Engineering Note

Hydronix Limited, 70 Smithbrook Kilns, Cranleigh, Surrey GU6 8JJ England
☎ +44 (0)1483 271769 🖷 +44 (0)1483 276219

Title:	Multi-point method improves calibration in Hydro-Control IV
Document reference (DRC):	EN0019 issue 2
Last updated:	12/6/97
Products affected:	HC-IV Operator Terminal
Author:	R.E.B. Holland
Search keywords:	HC-IV, Firmware, Calibration, Regression
Summary:	Improvements to the calibration method used in the Hydro-Control IV allow the results of several mix cycles to be combined to produce better overall performance and an extended working range. This document describes the operational changes required to use these new facilities and should be read in conjunction with the Hydro-Control IV User Guide (HD0044 V1.1).

Introduction

The calibration method used in the Hydro-Control IV requires that the operator chooses an optimum mix from the mix log display. The results recorded by the Hydro-Control during this mix cycle are then transferred to the relevant recipe when the 'Water OK' button is pressed, thereby providing a template of the Hydro-Mix sensor response for future mixes.

This approach has the main advantage of being easy to use - the operator uses his/her judgement to identify a 'good' mix and simply identifies this to the system. However, in use there are a number of disadvantages to the approach as implemented in existing systems…

- The judgement of the operator is very subjective - he or she may identify a mix as 'acceptable' for production purposes whilst it may be far from 'optimum'. The effect of this is that instead of the Hydro-Control being calibrated to the optimum mix it may be calibrated to one end of an acceptable working range, requiring use of the 'water trim' facility to correct the error.
- In certain cases, the moisture content change effected during a mix cycle used for calibration may be very small - close to the minimum 1% limit imposed by the Hydro-Control IV. If the system is calibrated on such a small moisture change it is very unlikely that the dry reading from the sensor will maintain accuracy when the materials begin to dry out and require larger water additions. This is in part due to the uncertainties in recording the readings from the Hydro-Mix sensor at the end of dry and wet-mix phases which lead to extrapolation errors outside the moisture ranges encountered during the calibration mix.
- Very dry (less than 3%) or wet (more than 10%) materials may begin to show up non-linearities in the readings from the Hydro-Mix sensor itself. Whilst the calibration method currently used will result in control being maintained around the calibration point, the non-linearities mean that as the (dry-mix) materials move further away in moisture content from the calibration point the control will begin to lose accuracy.

The first two points can be addressed by employing a method which combines the results of several mix cycles. In this case, the operator is allowed to calibrate from more than one 'good' mix - up to 10 in fact - and these may include a wide range of initial moisture contents. It is still up to the operator to pay some regard to achieving a good 'spread' however - the system does not do this for him.

The third point is addressed in the system by allowing the option of a 'quadratic' curve to be fitted to the calibration data rather than a straight line. This can be used to give a better 'fit' to calibration data at the extreme dry or wet ends of the working range thereby extending the useful working moisture range of the Hydro-Control IV.

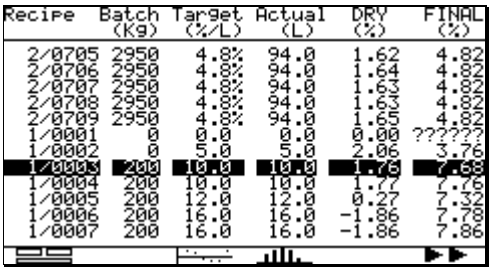
In implementing this new calibration regime, the ease-of-use aspect of calibration was still paramount in out thoughts and the basic method for calibrating the system is unchanged. However, some new features have been added to the operator interface to assist in calibrations involving multiple points and these are described in the following sections of this document.

Operational changes

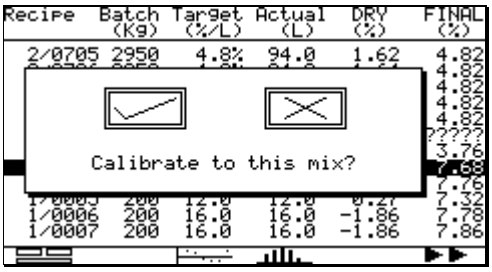
Choosing a mix cycle for calibration

This is performed in exactly the same way as in previous issues of firmware as the series of screen images below indicate.

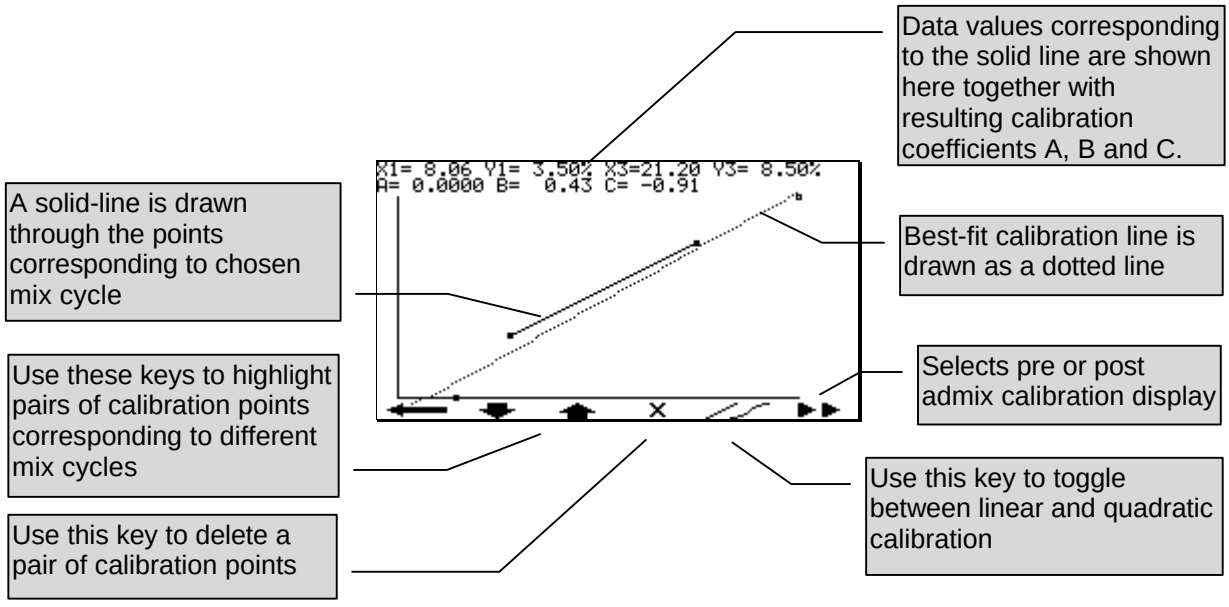
From the mix log, highlight the cycle required for calibration…



Press ✔ to select the mix (you may need to log in first). If the mix is suitable for calibration purposes (i.e. there have been no unusual occurrences during the cycle) the display will show…



Accept this pop-up and the first new feature of the firmware change will be displayed…



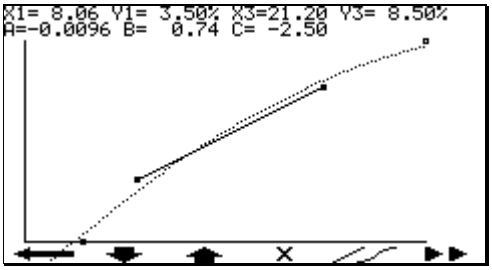
When you choose a mix cycle for calibration, the resulting pair of points will be indicated on the calibration graph with a solid line and the resulting best fit calibration line will be displayed as a dotted line.

The values A, B and C are the calibration coefficients which result from the data set given for either linear or quadratic functions. The calibration function is of the form…

$$Y = AX^2 + BX + C$$

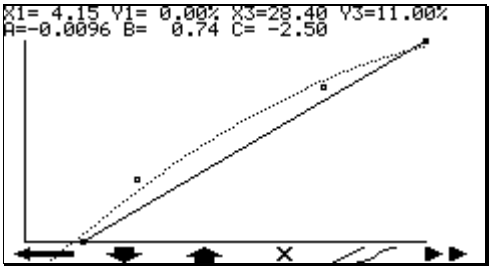
where Y is the moisture value in % and X is the corresponding unscaled input value. If the linear calibration function is chosen then coefficient A is always set to zero.

The display above indicates the best fit straight line (linear regression) for two pairs of points, that is two mix cycles. Choosing the quadratic function will give us instead…



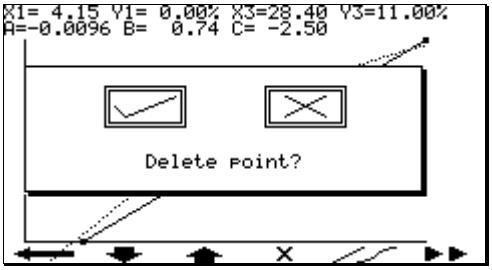
In this case, the 'best-fit' quadratic curve is drawn as a dotted line and you can see that the value of A is no longer zero. Clearly in this case the quadratic shows better agreement than the straight line function with the calibration points at low moisture contents whilst agreement at high moisture contents is similar.

The result of pressing the up or down arrow keys will be to move the solid line to a different pair of calibration points…

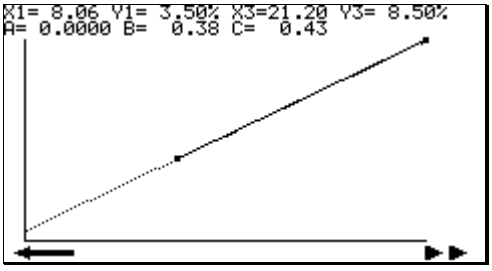


As you can see, the values on the top line have now changed to reflect the different set of data.

By default a recipe will contain a single set of calibration values. This default calibration will require changing to suit a particular situation and it is useful to delete the default values once a true reading has been obtained. The highlighted set can be deleted by pressing the **×** soft key…



Accepting the pop-up will cause the highlighted pair of points to be deleted…



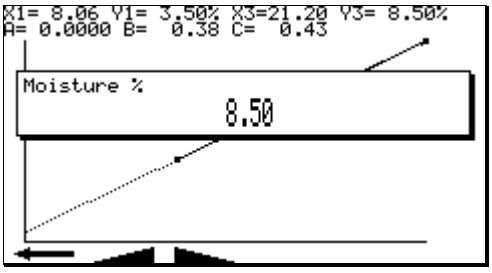
Since there is now only one pair of points, the unusable soft keys will also disappear from the display - it is not possible to fit a unique quadratic through two points and so this is no longer available. Note that the display will auto-scale the axes to suit the new data.

When you have finished and are happy that the new calibration data is acceptable, pressing the exit key will invoke an appropriate confirmation pop-up which you must accept to make the new calibration valid.

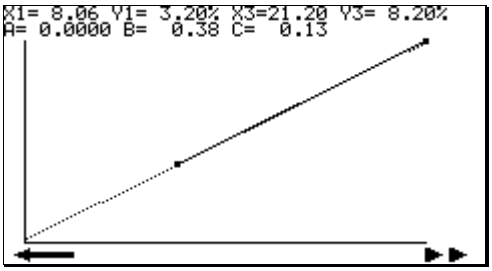
Adjusting final moisture values

When the operator presses the ‘Water OK’ key to choose a mix from the mix log, the wet end moisture value is set to the AUTO WATER % value which was stored in the recipe at the time the mix cycle occurred.

In the event that the results of a mix cycle are later analysed using a ‘bake-out’ test, existing firmware requires you to alter both the dry and wet calibration values stored in the recipe by the same amount. To avoid this manual calculation stage, in the new firmware only the wet value needs to be adjusted. For example, if the result of the mix cycle above were found to be 8.2% rather than 8.5%, then pressing the ‘menu’ key with the appropriate mix points highlighted will allow the value to be adjusted…



Entering the value 8.2% causes the associated dry and wet readings to be altered by a corresponding amount (both pre and post admix values are altered in this way)…

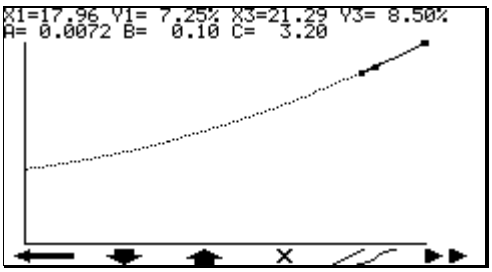


The result in this simple case is to cause a change in the offset (C) by 0.3% although in general A and B would also change.

Using the quadratic calibration function

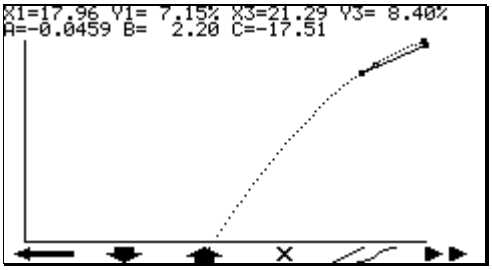
Care should be exercised when using the quadratic calibration function to make sure that it is indeed an improvement over the linear function.

When calibration data pairs are very close together, (i.e. there is little spread amongst the dry readings) then it is possible to view these as a single pair of points. However, the system will still try to fit a quadratic curve through them given chance. The danger here is that the value of the calibration coefficients will become extremely sensitive to small changes in data, as the following example shows…

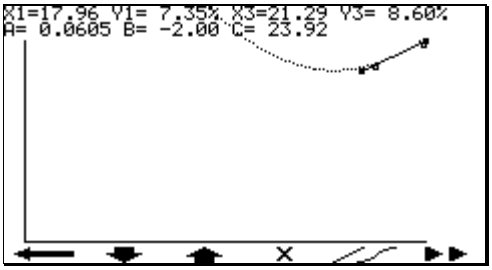


In this case, two calibration mixes have produced very similar results and the change in moisture content between dry and wet is close to 1%. The quadratic fit in this case looks quite reasonable.

However, our lab sample for the highlighted mix later returns a value of 8.4% instead of 8.5%. This is a tiny change in the final value (it would be very difficult to dry a sample of concrete to with 0.1% accuracy) but the change in the quadratic response is quite dramatic…

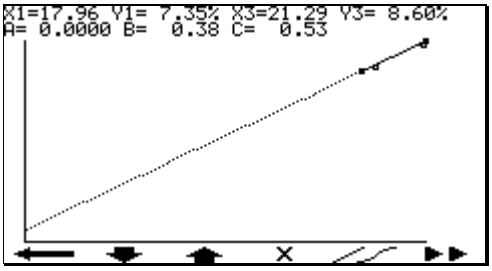


A similar deviation of 0.1% in the other direction gives us…



…which is even more undesirable!

The linear function in this case produces a much more sensible and believable result…



In general, the quadratic function should only be applied when you can achieve a reasonable distribution of dry mix readings - say over a minimum range of 4%, but you should always check the graphic display to see whether extrapolations beyond the calibration data points will be meaningful - clearly the third figure in this section indicates a system which initially has a negative slope, resulting in an increase in the amount of water added as the dry reading increases.

Accessing calibration data from the recipe menu

Earlier revisions of firmware allowed access to calibration data via the recipe menu. This latest revision implements similar features by introducing a calibration sub-menu in the recipe menu…

Selecting Calibration from this menu will invoke the graphical calibration display described earlier. As before, the supervisor pass-code is required.

Other changes

Hand water addition

Water added in hand mode during the dry mix phase is no longer taken into account in the water calculation although it is still measured. The actual water added value displayed is now reset at the end of the dry-mix phase. This allows the dry-mix moisture reading to be varied by the addition of hand water during the dry-mix period and permits a range of calibration mixes to be obtained and the performance of the system in automatic to be easily verified.

Serial port commands

Read/write recipe parameter command codes 17 through 22 will return or set the values for one calibration point only. No access is provided at this stage to the remaining nine calibration pairs.

Upgrading from earlier versions

Changes in recipe storage requirements

Sensor calibration data is stored within a recipe. Since more than one calibration point is now stored per recipe, the storage requirements for the recipe database have increased.

The implications of this as far as the user is concerned are that simply installing the new EPROM will lead to the loss of **all** data held within the Hydro-Control IV. It is therefore advisable that a back-up of this data is taken before upgrading the firmware and that this is restored after use. The recommended procedure is as follows if you wish to preserve all the existing data…

1. If the existing version of firmware is below 2.40, then upgrade to 2.40 first. Earlier versions do not support the backup/restore facility.
2. Use the Hydro-Control IV BACKUP utility to save the existing HC-IV database to disk.
3. Run the CONVERT utility to expand the recipe database to the correct size for the new software. This will preserve existing calibration data but will create room for the additional points.
4. Upgrade the HC-IV operator terminal firmware to 2.42. When power is applied, you will see a series of errors indicating that all the HC-IV database is being reset to default - accept all of these messages.
5. Use the Hydro-Control IV RESTORE utility to re-load the HC-IV database from the CONVERTed disk file.

Use of the HC-IV BACKUP and RESTORE utilities described above is described in EN0016. The CONVERT utility operates as follows…

Type…

convert <directory>

where <directory> is the path to the data which you created using the BACKUP utility.

Important: Updating the calibration coefficients

When you first restore the HC-IV database after upgrading the EPROMs, the calibration coefficients for every recipe will be set to zero. To force these values to be re-calculated, it will be necessary to use the following procedure **on every recipe which is being used.** If this is not done, the moisture display will always remain at 0.0% for that recipe and will lead to an erroneous water calculation.

1. Log on with recipe editing privileges.
2. View the recipe.
3. Select ‘calibration’ in the recipe. This will display the new graphic calibration display and will show the existing calibration points.
4. Press ‘exit’. This will calculate the calibration coefficients using the points on the graph.
5. Press ‘exit’ again and accept changes to the recipe.
6. Repeat for each recipe you are using.

It is anticipated that a future release of the utilities will correct this problem.

R.E.B. Holland

12/6/97