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# Automation of Target / Reference Values in Automated QC Checks

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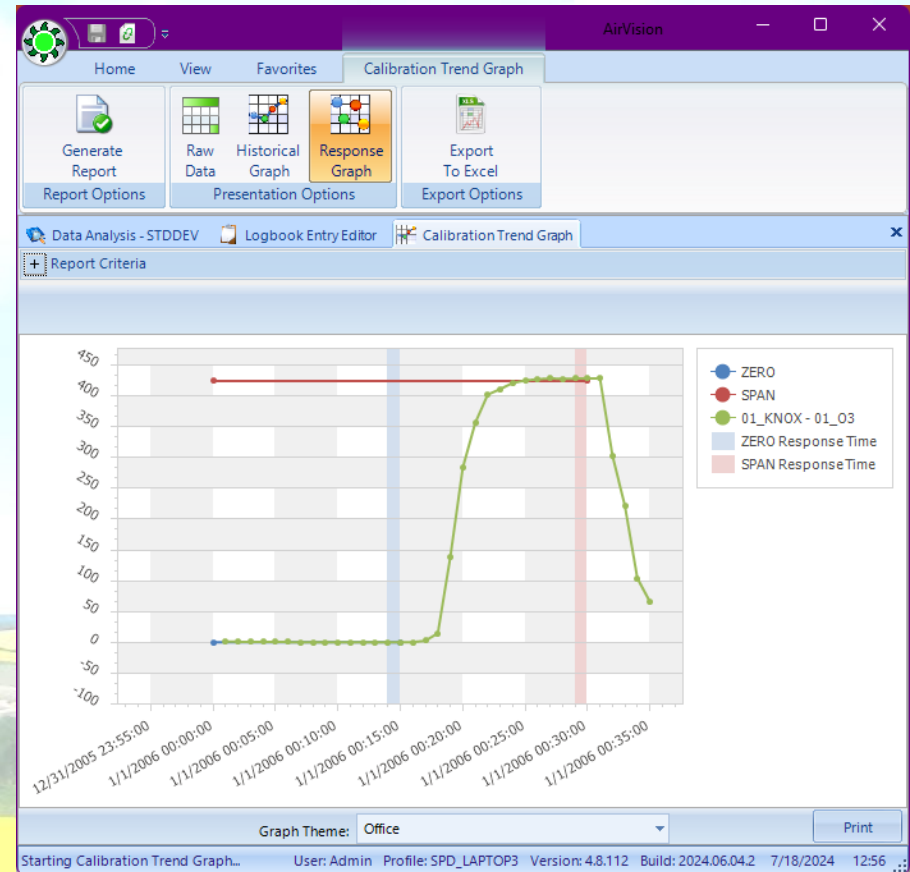
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# Why?

For many years, agencies would program a fixed target (expected) value into the calibrator, put the same number into the DAS, and that was good enough for most high level checks (e.g., ~ 400ppb for ozone, NO, etc)

Lower concentration precision checks and lower potential sensor ranges have challenged this older approach.

As we moved to digital connections to the calibrators, we gained the ability to access 'actual concentration' or flow rates of cal gas and diluent gases.



# Two Methodologies

1. If the calibrator offers an 'actual concentration' over its digital interface ,we can use that.
2. If the calibrator doesn't offer it, or we don't trust it, we can calculate using diluent and cal gas flows:

$$C_{actual} = (gas\ bottle\ conc) * (CGF) / (CGF+DAF+O3F)$$

*CGF = cal gas flow (from bottle)*

*DAF = dilution air low*

*O3F = O3 generator flow*

# Acquiring The Data

Method 1 for common dilution calibrators:

| Calibrator Brand        | Ethernet/Modbus?   | RS-232                                 |
|-------------------------|--|--|
| Teledyne T70x series    | Ozone only (Modbus)<br><br>Gas concentrations via <u>http</u> interface only | ACTCONC                                |
| Thermo 146i / iQ series | Yes  | 146i – gas conc<br>iQ – N/A            |
| Serinus                 | Yes  | N/A                                    |
| EnviroNics 6103         | Not available  | CONC OZONE ACTUAL?<br>CONC GAS ACTUAL? |



# Method 1

The DAS should have a way to set recording the target value in the calibration record. For AirVision / 8872, “math constants” are used as internal holding registers to record target values, and then to store them as the reference/expected values in the record.

*This can get tricky if calibrator digital interface is in ppm, but you report in ppb. “Scaling Factor” setting in the channel may need to be used to put calibrator parameter into correct units.*

The screenshot displays the AirVision software interface, specifically the 'Data Source Details' window. The window title is 'AirVision' and it has a menu bar with 'Home', 'View', 'Favorites', and 'Data Source Details'. The main content area is titled 'Data Source Details' and shows a tree view on the left with 'Calibrations' expanded to 'QC-O3'. The main panel shows a 'Sequence:QC-O3' with 'Phase(s)' selected. Below this is a table of phases and a table of phase channels.

| Phase Name | Phase Number | Duration Time | Response Time | Enabled                             | Status Pattern | Level |
|------------|--------------|---------------|---------------|-------------------------------------|----------------|-------|
| O3-PREC    | 1            | 10M           | 5M            | <input checked="" type="checkbox"/> | 29             | PREC  |
| PAUSE      | 2            | 1M            | 5S            | <input checked="" type="checkbox"/> | Select Lines   |       |
| O3-ZERO    | 3            | 10M           | 5M            | <input checked="" type="checkbox"/> | 28             | ZERO  |
| STANDBY    | 4            | 010S          | 005S          | <input checked="" type="checkbox"/> | 31             |       |

| Channel | Expected Value | Expected Value From Constant | Write Expected Value To Constant | Write Result To Constant | Store Calibration Results           | Error Method | Warning Drift Limit | Out of Control Limit |
|---------|----------------|------------------------------|----------------------------------|--------------------------|-------------------------------------|--------------|---------------------|----------------------|
| O3      |                | K16                          |                                  |                          | <input checked="" type="checkbox"/> | Difference   | 0                   | 0                    |
| O3CAL   | 0.06           |                              |                                  | K16                      | <input checked="" type="checkbox"/> | Difference   | 0                   | 0                    |

# NO / NO2 GPT Checks

Things get a little different when doing GPT checks, as we want to 'carry over' measurements from previous phases/steps to determine the NO2 target based on the analyzer response.

Here, we are storing the actual NO conc from the calibrator and the the NO result from the analyzer.

The screenshot displays the 'Data Source Details' window for 'Sequence:NOX-SP-Z'. The left sidebar shows a tree view with categories like 'Calibrations' and 'Modbus Instruments'. The main area contains two tables:

| Phase Name | Phase Number | Duration Time | Response Time | Enabled                             | Status Pattern | Level |
|------------|--------------|---------------|---------------|-------------------------------------|----------------|-------|
| CHARCHEK   | 1            | 10m           | 5m            | <input checked="" type="checkbox"/> | 1,3,13         | ZERO  |
| NO-SPAN    | 2            | 20M           | 5m            | <input checked="" type="checkbox"/> | 1,3,19         | SPAN  |
| NO2-SPAN   | 3            | 10M           | 5m            | <input checked="" type="checkbox"/> | 1,3,20         | SPAN  |
| NOX-ZERO   | 4            | 10M           | 5m            | <input checked="" type="checkbox"/> | 1,3,13         | ZERO  |
| STANDBY    | 5            | 10s           | 5s            | <input checked="" type="checkbox"/> | 27             |       |

| Channel  | Expected Value | Expected Value From Constant | Write Expected Value To Constant | Write Result To Constant      | Store Calibration Results           | Error Method | Warning Drift Limit | Out of Control Limit |
|----------|----------------|------------------------------|----------------------------------|-------------------------------|-------------------------------------|--------------|---------------------|----------------------|
| ACTCONC  | 600            |                              |                                  | NO Actual result from 700     | <input checked="" type="checkbox"/> | Difference   |                     |                      |
| CAO3FLOW | 0.1            |                              |                                  | K02                           | <input checked="" type="checkbox"/> | Difference   |                     |                      |
| NO       | 600            |                              |                                  | NO result during non-titratio | <input checked="" type="checkbox"/> | Difference   |                     |                      |
| NO2      | 0              |                              |                                  |                               | <input checked="" type="checkbox"/> | Difference   |                     |                      |
| NOX      | 600            |                              |                                  |                               | <input checked="" type="checkbox"/> | Difference   |                     |                      |

Red handwritten annotations are present on the Phase Channels table: '-K8' is next to the 'NO Actual result from 700' value, and '-K6' is next to the 'NO result during non-titratio' value.

# NO / NO2 GPT Checks

We use a math channel to calculate the target (“NOreduct span level”) and use that as the expected / target value for NO2.

The screenshot shows the 'Data Source Details' window for 'Sequence:NOX-SP-Z'. The 'Phases' table is as follows:

| Phase Name | Phase Number | Duration Time | Response Time | Enabled                             | Status Pattern | Level |
|------------|--------------|---------------|---------------|-------------------------------------|----------------|-------|
| CHARCHEK   | 1            | 10m           | 5m            | <input checked="" type="checkbox"/> | 1,3,13         | ZERO  |
| NO-SPAN    | 2            | 20M           | 5m            | <input checked="" type="checkbox"/> | 1,3,19         | SPAN  |
| NO2-SPAN   | 3            | 10M           | 5m            | <input checked="" type="checkbox"/> | 1,3,20         | SPAN  |
| NOX-ZERO   | 4            | 10M           | 5m            | <input checked="" type="checkbox"/> | 1,3,13         | ZERO  |
| STANDBY    | 5            | 10s           | 5s            | <input checked="" type="checkbox"/> | 27             |       |

The 'Phase Channels' table is as follows:

| Channel | Expected Value      | Expected Value From Constant | Write Expected Value To Constant | Write Result To Constant         | Store Calibration Results           | Error Method | Warning Drift Limit |
|---------|---------------------|------------------------------|----------------------------------|----------------------------------|-------------------------------------|--------------|---------------------|
| ACTCONC | 600                 |                              |                                  |                                  | <input checked="" type="checkbox"/> | Difference   |                     |
| NO      | 250                 |                              |                                  | NO result during titration phase | <input checked="" type="checkbox"/> | Difference   |                     |
| NO2     | NOreduct span level |                              |                                  |                                  | <input checked="" type="checkbox"/> | Difference   |                     |
| NOX     | 600                 |                              |                                  |                                  | <input checked="" type="checkbox"/> | Difference   |                     |

A red arrow points to the 'NO2' row in the 'Phase Channels' table, highlighting the 'NOreduct span level' value.

$$\text{NO2\_target} = (K8/K6) * (K6 - K7) \text{ or}$$

$$= (\text{NOACT\_700} / \text{NOmeas}[1]) * (\text{NOmeas}[2] - \text{NOtitrate})$$

# NO / NO2 GPT Checks

Example:

During NO span:

- Calibrator reports NO = 600
- Analyzer response NO = 580

During NO2 span:

- Analyzer response NO = 230

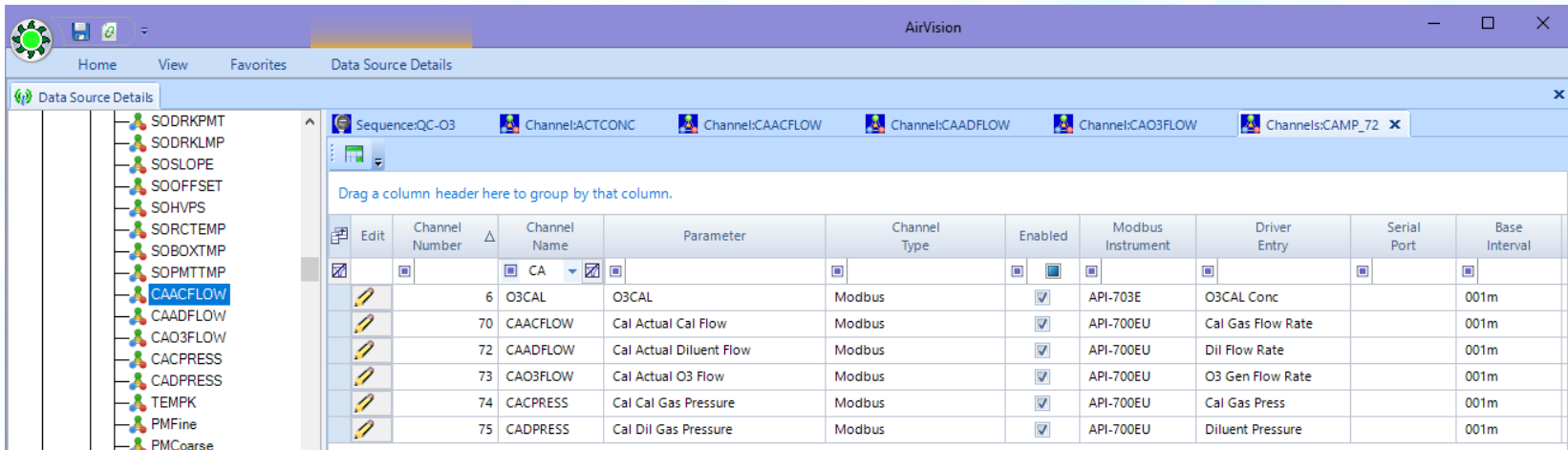
$$\text{NO2\_target} = (600/580) * (580-230) = 362.1$$

$$\begin{aligned} \text{NO2\_target} &= (K8/K6)*(K6-K7) \text{ or} \\ &= (\text{NOACT\_700} / \text{NOmeas}[1]) * (\text{NOmeas}[2] - \text{NOtitrate}) \end{aligned}$$



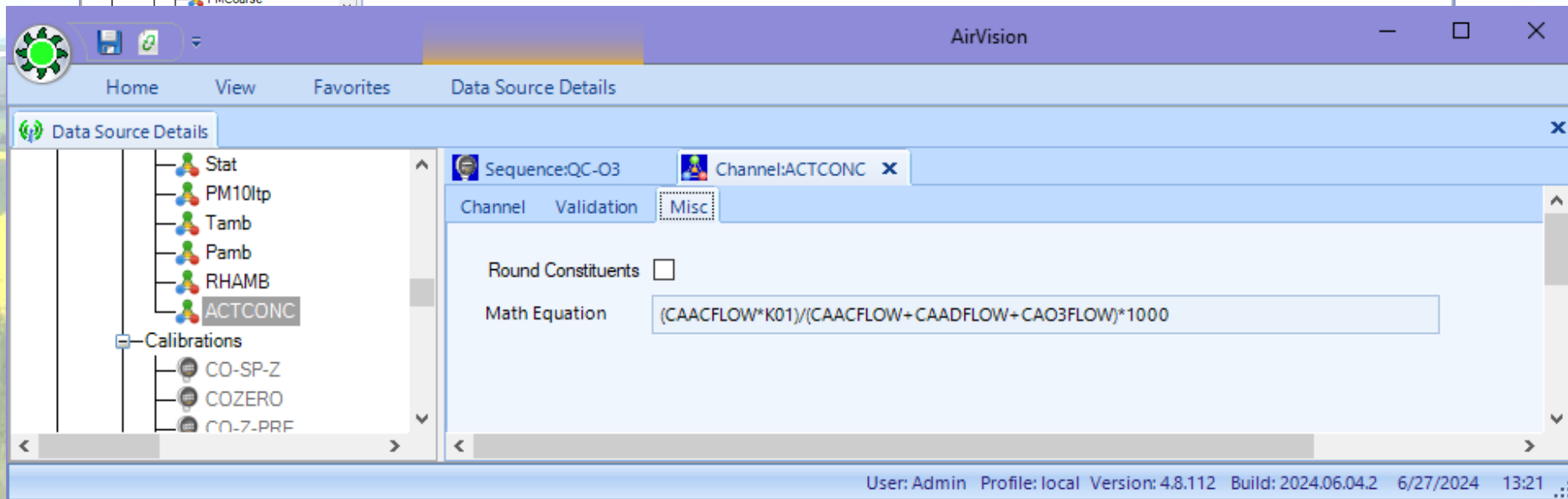
# Method 2

We acquire our three gas flows, and implement a math function in the logger to calculate the actual concentration from the bottle conc.:



The screenshot shows the 'Data Source Details' window in AirVision. The left pane lists various channels, with 'CAACFLOW' selected. The right pane displays a table of channel configurations.

| Edit | Channel Number | Channel Name | Parameter               | Channel Type | Enabled                             | Modbus Instrument | Driver Entry      | Serial Port | Base Interval |
|------|----------------|--------------|-------------------------|--------------|-------------------------------------|-------------------|-------------------|-------------|---------------|
|      | 6              | O3CAL        | O3CAL                   | Modbus       | <input checked="" type="checkbox"/> | API-703E          | O3CAL Conc        |             | 001m          |
|      | 70             | CAACFLOW     | Cal Actual Cal Flow     | Modbus       | <input checked="" type="checkbox"/> | API-700EU         | Cal Gas Flow Rate |             | 001m          |
|      | 72             | CAADFLOW     | Cal Actual Diluent Flow | Modbus       | <input checked="" type="checkbox"/> | API-700EU         | Dil Flow Rate     |             | 001m          |
|      | 73             | CAO3FLOW     | Cal Actual O3 Flow      | Modbus       | <input checked="" type="checkbox"/> | API-700EU         | O3 Gen Flow Rate  |             | 001m          |
|      | 74             | CACPRESS     | Cal Cal Gas Pressure    | Modbus       | <input checked="" type="checkbox"/> | API-700EU         | Cal Gas Press     |             | 001m          |
|      | 75             | CADPRESS     | Cal Dil Gas Pressure    | Modbus       | <input checked="" type="checkbox"/> | API-700EU         | Diluent Pressure  |             | 001m          |



The screenshot shows the 'Data Source Details' window in AirVision, with the 'Misc' tab selected for channel 'ACTCONC'. The 'Math Equation' field contains the following formula:

$$\text{Math Equation} = (\text{CAACFLOW} * \text{K01}) / (\text{CAACFLOW} + \text{CAADFLOW} + \text{CAO3FLOW}) * 1000$$

The status bar at the bottom indicates: User: Admin Profile: local Version: 4.8.112 Build: 2024.06.04.2 6/27/2024 13:21

## Method 2

### Why this method?

- The RS-232 method (and potentially the HTTP method) from the T700 may not offer enough digits of precision since it's parsed from text. (as opposed to Modbus = full floating point representation).



Also note that it's been found that O3 flow may not go perfectly to zero during non-titration. One solution is to use the "Secondary Value" on math constants as a multiplier for O3 flow, e.g.:

$DILFLOW + CALFLOW + K07 * O3FLOW$  (K3=1 during GPT, 0 otherwise)

*Thanks to Erick Mattson and Phillip Stauffer at Colorado Department of Public Health and Environment for 'in the field' details.*



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**Questions?**

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