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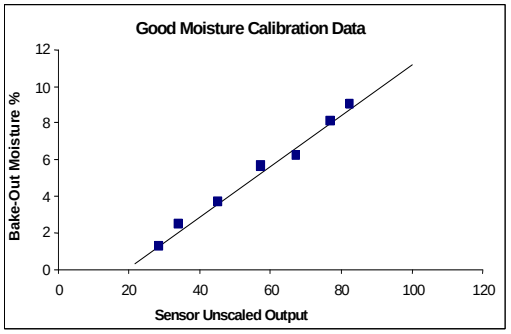
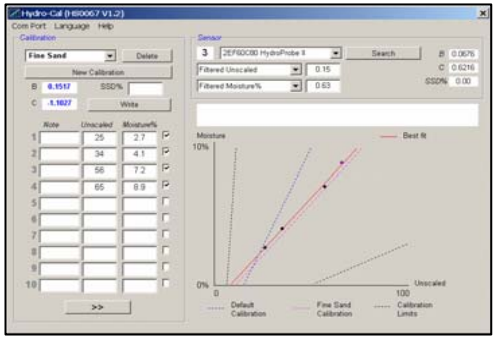
Hydro-Probe II Calibration

For aggregates and other materials





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Contents

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Introduction

The Hydronix range of digital sensors are robust and precise scientific instruments.

This presentation focuses on using the sensors in sand and aggregates; however the equipment is successfully used in numerous other applications with moisture contents ranging between 0 and 80% moisture.

It does not discuss the many advantages of 'moisture measurement' in detail such as savings in material (cement, colour etc) which can be significant or other quality issues such as the determination of water/cement ratios, consistency, finish, yields etc. For further specific application information please contact support@hydronix.com and we will be happy to help.

This presentation explains the resolution of measurement and potential accuracy that is realistically achievable in the field of the sensor. The sensor can theoretically measure in sand to a precision of approximately 0.045% however due to the limitations of calibration, this precision cannot be achieved in practice. The sensor measures to a far higher precision than it can be calibrated to. Effectively, the sensor will be as accurate as the user can make their calibration. This presentation identifies some of the variables in order to help assist the user in achieving the best possible material calibration results.

The sensors have a linear output, this simplifies direct integration into any control system. They may also be configured to output various parameters or to multiplex between two parameters such as moisture and temperature. The sensors also have additional features such as digital input/output capability for automated batch averaging and configurable high/low limits to trigger alarms (bin empty!). Full information is available in the user guide available at www.hydronix.com.

The presentation begins by giving an overview of 'how the sensors work' and installation options. For more detailed information on configuration and physical installation please see the accompanying presentations or the user guides.

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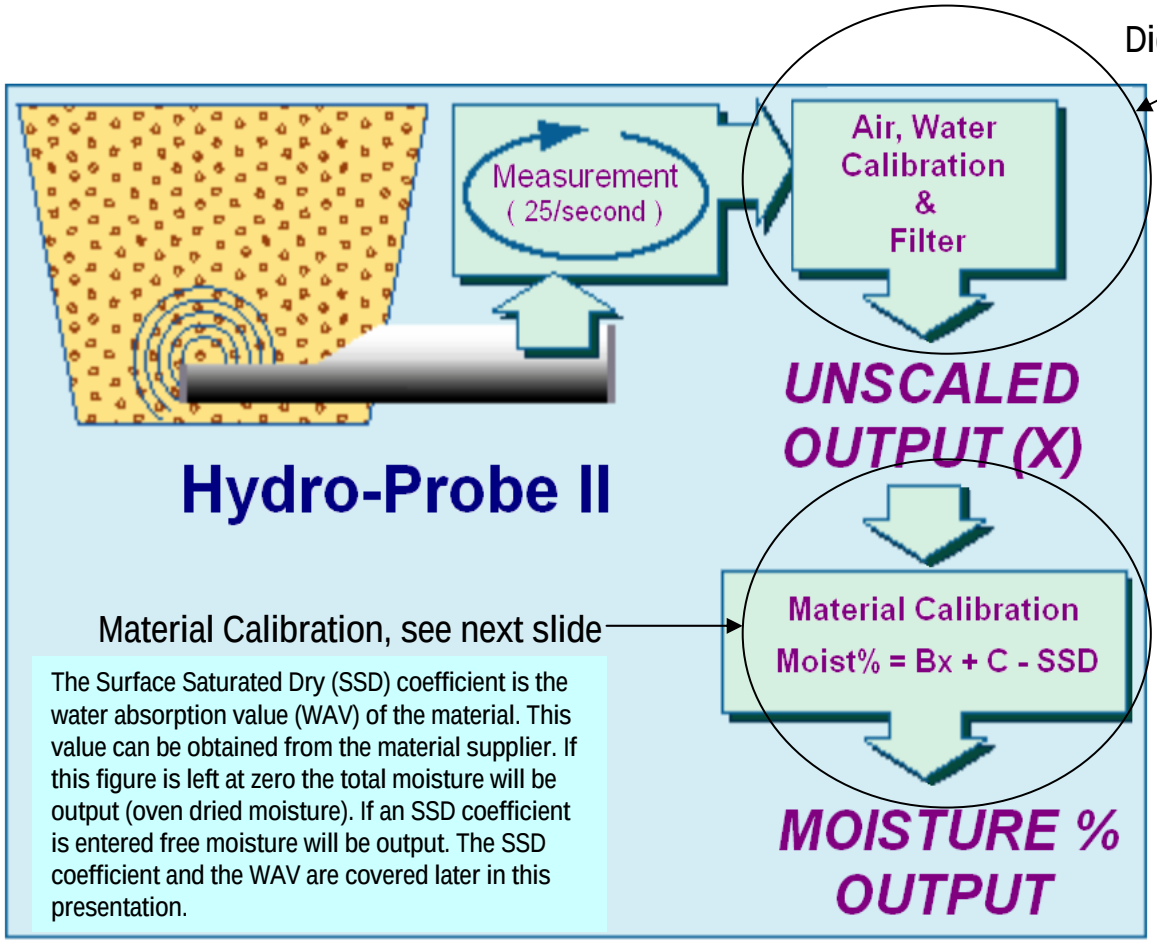
How the sensor works

The sensors measure 25 times per second and will output a linear signal dependant upon the electrical properties of the material that is measuring.



One advantage of a digital sensor is that they are 'digitally' factory calibrated. This ensures that every sensor is **identical**.

Benefits

- Linearity ensures that just one good calibration is all that is required for a given material.
- Known calibration values for a given material may be used across multiple sensors
- If a replacement sensor is installed the known calibration values for the material may be used immediately without the requirement for further calibration

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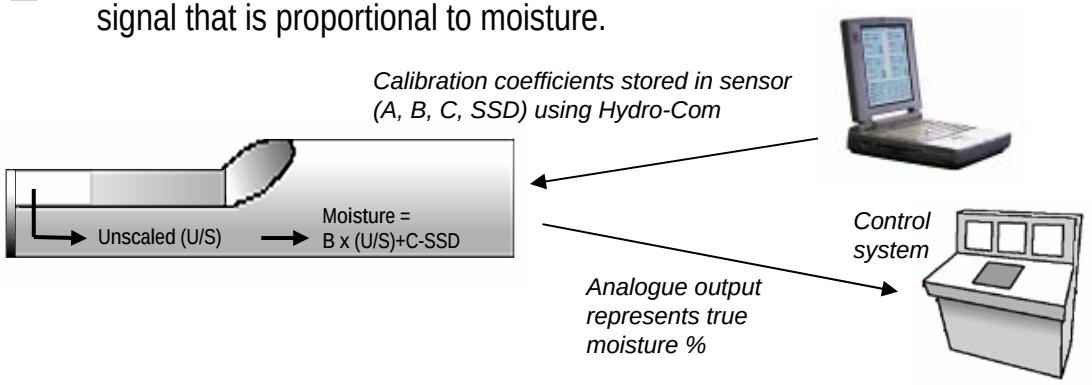
Storing calibration data

There are two ways of storing the calibration data.

1

The sensor may be configured using the Hydronix Hydro-Com software to output a signal that is proportional to moisture.

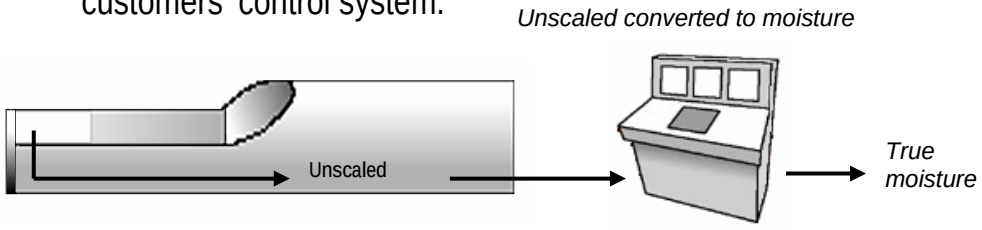


Advantages

- Advanced free software improving calibration accuracy, including diagnostics software.
- Control system does not need modification to calibrate the sensor.
- Ability to use Hydronix known calibration data for different materials.
- Calibrations can be transferred between sensors.

2

The sensor may configured using the Hydronix Hydro-Com software to output a linear signal that that may be calibrated to moisture in the customers' control system.



Advantages

- Direct calibration without the need for an additional computer or RS485 adapter.
- No need to learn how to use additional software.
- If it is necessary to replace the sensor, a replacement Hydronix sensor can be connected and valid results obtained immediately without connecting the sensor to a PC to update the material calibration.
- Calibrations can be switched between sensors easily.

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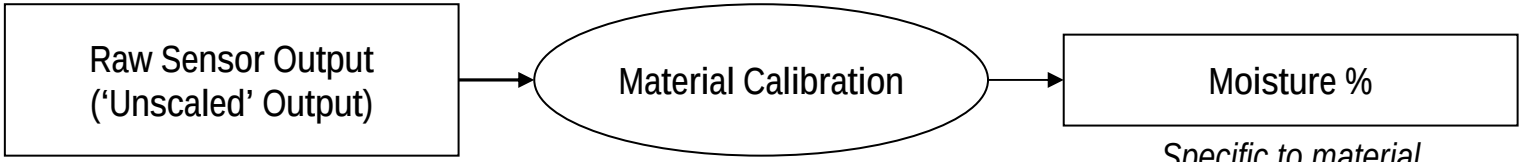
What is material calibration?

Calibration defines the relationship between the raw output ('Unscaled') from a Hydronix moisture sensor to actual moisture in the material.



Why is calibration required?

Every material has different electrical properties, therefore it is not possible to produce a sensor that can measure true moisture for all materials without having to be calibrated.

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What is material calibration?

The raw ‘Unscaled’ output from a Hydronix sensor increases linearly with moisture in the material.

For example:

- If ‘Unscaled’ reading was 30 @ 2% moisture
- If ‘Unscaled’ reading was 70 @ 6% moisture

  Then if the ‘Unscaled’ reading = 40 then the moisture = 3%

  Then if the ‘Unscaled’ reading = 80 then the moisture = 7%

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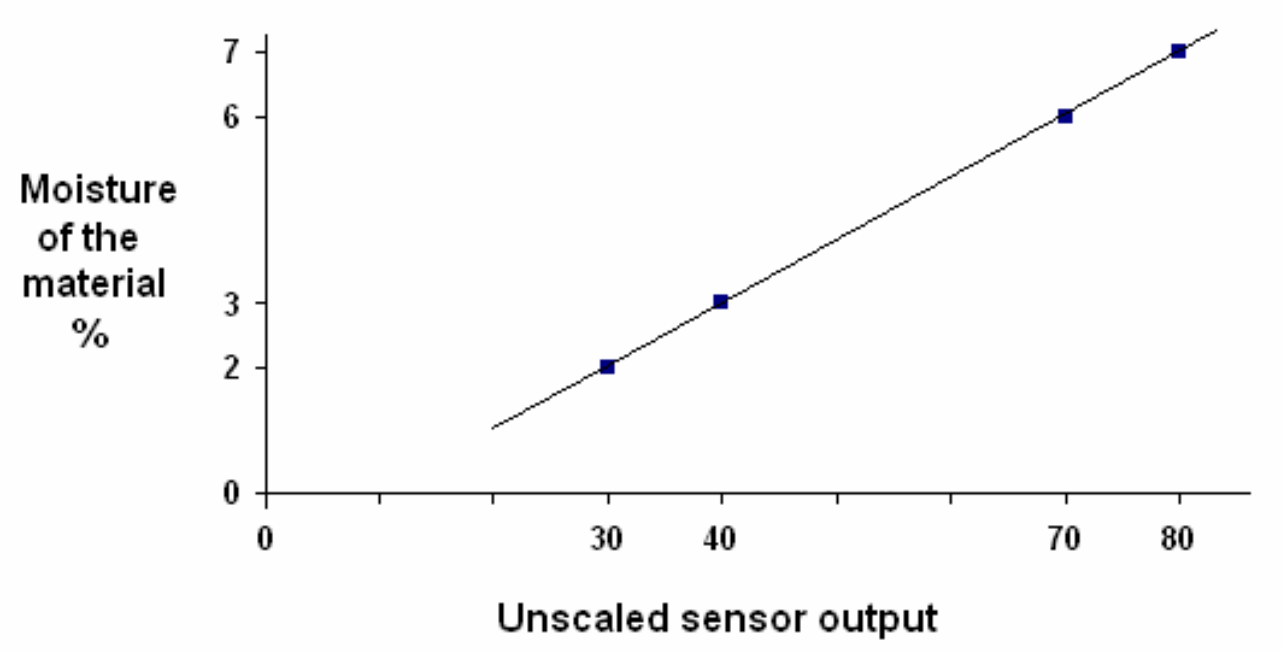
What is material calibration?

This linear relationship is shown below, this is a straight line graph.

The line is unique for each material.

Once correctly calibrated any moisture value can be determined from any unscaled reading.



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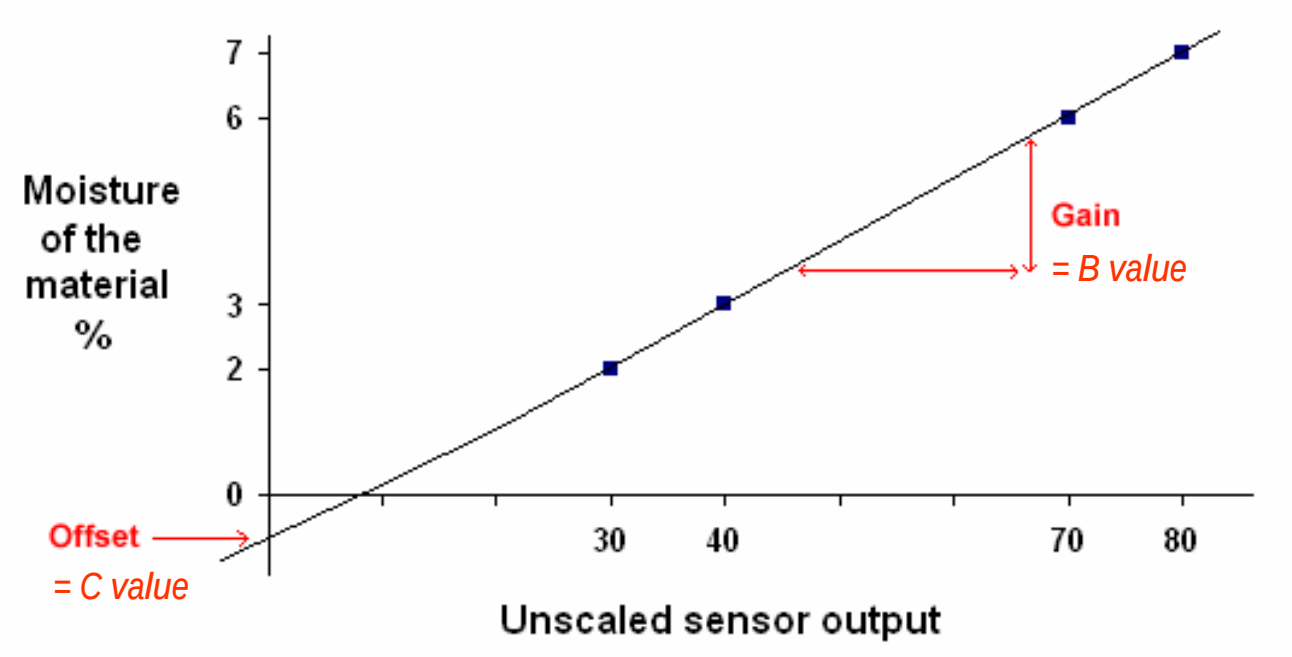
What is material calibration?

The properties of a straight line are described by its gain (gradient) and offset. The gain and offset correspond to the B and C values in the sensor and Hydro-Com software respectively.



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Advantages of a good moisture calibration

Question:

How often do I have to re-calibrate? This is a question that we are frequently asked by new customers.

The sensors are no different to any other equipment that requires calibration.

The sensors are precise instruments that are manufactured to have identical measurement characteristics. Unscaled values for both *'air' (zero unscaled) and *'water' (100 unscaled) are obtained under controlled conditions and are electronically recorded in each sensor. This means that…

Answer:

One good calibration is all that is required.

One good calibration is required for each material but once correctly calibrated a sensor should require little in the way of maintenance.

It is recommended to check calibration data as part of the plant quality procedures. The frequency of this will depend on the requirements of each plant and may vary between weekly and 6 monthly. Hydronix provide a template to record the results of moisture sample tests (next page).

A poor moisture calibration used with Hydronix sensors or the use of inferior sensors will result in the requirement to frequently recalibrate. This presentation explains why this occurs and how to correctly calibrate the precision Hydronix sensors to avoid unnecessary problems.

*See the Hydro-Probe II and Hydro-Com user guide for further details, 'Factory Calibration'.

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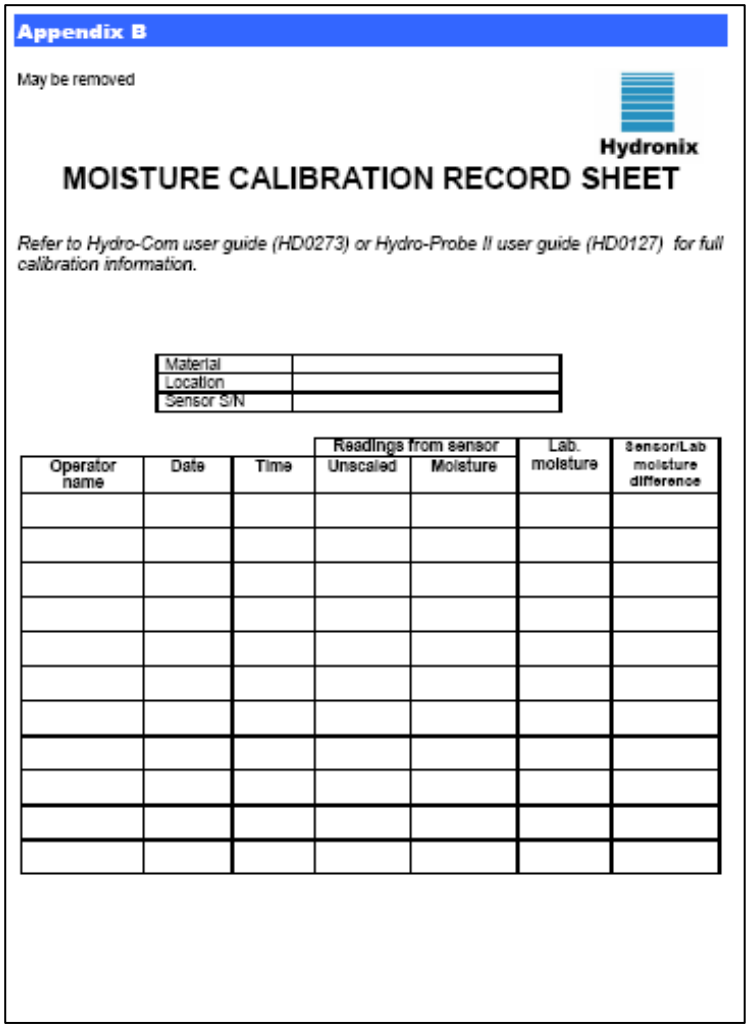
Recording calibration data



Appendix B

May be removed

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MOISTURE CALIBRATION RECORD SHEET

Refer to Hydro-Com user guide (HD0273) or Hydro-Probe II user guide (HD0127) for full calibration information.

Material	
Location	
Sensor S/N	

Operator name	Date	Time	Readings from sensor		Lab. moisture	Sensor/Lab moisture difference
			Unscaled	Moisture		

The Hydro-Probe II user guides incorporates a template that may be used to record the results of periodic moisture sample tests.

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Resolution and Accuracy

The sensor measures to a resolution of +/-0.16 unscaled units. Technical details are available upon request.

For sand, calibration gradients will vary between approximately 0.1 (a fine sand) and 0.3 (a course sand). The potential accuracy of the sensor increases with a decrease in gradient, the following example uses a gradient of 0.2857 which is the recommended default gradient for course sand (4-8mm).

This means that, in course sand, for every 1 unit change in unscaled value the moisture % will change by 0.2857%.

With a measurement precision of +/- 0.16 unscaled units this gives an accuracy of +/- 0.045% moisture in sand.

$$0.2857 \times 0.16 = +/- 0.045\% \text{ moisture}$$

In practice it is difficult to obtain a calibration accuracy of greater than +/- 0.2%. This is due to external errors in determining the actual moisture content of the materials. This means that effectively, for these type of applications, the sensor will be as accurate as the user can make their calibration.

It should be noted that for applications where it is possible to calibrate more accurately the sensor is more than capable of measuring to a greater accuracy. Hydronix quote a precision of +/- 0.16 unscaled units, the actual moisture percentage accuracy will be a function of the gradient of the line for a given material.

For applications such as mixer applications the Hydro-Mix sensor (identical in measurement characteristics to the Hydro-Probe II) is often used to measure the relative change in moisture rather than to determine the absolute moisture content (by use of a moisture sample test) thus the resolution in this case is the unscaled resolution of the sensor. In this way the effective accuracy is far higher and tolerances of approximately +/- 0.1% moisture are achievable or roughly 2 litres of water in a 1m3 mix design.

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Surface Saturated Dry (SSD) and Oven Dried Conditions

This is applicable for materials that absorb an inherent level of water, such as is the case with aggregates. The surface saturated dry condition of a material is where it has been totally surface dried but may still contain absorbed water within the particles. The amount of absorbed water varies between aggregates, it is measured as a percentage which is called the material's Water Absorption Value (WAV).

In the concrete industry aggregate masses are based on SSD condition (zero Free Water), this is the water that has not been absorbed by the aggregate and that is available to react with the cement.

It is only possible to obtain calibration points by carrying out an oven dried moisture test. This test drives off 100% of the water and gives a Total Moisture result.

Absorbed Water	+	Free Water	=	Total Moisture

In order for the sensor to output a Free Water value Hydronix use an SSD coefficient, this is the Water Absorption Value (WAV) of the material. This value can be obtained from the material supplier and entered into the Hydronix calibration data for the material.

Oven dried moisture % (total moisture)	-	Water Absorption Value (WAV) % (Hydronix SSD coefficient)	=	Free Water

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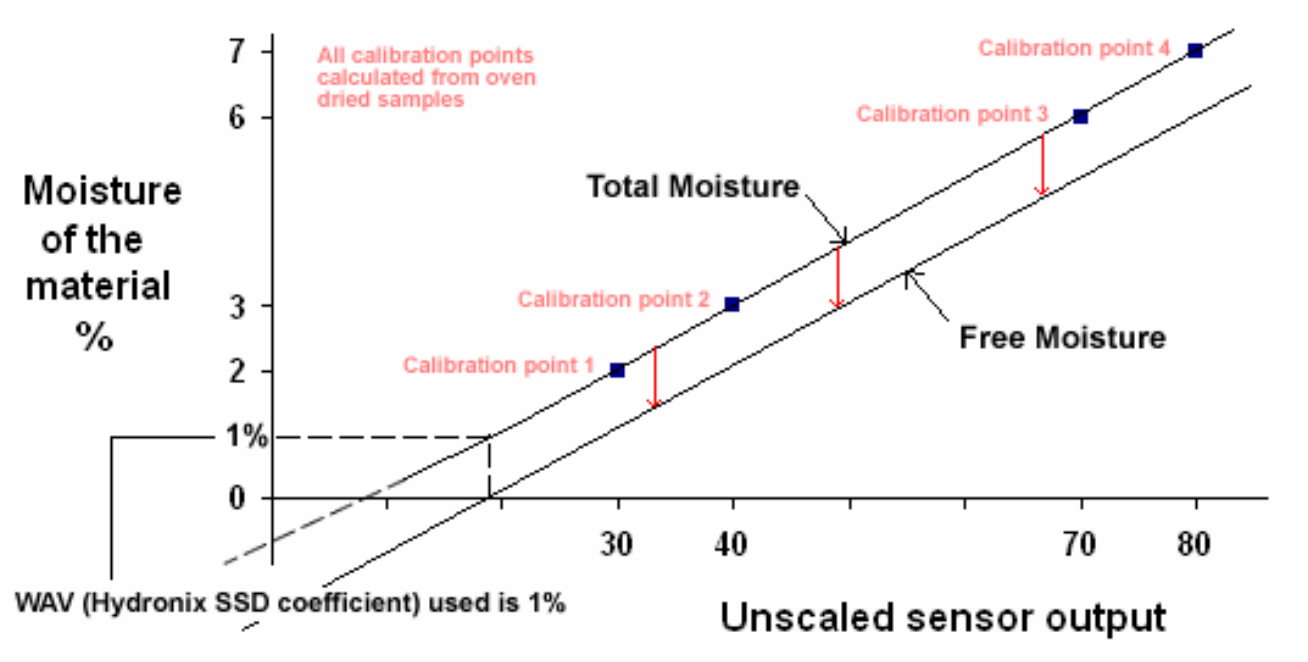
Surface Saturated Dry (SSD) and Oven Dried Conditions

In practice it is only possible to calibrate by oven drying material and to correct for the absorbed water by entering the Water Absorption Value (Hydronix SSD coefficient), the sensor will then output a Free Water value. The SSD coefficient is a constant value (or offset) and may be stored internally in the sensor or, alternatively, this may be applied in the control system.

The graph demonstrates the addition of a Water Absorption Value (Hydronix SSD coefficient).



The sensor measures the electrical properties of the oven dried material + total moisture.

Calibration removes the effect of the oven dried material.

This leaves the sensor measuring total moisture.

Total Moisture = Absorbed Water + Free Moisture.

The bound water is not available for hydration and in many applications only a free moisture output is meaningful.

The SSD coefficient may be used if a ‘free moisture’ value is required. The graph opposite shows the effect of using the SSD coefficient.

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Calibration – General points

- Wear safety glasses and protective clothing to guard against expulsion of material during the drying process.

- Do not attempt to calibrate the sensor by packing material on the face. The readings obtained will not be representative of those from a real application.

- Whilst recording the sensor unscaled output, always sample where the sensor is located.

- Never assume that material flowing out of two gates in the same bin is the same moisture content and do not attempt to take samples from the flow in both gates to get an average value – always use two sensors.

- Where possible, average the sensor's readings either in the sensor using the digital input, or inside the control system.

- Ensure the sensor sees a representative sample of material.

- Ensure a representative sample is taken for moisture testing.

- To calibrate the system accurately, at least two samples of material are required with at least 2-3% moisture difference.

- Certain industry standards may apply with regard to sampling and accuracy of test equipment.

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Calibration equipment

- *Weighing scales* – to weigh up to 2kg, accurate to 0.1g
- *Heat source* – for drying samples, such as an electric hot plate or oven.
- *Container* – with re-sealable lid for storing samples
- *Polythene bags* – for storing samples prior to drying
- *Scoop* – for collecting samples
- *Safety equipment* – including glasses, heat resistant gloves and protective clothing.

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Finding the calibration coefficients

1. If using Hydro-Com, ensure Hydro-Com is running with the calibration page open.

2. Create a new calibration.

3. Select the correct sensor from the Hydro-Com pull-down list.

4. When batching, look at the Average/Hold status next to the 'Average' reading from the sensor. The optimum installation is one where the digital input is wired into the bin-gate switch. When the bin opens, the status should change to 'Average' and when closed it should show 'Hold'.

5. For the next batch, take a sample. Using the scoop, collect at least 10 sample increments from the flow to yield a bulk sample of at least 5kg[1] of material in the container. The material MUST be collected at a position close to the sensor and therefore the sensor reading relates to the particular batch of material passing the sensor.

6. Return to the computer and record the 'Average Unscaled' output, which should show the 'Hold' status

7. Mix the collection of sample increments and remove a representative sub-sample of at least 10 smaller increments to yield approximately 1 kg. Dry it thoroughly and calculate the moisture content using the moisture calculator. *Take care not to lose any of the samples during the drying process.* A good test to ensure the material is thoroughly dry is to stir it around to distribute the moisture and reheat.

[1] Standards for testing aggregates recommend that for representative sampling, at least 20kg of bulk material is requires (0-4mm material)

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Finding the calibration coefficients

7. Mix the collection of sample increments and remove a representative sub-sample of at least 10 smaller increments to yield approximately 1 kg. Dry it thoroughly and calculate the moisture content using the moisture calculator. *Take care not to lose any of the samples during the drying process.* A good test to ensure the material is thoroughly dry is to stir it around to distribute the moisture and reheat.

8. Repeat step 7 for another 1kg representative sub-sample. If the moisture differs by more than 0.3%[2], then one of the samples was not dried out completely and the test has to be restarted.

9. Record the average moisture of the two samples in the calibration table. This 'Moisture' and 'Unscaled' value make up one calibration point. Tick this point to include the values in the calibration.

10. Repeat steps 5 – 9 for additional calibration points. Choose a different time of day or different time of the year to ensure a wide range of moistures are samples.

A good calibration is one where the calibration points cover the complete working moisture range of the material, and all points lie on, or near to, a straight line. If any calibration points are suspected to be wrong, then they can be excluded from calibration by deselecting their corresponding tick box. It is generally recommended that a spread of at least 3% will give the best results.

[2] Standards for testing aggregates recommend that for representative sampling, the difference in moisture should be no greater than 0.1%

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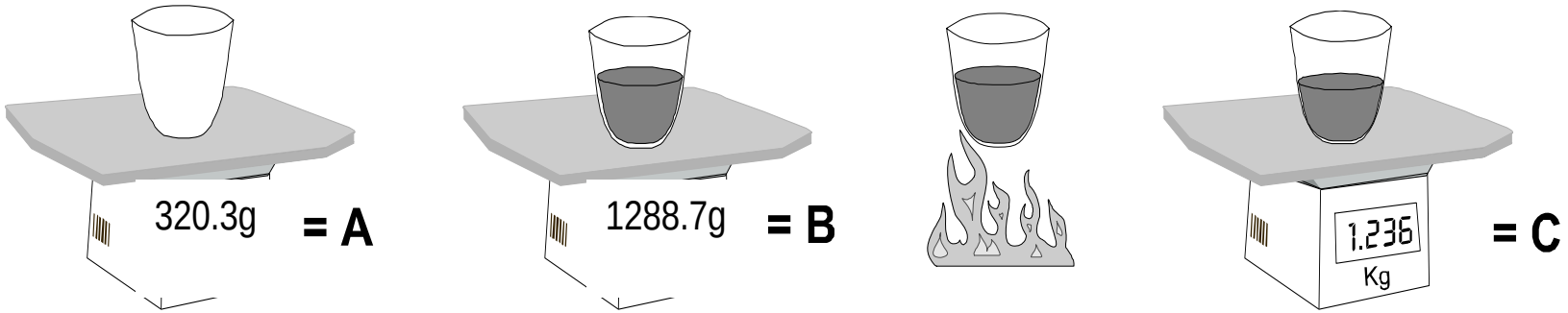
Calculating moisture content



Mass of wet material – Mass of dry material = Mass of water in material

$$\text{Moisture\%} = \frac{\text{Water in material}}{\text{Dry weight of material}} \text{ x } 100\% = \frac{\text{Wet - Dry}}{\text{Dry}} \text{ x } 100\%$$

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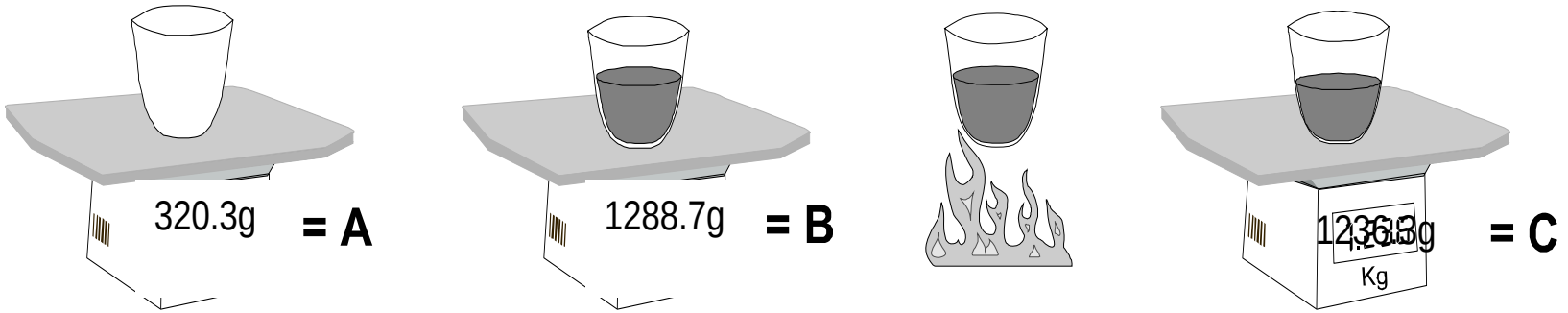
Calculating moisture content



$$\text{Moisture content} = \frac{1288.7\text{g} - 1236.3\text{g}}{1236.2\text{g} - 320.3\text{g}} \times 100\% = 5.7\%$$

Note that calculations are based on dry weights

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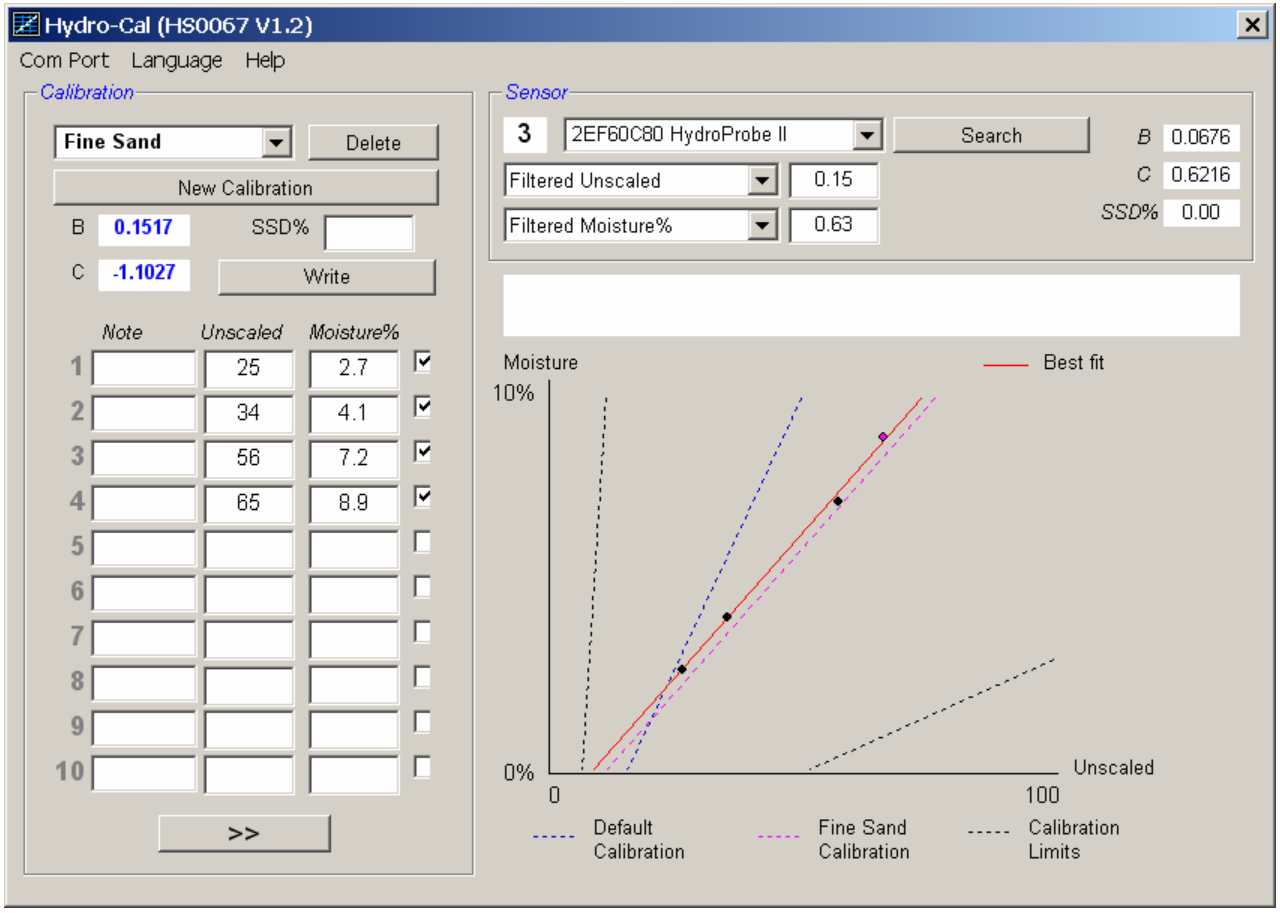
Hydro-Com/Hydro-Cal calibration software



Hydronix provide dedicated software for sensor calibration. This may be used if the sensor is configured to output a moisture value as opposed to an unscaled value. An unscaled value would be calibrated to a moisture value in the control system.

For detailed sensor configuration and installation information please refer to the Hydro-Com software user guide.

You may install the software on to a PC without a sensor attached and view most of the available functions.

The Hydro-Probe II user guide also describes configuration and calibration in detail.

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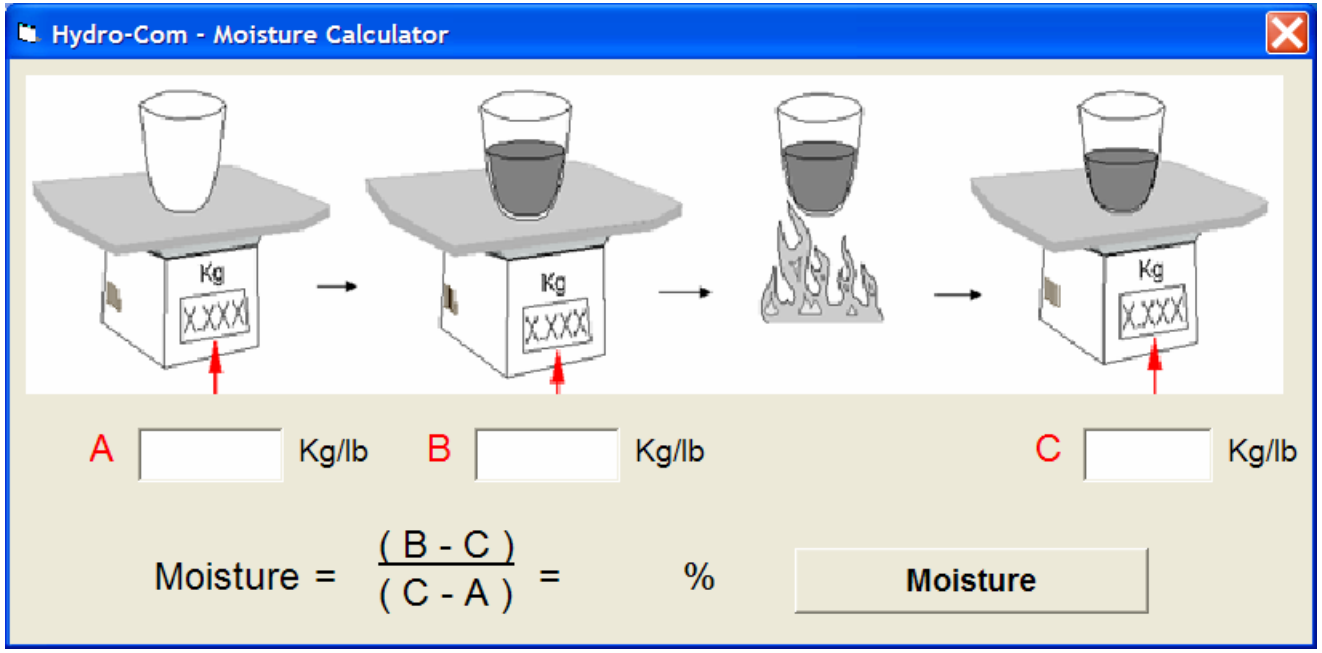
Calculating moisture content

The moisture calculation is simplified for you by the Hydro-Com or Hydro-Cal software. Calculations are based on dry weights.



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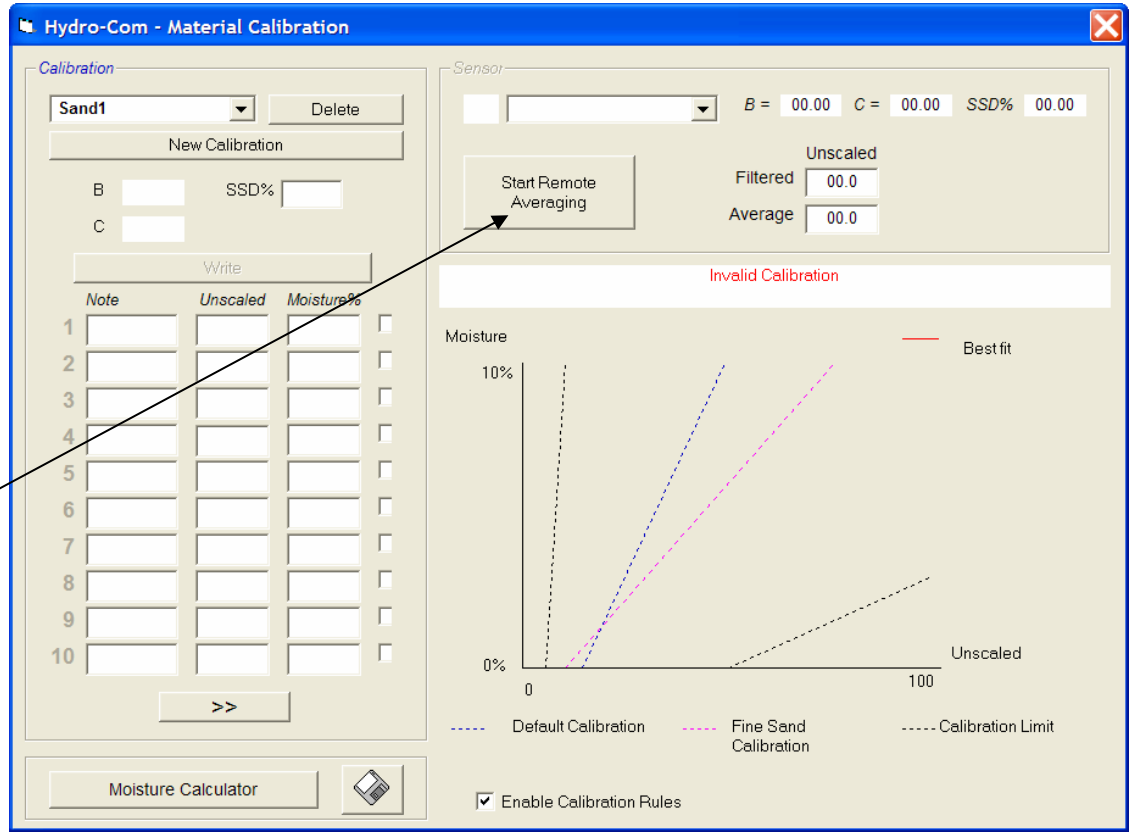
Taking samples



1
Start the flow and begin the sensor averaging.

Begin to collect samples, the use of an extending tool is recommended (unlike above).

If the sensor is configured with one of the digital inputs set to Average/Hold the averaging will begin automatically. If the sensor requires manually switching to averaging mode click the ‘Start Remote Averaging ’button in the calibration window.

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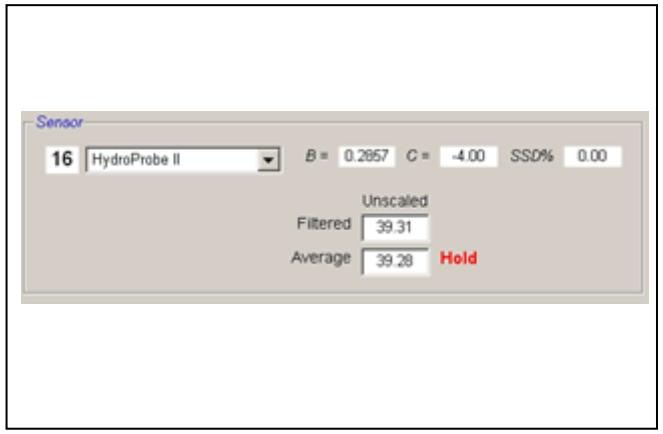
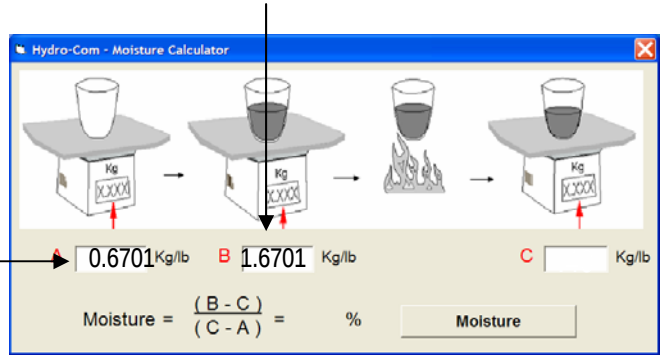
Taking samples



2 Stop the averaging and return to the control room and record the average unscaled reading. The figure shown will be held until the next batch.

3 Mix the samples, remove approximately 1kg, and weigh.

Weight of empty container



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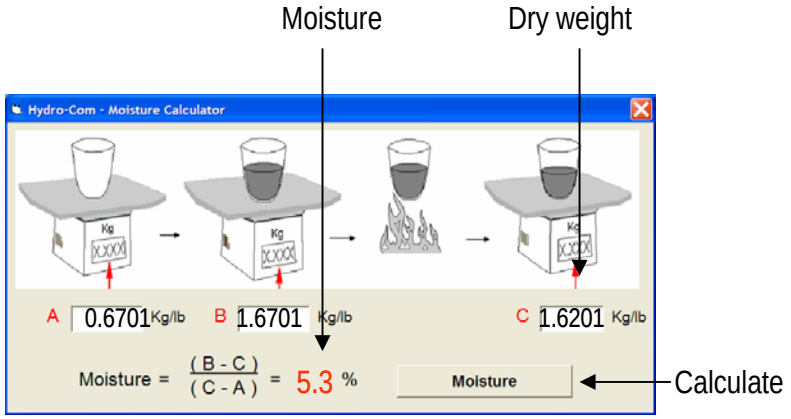
Taking samples

4 Dry the 1kg sample.

5 Re-weigh to ensure that there has been no change, i.e. material is in oven dried condition

6 Continue to dry for one minute to ensure that the material is completely dry.

If the weight has not changed then the material can be considered to be completely dry. Record the dry weight and calculate the moisture.



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Sample validation

Question:

How do you know if your moisture sample and calibration point is accurate?

Answer:

By repeating the drying test with another 1kg sub-sample.

If the results differ by more than 0.3%[1] then it can be assumed that there are errors in the measurements or procedure.

If there are errors it is recommended to begin the calibration procedure again with a new batch.

There are a number of ways in which errors may be introduced into the procedure, the most common are illustrated later in the 'Points to Consider' section of this presentation.

[1] For practical purposes Hydronix recommend 0.3%, applicable standards may differ.

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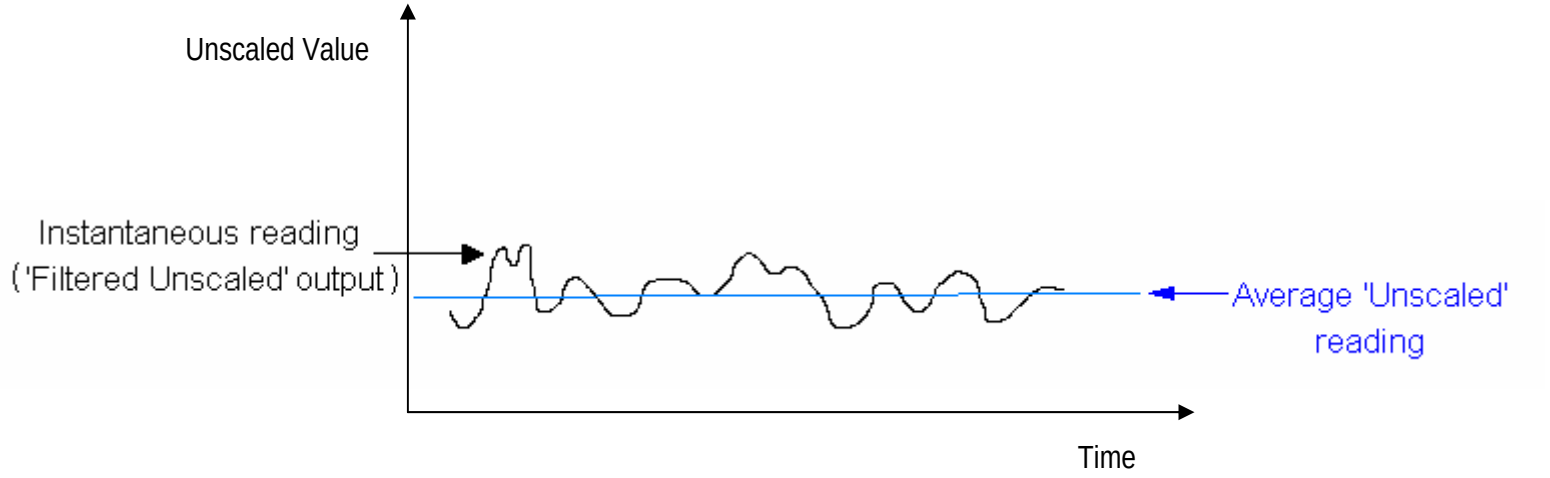
Collecting data

AVERAGE the readings during sampling. A changing signal makes it difficult to take a representative reading.



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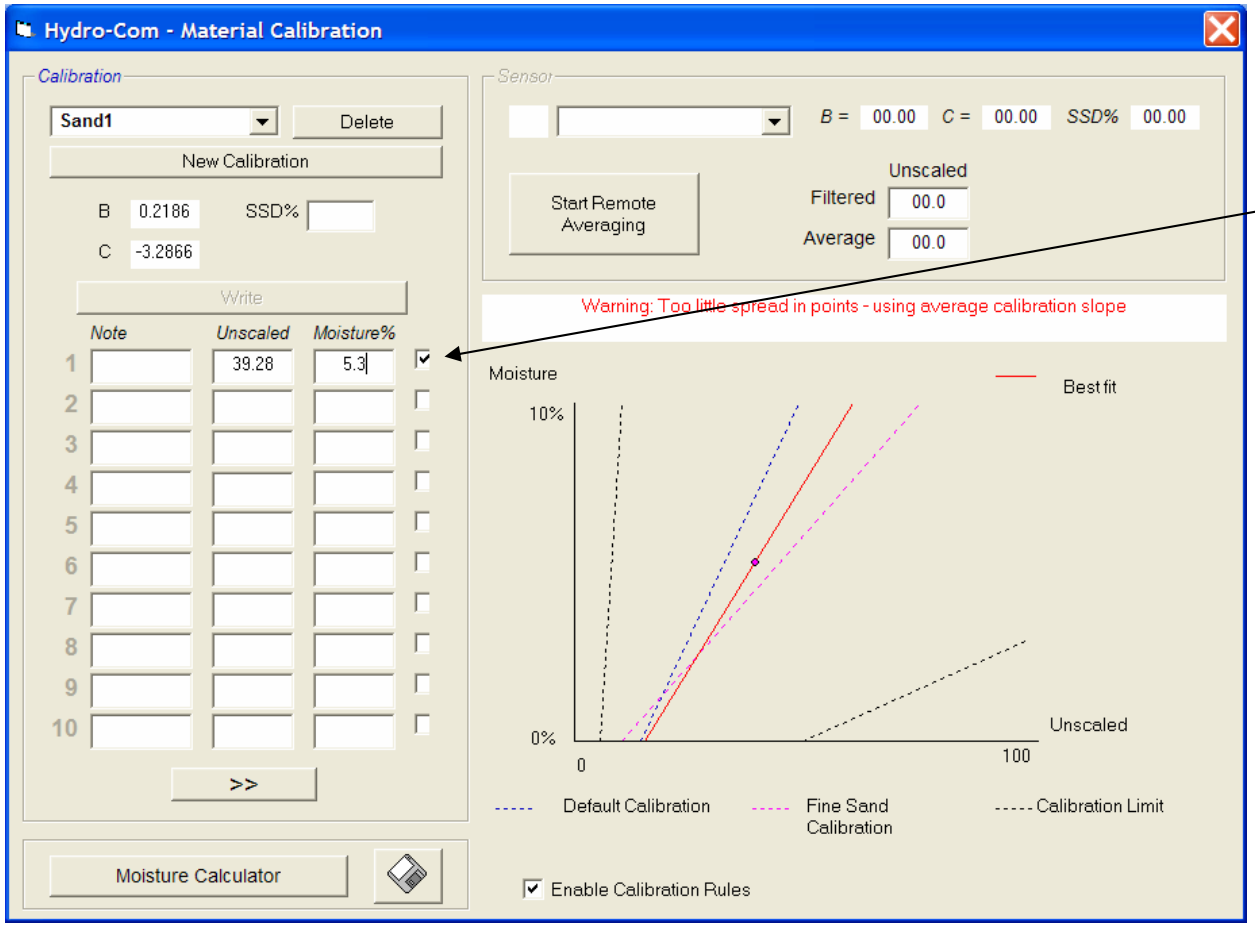
Entering data



Enter the data in to the calibration page and 'tick' to include this point in the calibration calculation.

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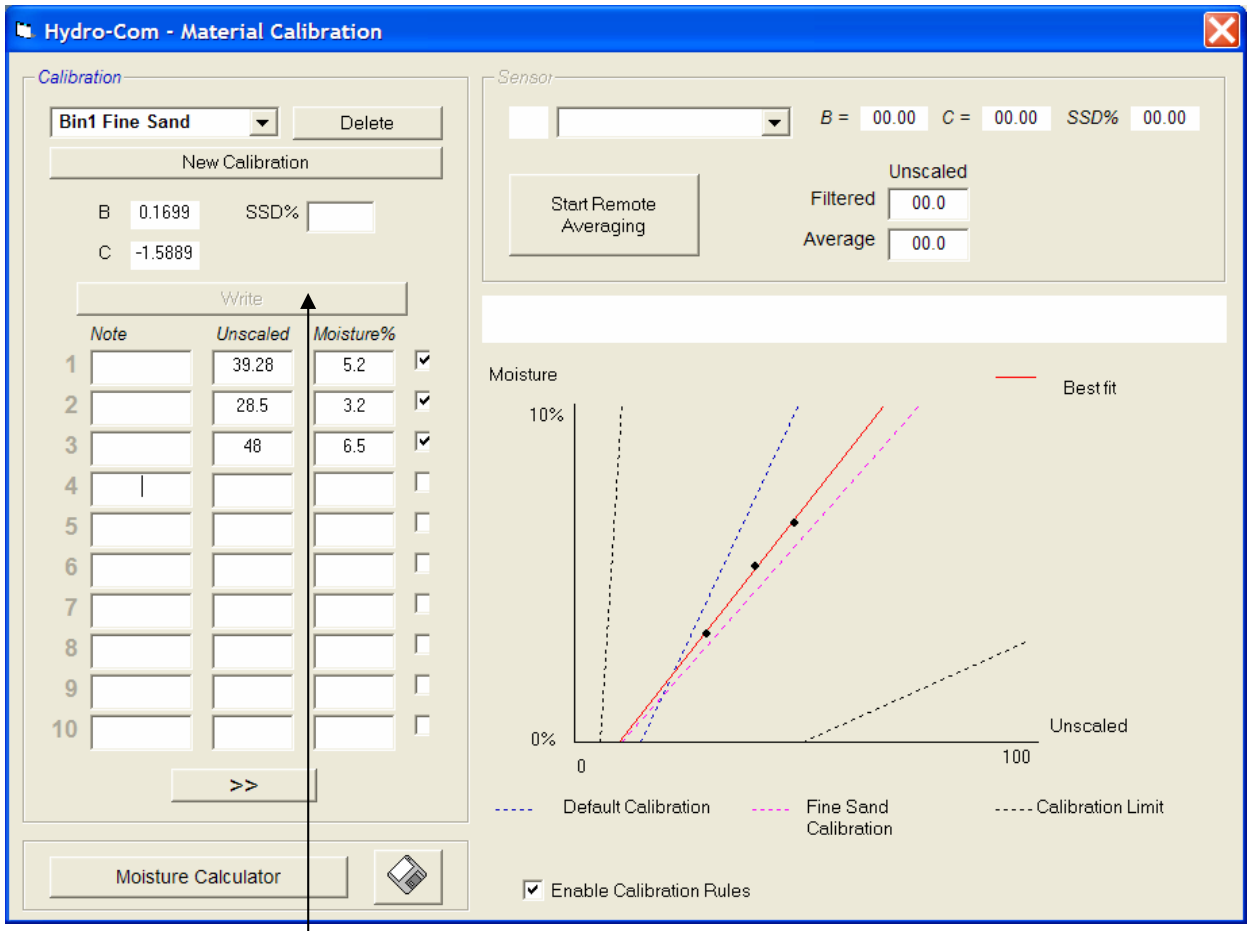
Entering data



Once sufficient data is entered click the 'write' button to update the sensor with the new material calibration.

Although it is possible to enter an exact calibration using only 2 points it is recommended that more points are taken and a linear regression used to determine the line of best fit. This is calculated automatically within the Hydronix software. Simply 'tick' all the points that you wish to include in the calculation.

If calibrating to moisture within a control system you may be limited to the use of only two calibration points. If this is the case, it is recommend that a number of samples are taken over the working moisture range and that a linear regression is calculated in a similar manner. Hydronix can supply an Excel spreadsheet to aid this calculation, contact, support@hydronix.com.

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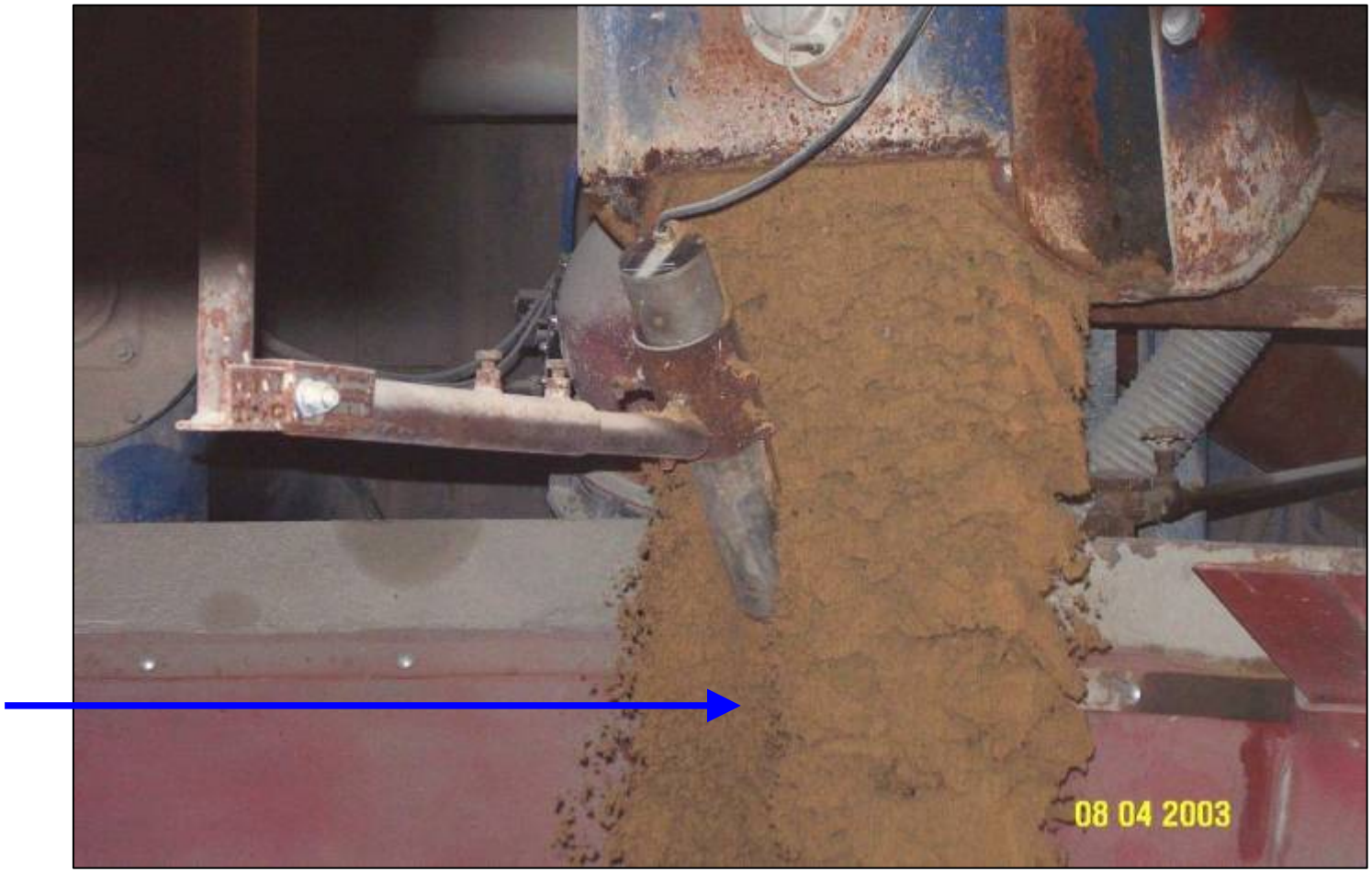
Taking samples

Bin/Hopper Application

Sample increments are taken from beneath sensor.



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Taking samples

Conveyor Application

Sample increments should be taken during averaging.

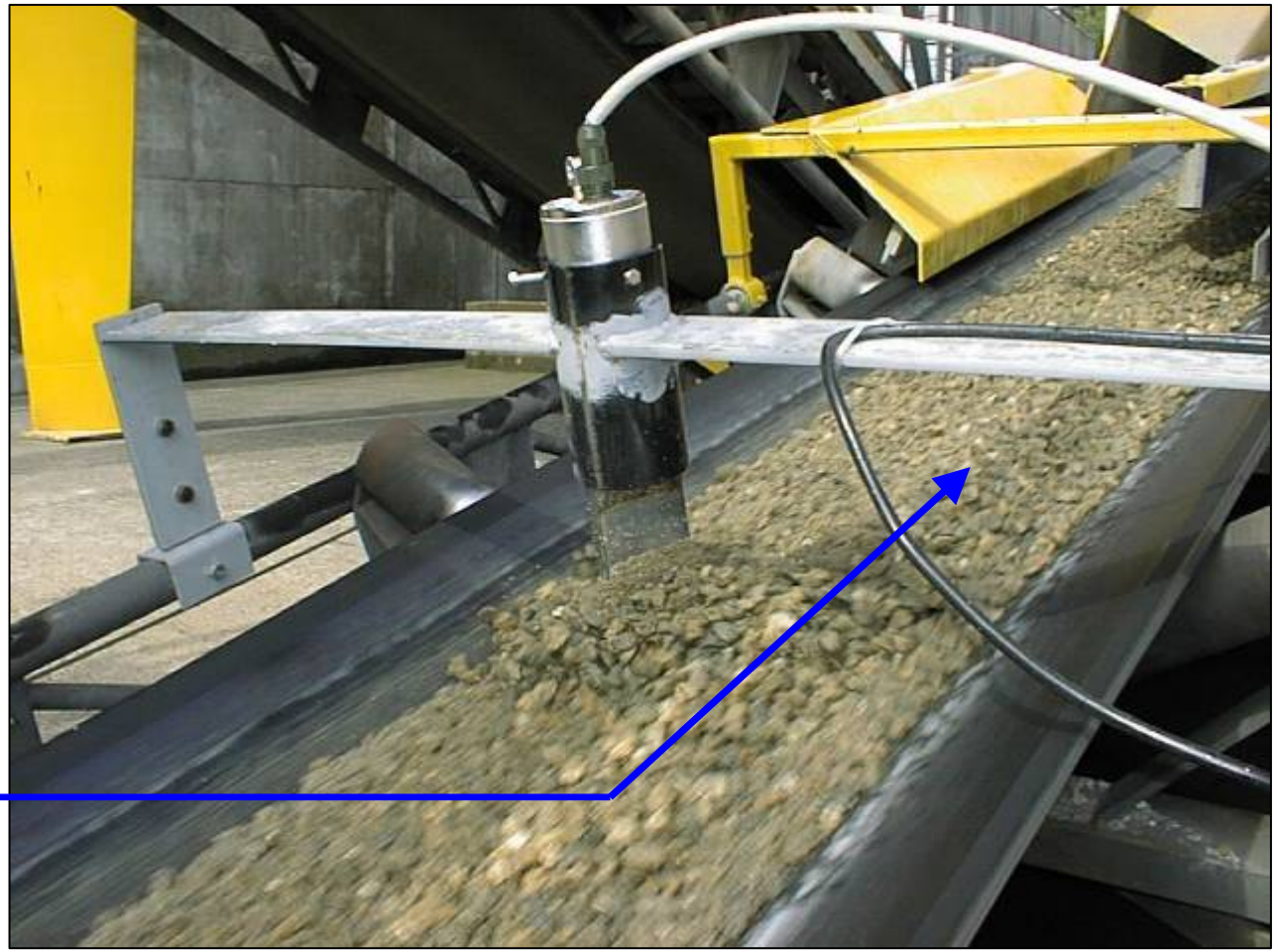
A common **mistake** is to :-

1/ average the unscaled readings,

2/ stop the belt to obtain the average unscaled value.

3/ Collect a **static** sample of material from the belt, possibly from in front of the sensor i.e. material that has not even been included in the average figure.

Samples should be taken from the **moving** material that has passed over the sensor faceplate during averaging.



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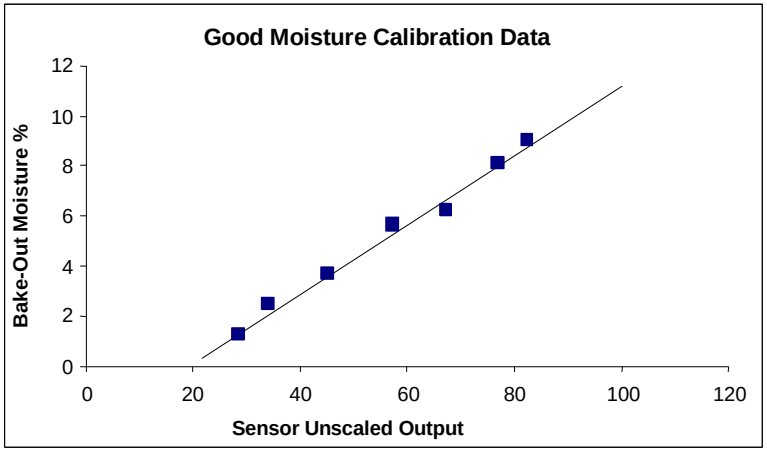
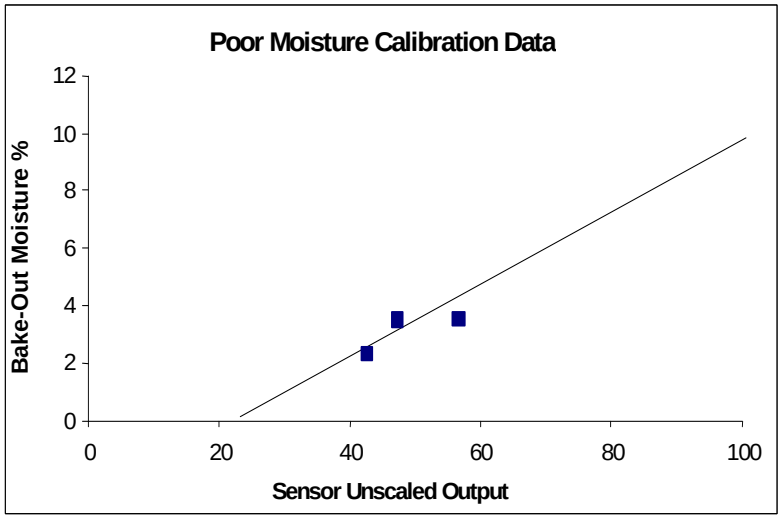
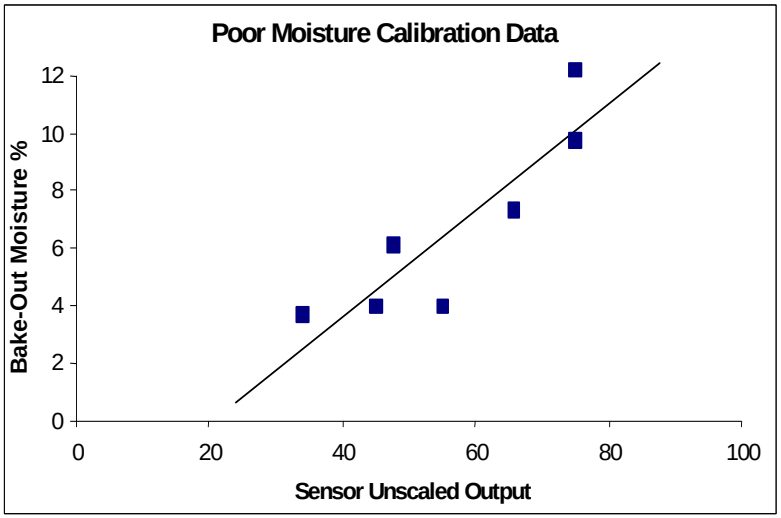
Calibration data – Good or bad?

- A good spread is essential (2-3%)
- Representative sampling
- Accurate moisture content determination







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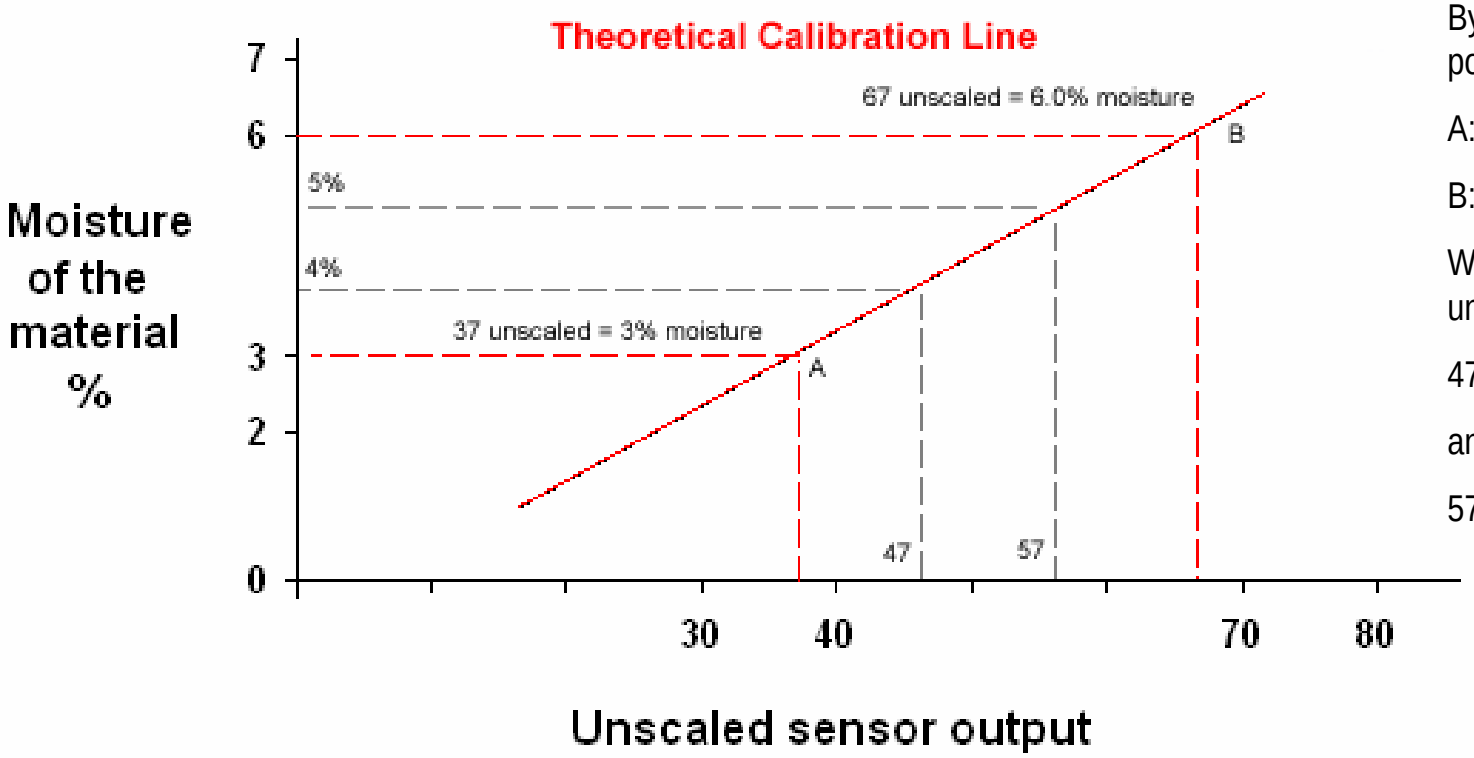
Possible error

The Theoretical Calibration Line

Every material has a theoretically perfect calibration line. By calibrating the senor we are trying to identify this perfect line. If correctly calibrated with 2 points (A and B below) it is possible to determine any moisture value along the line from any unscaled value measured by the sensor.



By calibrating using the points A and B :-

A: 37 unscaled = 3%

B: 67 unscaled = 6%

We can calculate that an unscaled reading of :-

47 is equivalent to 4%

and

57 is equivalent to 5%

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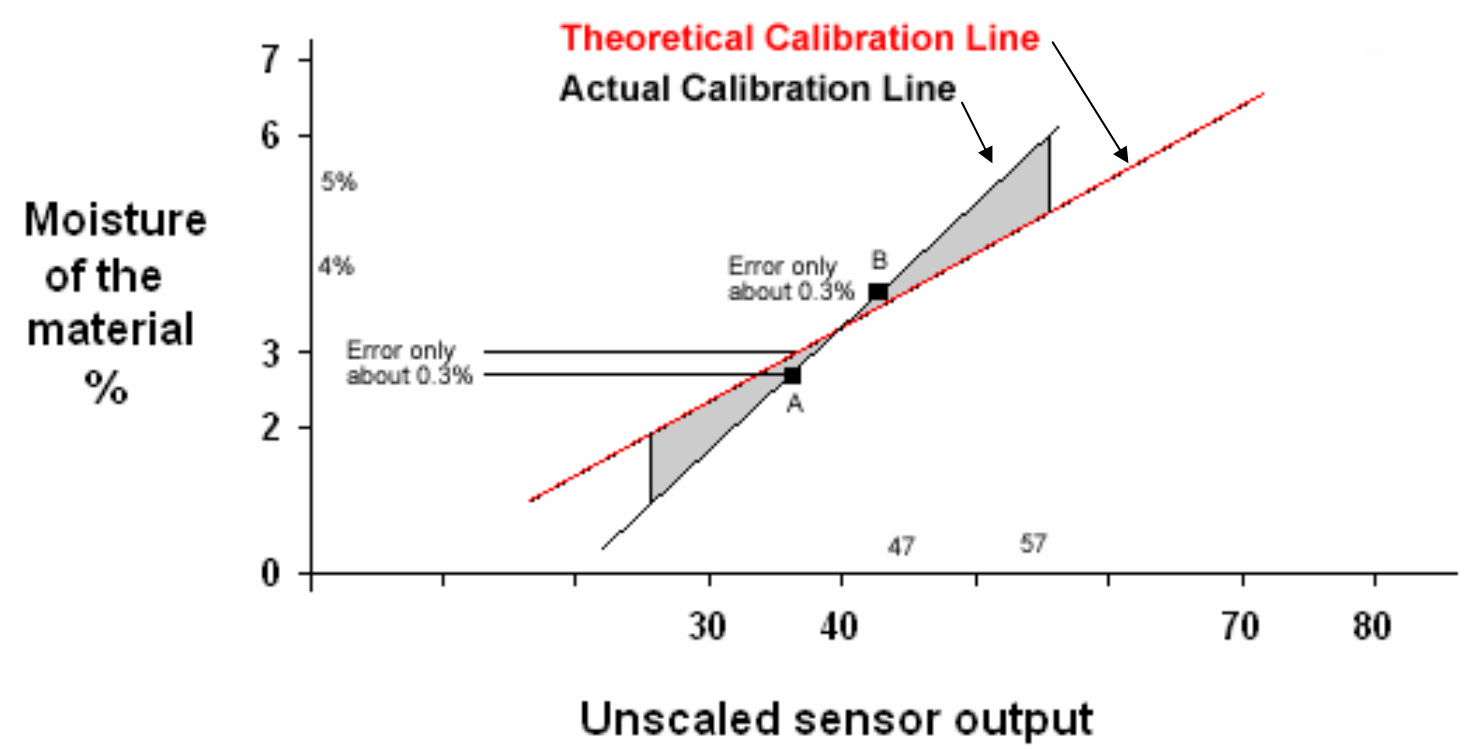
Possible error

Not enough spread

It is recommended that calibration points are taken over the full working moisture range of the material. If points are taken too close together the actual calibration line calculated may not lie on the on top of the theoretically correct line as shown below.

A small calibration error such as 0.3% from two points that are too close together will be magnified as the working moisture range widens.



If the working range drops:-

From 2.5 to 4.0%

To 1.0 to 3.5%

this may result in an error of approximately 1% moisture.

1% in $1m^3$ of concrete is approximately 20 litres of water.

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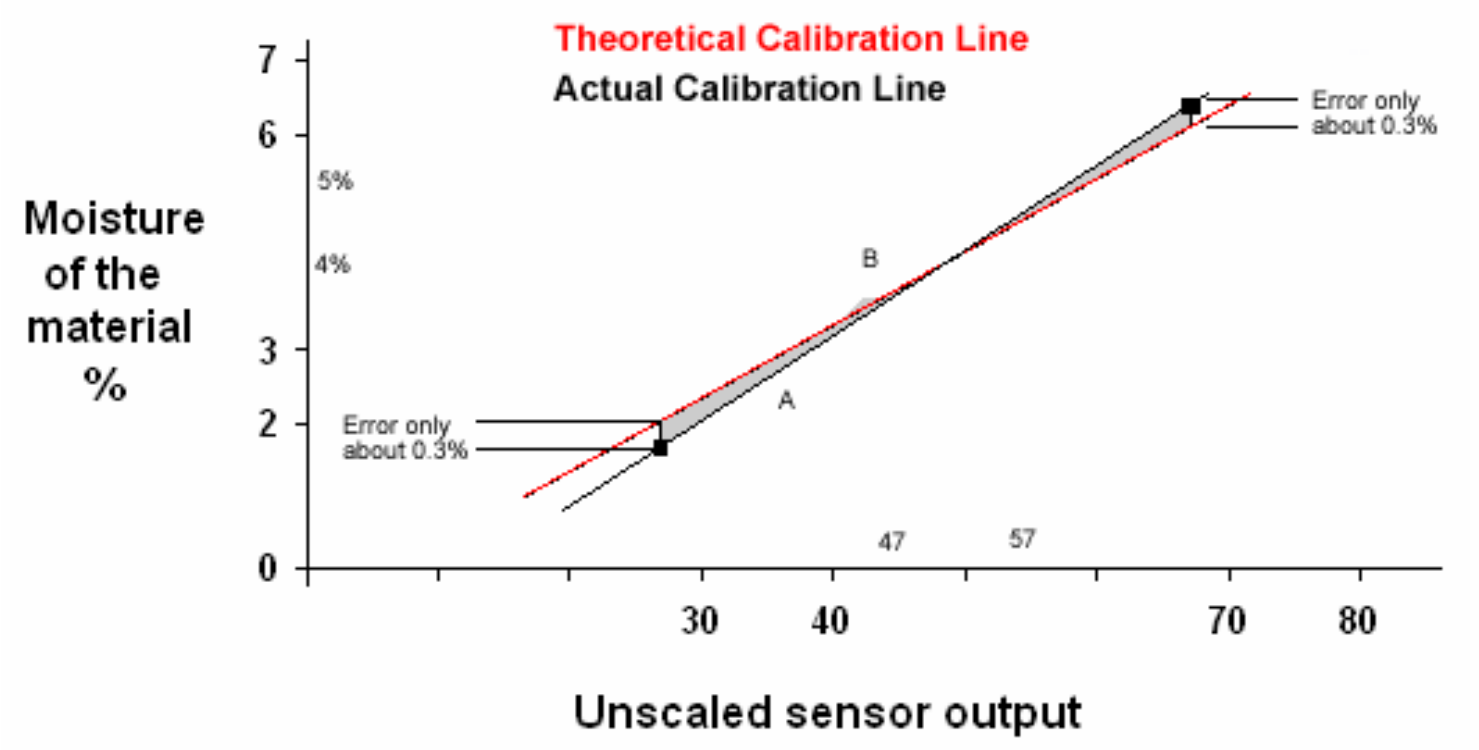
Possible Error

Good spread

With two points taken over a much wider moisture range the adverse effects of the same 0.3% error are dramatically reduced.



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Calibration - Quick start procedure

It is recommended that at least two points are used when calibrating the sensors although it is possible to use a ‘quick-start’ calibration routine which requires only one-point.

This will give an approximation of the final calibration and should be updated with more precise calibration data when available.

The one-point technique is automated using the Hydro-Com or Hydro-Cal software.

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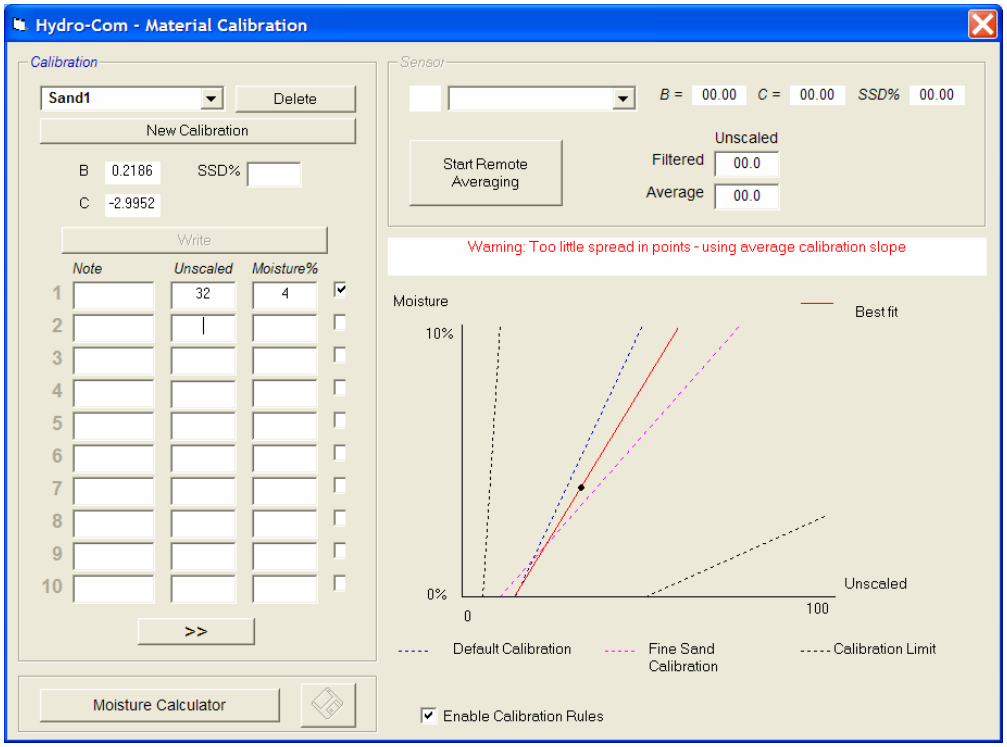
Quick Start or One-Point calibration

Because the error is minimal whenever the working range is narrow, a one-point calibration may be initially used to obtain a close approximation to the final calibration. This should be considered as a temporary measure and further calibration points should be taken as the moisture range widens.

Systems that purely rely on a one-point calibration, i.e. using a fixed gradient, will not be able to operate accurately over wide moisture ranges.



The red text indicates a WARNING of too few calibration points or not enough spread.

If the sensor is internally calibrated to output a moisture%, the Hydro-Com software automates the one-point calibration calculation. This is calculated using a known gradient that lies between 'fine' and 'coarse' sand.

The Hydro-Probe II user guide details this further and gives advice to enable a similar procedure to be made available in 3rd party control systems. This would be applicable if the sensor is calibrated to output an unscaled value that is then calibrated to moisture within the control system.

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Points to consider and common errors

- Ensure material is flowing with no build-up.
- Take samples of material where the sensor is located.
- Ensure the ‘Unscaled’ reading pertains to the collected sample.
- AVERAGE the readings during sampling. A changing signal makes it difficult to take a representative reading.
- Ensure that the weigh scales are accurate to +/- 0.1g
- Calibrate over complete working range of material, i.e. if sand ranges from 3%→9% calibrating between 4-5% is not sufficient !
- Take a large bulk sample of at least 5kg with 10 increments.
- Ensure that each drying test uses a representative sub-sample of at least 1kg.
- Start again if sub-samples give moisture results that differ by more than 0.3% moisture.
- Ensure that the ‘Average/Hold Delay’ (exclusion time) is set appropriately for the application. This ensures that the sensor measures only flowing material. The default setting is 0.5 seconds, see the Hydro-Com user guide for more details.

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~ end~