

Engineering Note

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Title:	Use of Brine solutions for Sensor Calibration.
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Summary:	To avoid possible interferences due to reflections, the use of a 0.5% brine solution for probe water calibrations is described & explained. It is expected that this will simplify the calibration procedure and improve the interchangeability of sensors.

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I – Summary

The resonant frequencies of all Hydronix digital sensors are measured in air and water. These values are used to normalise sensor response and eliminate the effects of the tolerances encountered in the manufacturing process, ensuring all sensors have an identical response. However in water, reflections from the water/air surfaces can cause errors in the recorded values resulting in erroneous calibrations and spoiling the interchangeability of sensors. The only way this can be overcome is to use an infinitely large water bath so that reflections occur so far from the sensor that they do not interfere with sensor reading. This is impractical and is not done.

However if instead of pure water, a solution of 0.5% by weight NaCl (table salt) is used, a suitable calibration can be performed with the sensor in the centre of a 20L bucket containing just 15L of solution.

This method of calibration is practical, stable and repeatable and should be used as the standard method.

II – Technical Background

As part of the factory calibration procedure, the resonant frequency of every Hydronix digital probe is measured in an air bath and in a water bath. These two frequencies are used to convert the frequencies measured by the sensor into unscaled units (Air frequency = 0 unscaled, Water frequency = 100 unscaled). By using unscaled units it is expected that the effects of the various manufacturing tolerances (mechanical & electronic) are eliminated and that under identical conditions (material, temperature, flow regime etc.) all probes will give the same unscaled reading. In this manner a calibration between unscaled units and sample

moisture will be applicable to any properly calibrated sensor, permitting sensors to be swapped out if one is damaged without requiring re-calibration.

This procedure presupposes that the air & water calibrations are performed properly. The air calibration is fairly simple and results are repeatable providing that a few basic variables are controlled (electronics must be warmed up & stable, air temp = 20°C +/- 1°C, no reflecting surfaces within ~ 50 cm of sensor face.) However the water calibration is more difficult.

In order to measure the water resonance, the sensor being calibrated must be placed in a container of water. Unfortunately the size and shape of the container, as well as the location of the sensor within the container, can all affect the measured reading. As an example, with a Hydroprobe 2 sensor in the centre of a 20 L bucket containing 15L water (approx 15 cm water depth), the reading was 97.12 unscaled. At one side of the bucket and looking across the diameter (23 cm water) the sensor read 98.36 and in the same position but looking away from the centre (93cm water depth) it read 88.34.

The reason for these differences is that the microwaves emitted by the sensor get reflected when they hit an air/water interface (or water/plastic interface or water/metal interface). These reflected waves get picked up by the sensor and so affect the measured value. As an example, Figure 1 shows the unscaled readings obtained from an HM05 mounted in the bottom of a 20L bucket as water was slowly siphoned into it.

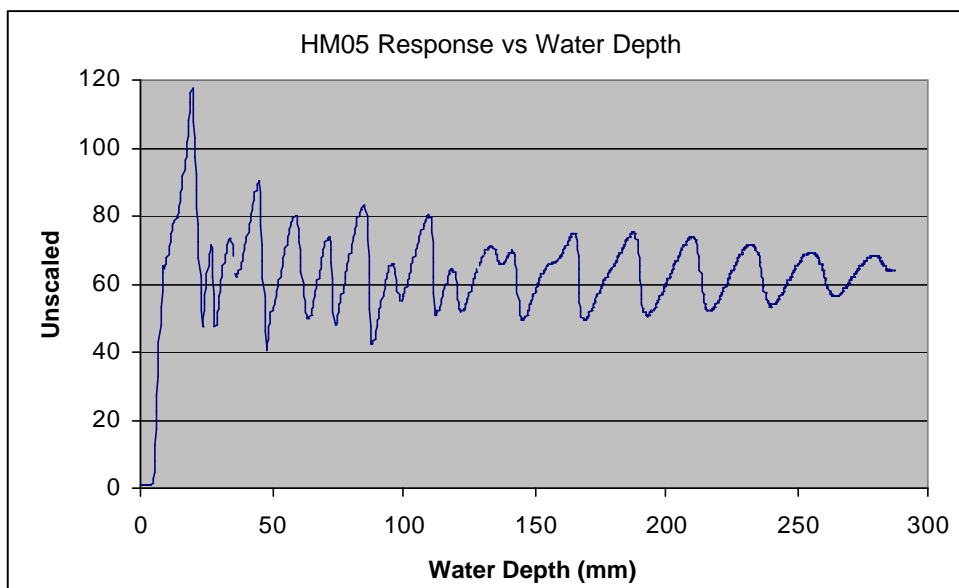


Figure 1 – Response of HM05 to Water Depth

As the depth of water increased, the unscaled reading oscillated with a slowly diminishing amplitude. These oscillations die away very slowly and it is apparent that even with a sensible depth of water (say 250 mm) the recorded unscaled reading could vary from ~ 55 unscaled units to ~ 70 unscaled units, dependent upon the exact water depth. This could clearly have a significant effect upon the

uniformity of sensor calibrations. To minimise this effect, the current production procedure requires water calibrations to be done in a water bath > 500 mm long, which is assumed to be effectively infinitely long so that no reflections arrive back at the sensor. Such large baths are not always available and thus the calibration may not always be done properly (except when Pascal Scientific do it, since they always do everything properly).

The only way to stop this effect and achieve consistent calibration curves is to ensure that no reflections are detected by the sensor. The fraction of the microwaves reflected at any boundary depends upon the geometry involved and the dielectric constants of the two materials forming the interface. Nothing can be done about the latter, and little can be done about the former without requiring a special calibration cell. Also it is not easy to see how the sensor can be made to discriminate against unwanted reflected waves. Fortunately there is a relatively simple way of reducing the size of the reflections arriving back at the sensor.

The dielectric properties of a material are characterised by two parameters; the dielectric constant (which is the parameter that ensures that the sensor resonant frequency will change with moisture content) and the dielectric loss factor. The loss factor determines how quickly the microwave energy is attenuated as it travels through a material. One parameter that strongly influences the dielectric loss is the electrical conductivity of the material. Materials with high electrical conductivities (e.g. metals) have high dielectric loss. Ionic solutions can also have high electrical conductivities and hence high dielectric losses. Hence by making the water used for calibration slightly conductive (e.g. by adding a small amount of table salt) the loss factor is greatly increased and the reflected waves arriving back at the sensor are significantly reduced in amplitude. Figure 2 shows how, when the experiment of Figure 1 is repeated using weak brine solutions (0.5, 1.0 and 2% NaCl) instead of water, the reflections detected by the sensor are significantly reduced.

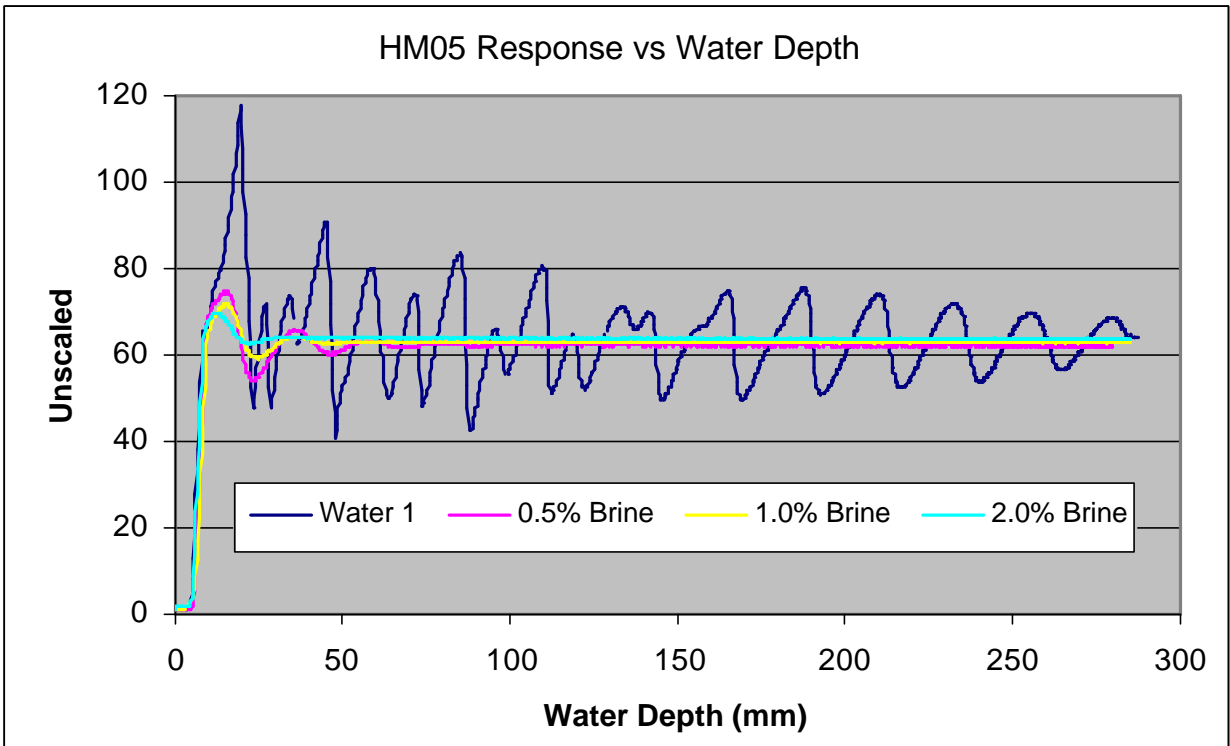


Fig 2: The effect of NaCl solutions on Reflections.

From Figure 2 it is apparent that in 0.5% brine, the effect of reflections is negligible after ~ 75 mm, and that in 1% and 2% brine the reflections die away even more quickly (~ 40 mm and ~ 25 mm respectively).

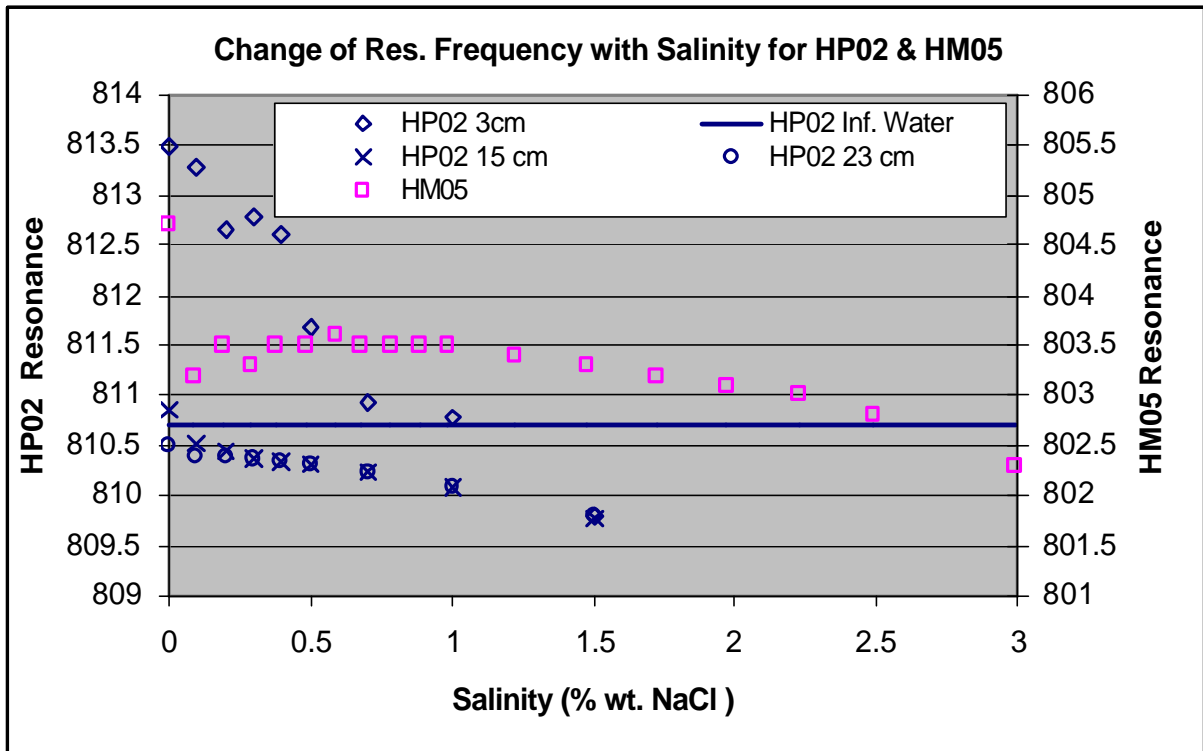


Figure 3: Effect of salinity upon Resonant Frequency for HP02 & HM05

Figure 3 shows the effect of salinity of the brine upon the resonant frequency for an HM05 and a HP02.

The figure shows 3 sets of data for the HP02, each set representing a different depth of fluid. In pure water the presence of reflections means that the three curves start off at different frequencies. However by the time the salinity has increased to 0.3% the response with 15 cm of fluid (blue crosses) has become identical to the response with 23 cm (blue circles). Eventually, at 1.5% salinity, the 3cm response (blue diamonds) is identical to the other two responses. Also shown on the figure is a solid line representing the frequency measured using the HP02 in a large (~1.4m) tank of water. The frequency obtained under these conditions was ~ 810.7 MHz.

The inference from this data is that if 0.3% brine is used, for example, providing the sensor sees at least 15cm of fluid, then the sensor response will be identical to that obtained in an infinitely large container of brine. If the salinity is 1.5% then only a few cm of fluid are needed to look like an infinitely large container of brine. Hence valid, repeatable, reflection free results can be obtained by placing a sensor in the middle of a 30 cm bucket filled with 0.5% brine.

Using this 0.5% brine, a 'Low' calibration of ~ 810.3 would be obtained on the HP02 used for these tests, which is 0.4 MHz lower than the infinite water bath result. Hence if 0.5% brine was used for calibration instead of an infinite water bath, the unscaled units will be slightly different (a given material will give a brine unscaled unit which is ~ 1.37% smaller than the water unscaled units). In practice this discrepancy is likely to be insignificant compared to the experimental scatter and any difficulty this causes is likely to be more than countered by the much superior repeatability of the brine calibration.

Finally Figure 3 also shows the results obtained using an HM05 mounted at the bottom of a 20L bucket and pointing upwards. The results are qualitatively similar to the HP02 results, in that initial scatter due to reflections dies away and appears negligible above ~ 0.5% salinity. Above 0.5% salinity the measured resonance decreases as it does in the HP02.

Hence while higher salinities permit the use of smaller calibration baths, these higher salinities have resonances further from the 'infinite water bath' calibration. The use of 0.5% salinity brine in a 20L bucket (ensuring 15-20cm of fluid in front of the sensor face) appears to be a reasonable compromise.