	(4.00% on display)

for the heavy 924 kg/m^3 crude only. A 0-10% Range Low Cut Analyzer is usually recommended for this type of application to maintain a good water cut range across all densities of crude.

If a digital interface to the Phase Dynamics system is being used, a corrected "Cal Factor" may be written to the analyzer to have the display equal the actual water cut. One additional manner In which to handle this is to use the optional feature 4-20 mA input for Flow instead as a stream select where each "Stream" has a different Cal Factor stored.

Data Sheet for Density Correction Problem Determination

Sample ID	Date Time	Flowing Density	PDI "Cal Factor" (%)	PDI Temperature Deg. C or F	PDI Display (%)	PLC* Offset (%)	PLC ** Water Cut (%)	Lab W/C (%)

NOTES: The PDI "Cal Factor" is the water cut offset entered into the Phase Dynamics, Inc. analyzer in order to always have a positive water cut with the lightest density crude.
* This is the offset put into the PLC to offset the error between the lab and the PLC displayed at the time of the sample. This number is added to the density correction and then displayed as the PLC W/C %
** This is the PLC reading after all of the math to correct for density is done.

REMARKS:

1.) Describe the method used in the Laboratory to analyze the sample.

2.) What is the sample size?

3.) How was the sample obtained. Location of the sample port and how the port is situated on the main line.

4.) Is there a static mixer upstream?