



Automatic Computer Density Correction of the Phase Dynamics FOR DENSITIES FROM 750 kg/m³ TO 998 kg/m³

Phase Dynamics calibrates at the factory with an oil of approximately 865 kg/m³. 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 848 kg/m³, then a "Cal Factor" is required that is equal to approximately:

$$\text{Cal Factor} = - 0.0286 \times \text{density (kg/m}^3\text{)} + 24.6 = \\ [- 0.0286 \times 848] + 24.6 = + 0.34$$

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 848 kg/m³ 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 922 kg/m³ then this heavier oil looks like there is water in the oil when there is not. The 922 kg/m³ density oil would require that a "Cal Factor" of (- 1.76%) be entered to make the 922 kg/m³ 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:

$$\text{Corrected W/C} = [\text{Measured Water Cut} - \text{PDI Cal Factor} + \text{Flow Computer Offset}] + \\ - 0.0286 \times \text{density} + 24.6$$

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 = Temperature Corrected to standard temperature and pressure from a densitometer



In the earlier text where the density goes from 848 to 922 kg/m³ the steps to correct across this range are described as follows:

- 1.) Calculate the "Cal Factor" required to make the water cut always read above zero:
Use the minimum density (848 kg/m³) that will be seen to calculate:

$$\text{Cal Factor} = - 0.0286 \times 848 + 24.6 = + 0.34 \%$$

Since this is the minimum required to make the measurement always above zero, a larger number would be recommended. Arbitrarily we would 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 922 kg/m³ oil.

EXAMPLES

EXAMPLE 1:

PDI Water cut Display = 1.35% PDI Cal Factor = + 0.5% Flow Computer Offset = - 0.30
Density = 848 kg/m³ Actual Water Cut From Lab Analysis = 0.89%

$$\text{Corrected W/C} = [1.35 - (+0.5) + (- 0.3)] - 0.0286 \times 848 + 24.6 = 0.55 + 0.34 = 0.897\%$$

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 = 922 kg/m³ Actual Water Cut From Lab Analysis = 0.76%

$$\text{Corrected W/C} = [3.32 - (+0.5) + (- 0.3)] - 0.0286 \times 922 + 24.6 = 0.75 \%$$

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 = 922 kg/m³ Actual Water Cut From Lab Analysis = 1.44%

$$\text{Corrected W/C} = [4.00 - (+0.5) + (- 0.3)] - 0.0286 \times 922 + 24.6 = 1.43 \%$$

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 1.43% water cut for the 922 kg/m³ 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 Created Offset	PDI "Cal Factor" (%)	PDI Internal Calculation Plus "Cal Factor" (%)	PDI Display, Digital or Analog Output (%)	Flow Computer Offset (%)	Water Cut minus Flow Offset minus Density Correction (%)	Status
930	0	2.00	3	5.00	4.0	-3.0	-1.0	Not Good
900	0	1.14	3	4.14	4.0	-3.0	-0.1	Not Good
890	0	0.85	3	3.85	3.9	-3.0	0.0	Okay
875	0	0.43	3	3.43	3.4	-3.0	0.0	Okay
860	0	0.00	3	3.00	3.0	-3.0	0.0	Okay
820	0	-1.15	3	1.85	1.9	-3.0	0.0	Okay
750	0	-3.15	3	-0.15	-0.2	-3.0	0.0	Okay

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 (%)	Density Created Offset	PDI "Cal Factor" (%)	PDI Internal Calculation Plus "Cal Factor" (%)	PDI Display, Digital or Analog Output (%)	Flow Computer Offset (%)	Water Cut minus Flow Offset minus Density Correction (%)	Status
930	0	2.00	3	5.00	5.0	-3.0	0.0	Okay
900	0	1.14	3	4.14	4.1	-3.0	0.0	Okay
890	0	0.85	3	3.85	3.9	-3.0	0.0	Okay
875	0	0.43	3	3.43	3.4	-3.0	0.0	Okay
860	0	0.00	3	3.00	3.0	-3.0	0.0	Okay
820	0	-1.15	3	1.85	1.9	-3.0	0.0	Okay
750	0	-3.15	3	-0.15	-0.2	-3.0	0.0	Okay

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

Density kg/m ³	Actual Water Cut (%)	Density Created Offset	PDI "Cal Factor" (%)	PDI Internal Calculation Plus "Cal Factor" (%)	PDI Display, Digital or Analog Output (%)	Flow Computer Offset (%)	Water Cut minus Flow Offset minus Density Correction (%)	Status
930	0	2.00	4	6.00	6.0	-4.0	0.0	Okay
930	1	2.00	4	7.00	7.0	-4.0	1.0	Okay
930	4	2.00	4	10.00	10.0	-4.0	4.0	Okay
750	0	-3.15	4	0.85	0.8	-4.0	0.0	Okay
750	1	-3.15	4	1.85	1.9	-4.0	1.0	Okay
750	4	-3.15	4	4.85	4.9	-4.0	4.0	Okay
750	10	-3.15	4	10.85	10	-4	9.15	Not Good



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 = 922	Density = 860	Density = 848
0.0	1.76+0.5= 2.26	0.0+0.5= 0.50	-0.34+0.5= 0.16
0.4	2.16+0.5= 2.66	0.4+0.5= 0.90	0.08+0.5= 0.56
1.0	2.76+0.5= 3.26	1.0+0.5= 1.50	0.68+0.5= 1.16
2.0	4.00 Overrange (4.26)	2.0+0.5= 2.50	1.68+0.5= 2.16
3.0	4.00 Overrange (5.26)	3.0+0.5= 3.50	2.68+0.5= 3.16
4.0	4.00 Overrange (6.26)	4.00 Overrange (4.5)	4.00 Overrange (4.16)

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 (2.26% on display)
 to 4.00% - 2.26% = 1.74% Real W/C (4.00% on display)

for the heavy 922 kg/m³ 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.

