SAND2010-2028P

CANARY Tutorial Series Advanced Techniques

Composite Signals and Incorporating Operations Information

CANARY was developed through an InterAgency Agreement between the U. S. Environmental Protection Agency and Sandia National Laboratories.
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Sandia National Laboratories

A Department of Energy National Laboratory

Overview

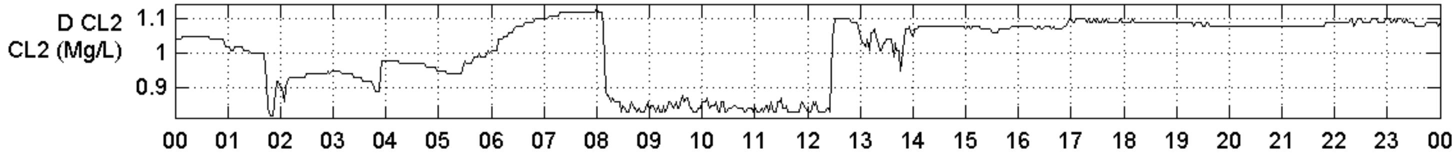
- Simple transformations of signals can be useful in refining water quality event detection
- SCADA systems often provide more than just water quality data (operations data)
- Water quality data is typically "noisy" due to the constant flux of flow rates and mixing
- Some of this noise is due to operations events, such as pumps cycling, tanks filling or draining, or direct water quality actions, such as re-dosing chlorine
- The composite signal techniques discussed in this tutorial were created to help find new ways to decrease false positives by combining water quality and operations data

Three examples

- Create a custom filter to accentuate significant changes in a signal
- Use an upstream water quality measurement to create an adaptive set point within CANARY
- Process a combination of operational signals to define a "calibration alarm" and disable CANARY alarms for a specified time period after calibration

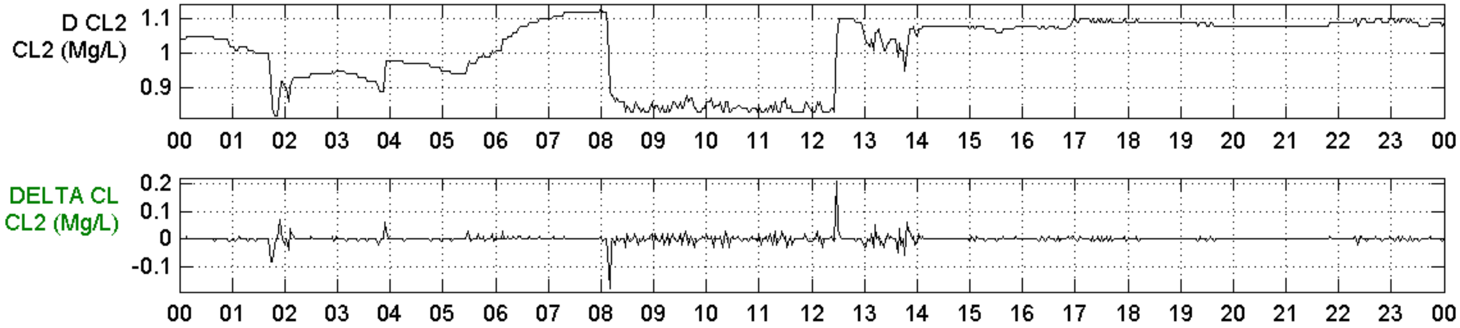
Composite Signals: Custom Filter

- Because the SCADA system is not the ideal place to do data transforms, CANARY uses the idea of a "composite signal" to allow custom transformation of the incoming data
- For example, below is 24 hours of chlorine measurements taken every 2 minutes



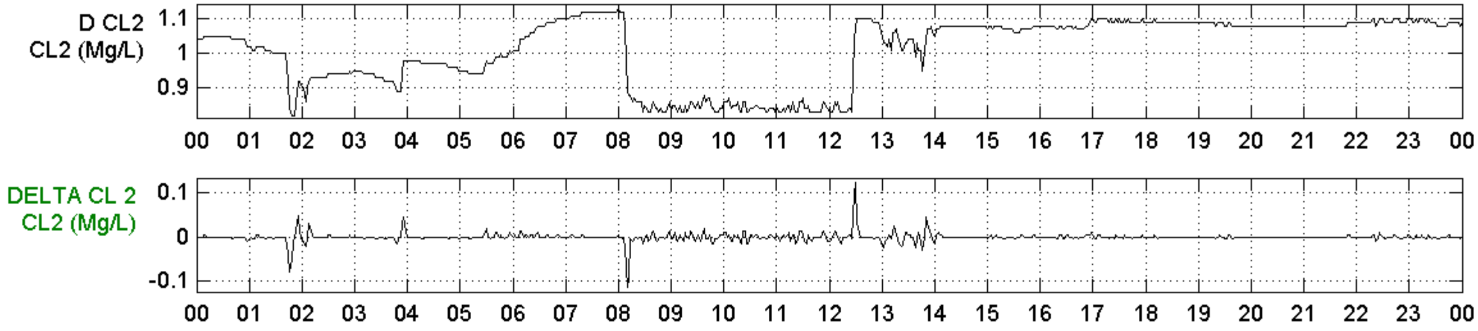
Composite Signals: Custom Filter

- Now, we look at a composite signal that has been created from the original chlorine data
  - This signal looks at only the difference between the current time and the previous time
  - Notice that even in the areas where chlorine is fairly steady, the new signal shows the jitter in the original chlorine data



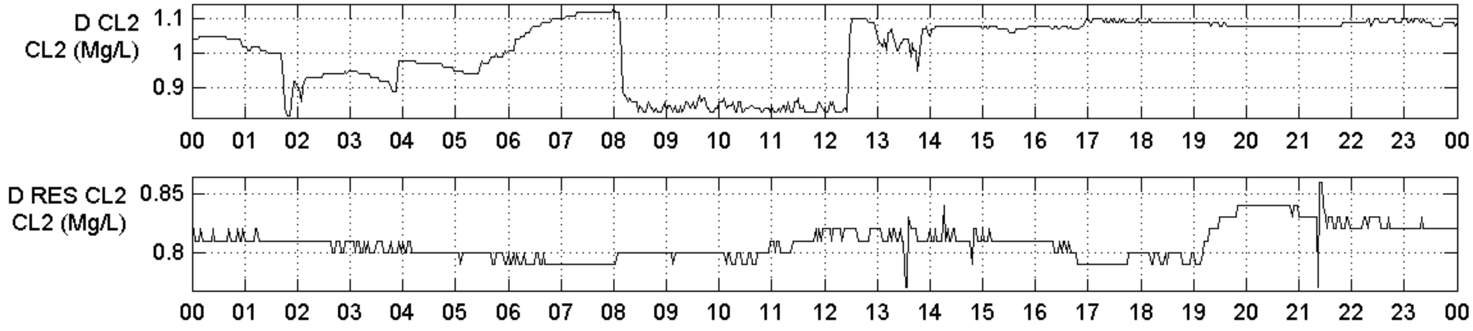
Composite Signals: Custom Filter

- Changing the signal slightly, we can create a simple filter, that averages the current value with the last value, and then looks at the difference between the current average and the last average
  - Notice that the peaks from hours 12 to 14 are much cleaner than before, and that the changes at hour 02 and 08 are at a more comparable scale

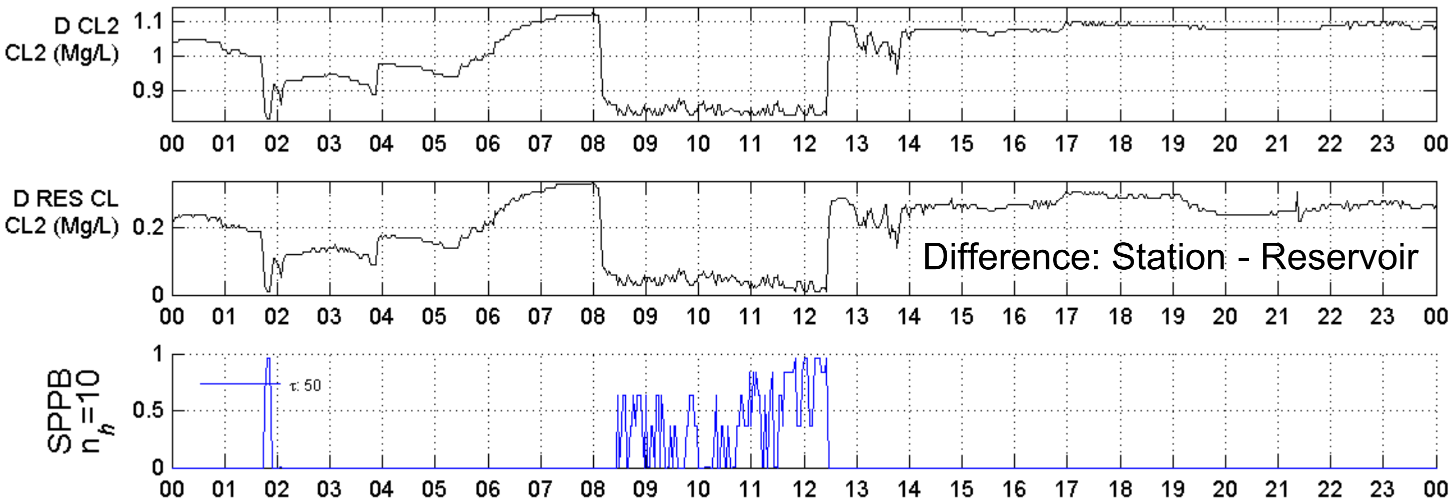


Composite Signals: Adaptive Set Point

- We have a minimum chlorine given by the water in the upstream reservoir
- Using the reservoir value, we can create an adaptive set-point; the chlorine value in the reservoir (or some slight decrease) is the minimum chlorine level we should ever expect at this location



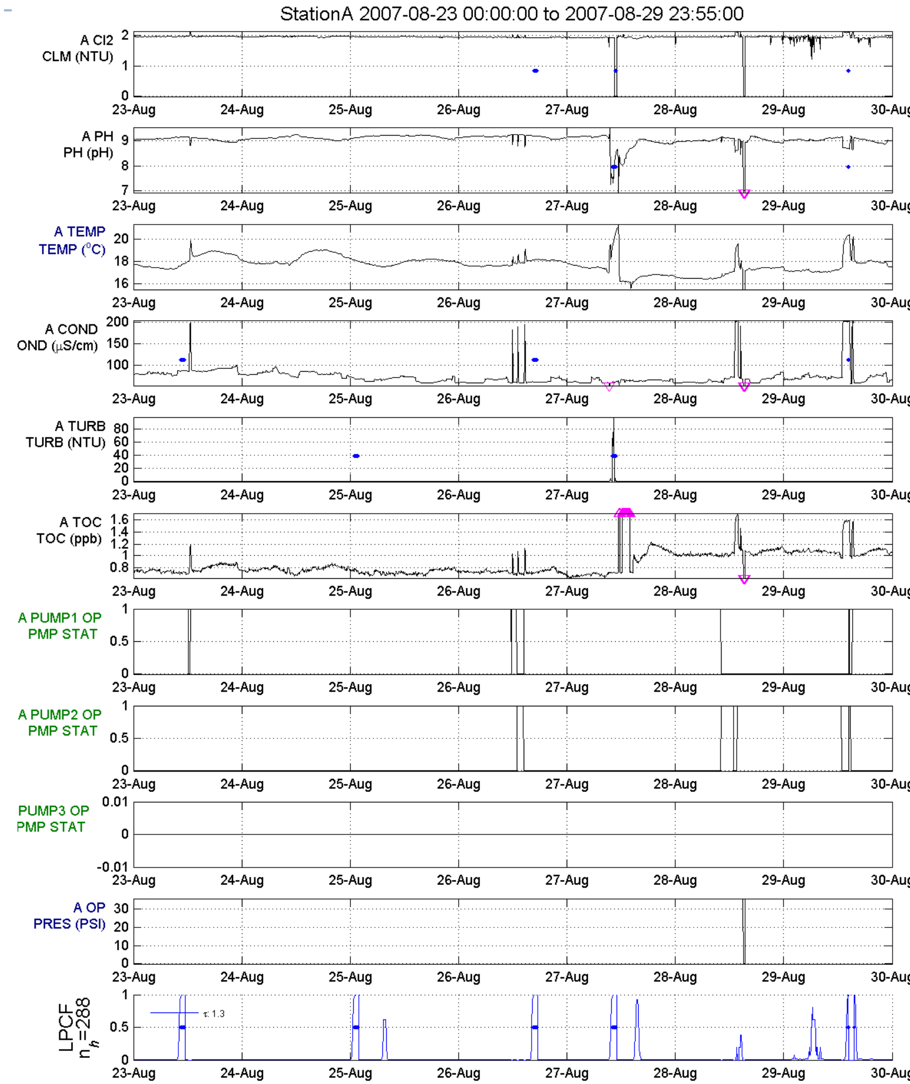
Composite Signals



- Using the reservoir as a dynamic set-point, we can now see the probability that an event is occurring increase during those times when the chlorine approaches the level in the reservoir (difference goes to zero)

Composite Signals: Post Calibration

- Water quality data from a monitoring station are provided along with operational data
  - Pumps are located away from monitoring station
  - Pressure data recorded at monitoring station
- Some relation between CANARY alarms and operational changes

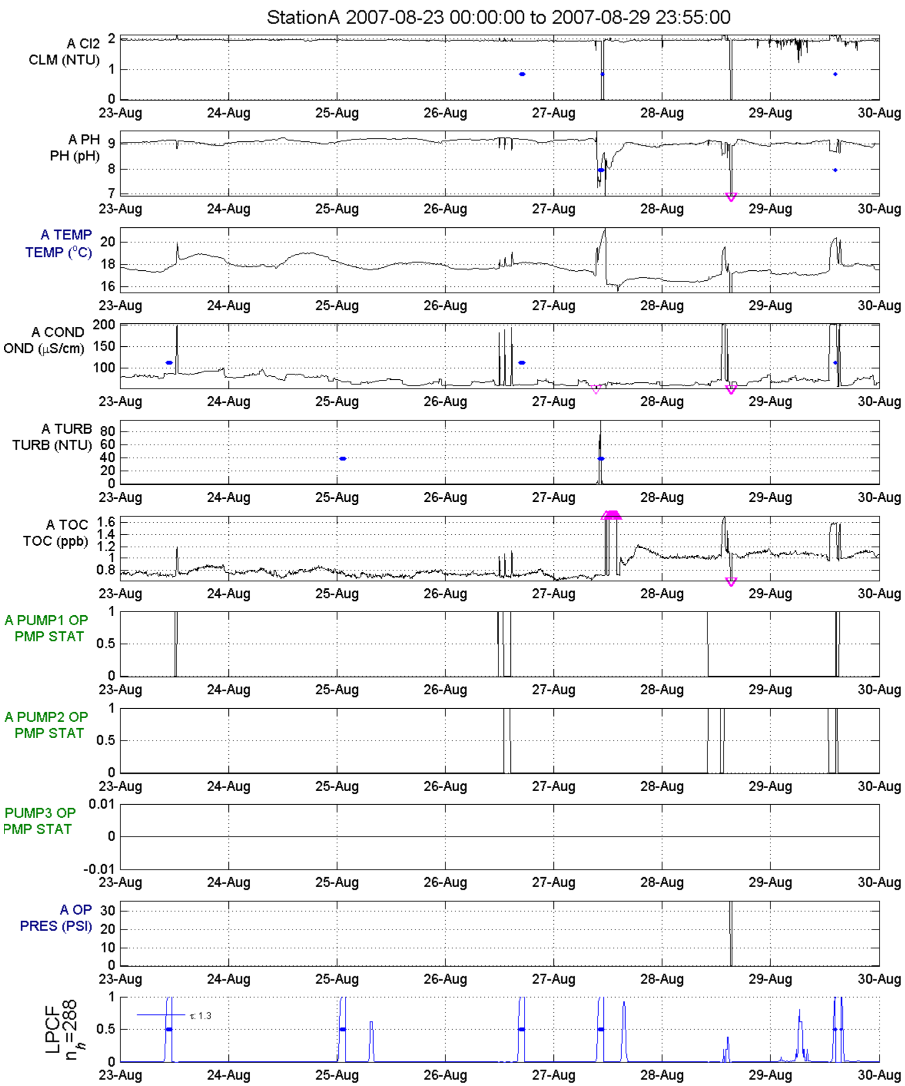


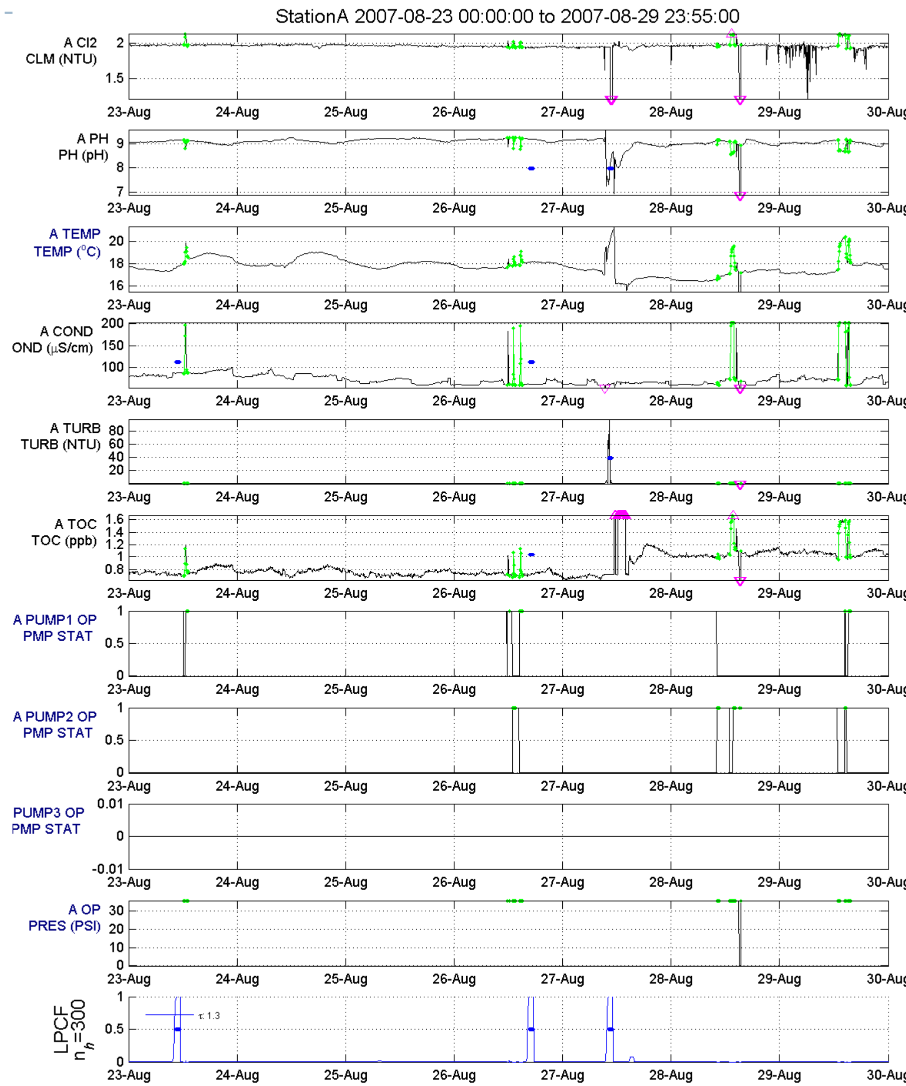
One week of data with a 5 minute sample interval

Composite Signals: Post Calibration

- Determine delay between change in pump status and change in water quality
  - Appears to be 45 minutes
- Create operational signal that integrates changes in any pump status
  - Composite signal that is absolute value of difference between current pump status and status 45 minutes ago (0/1)
  - Take maximum of composite over all 3 pumps (0/1)
- Create operational signal that is change in pressure between current and previous time steps (Delta PSI)
- Combine new operational signals into a single calibration signal
  - Convert pressure changes to 0/1 based on exceeding 10 PSI threshold
  - Final calibration signal is maximum of two 0/1 operational signals
  - If calibration signal = 1, suppress alarms for current time step

Results


StationA 2007-08-23 00:00:00 to 2007-08-29 23:55:00
A Cl2
CLM (NTU)
A PH
PH (pH)
A TEMP
TEMP (°C)
A COND
OND (μS/cm)
A TURB
TURB (NTU)
A TOC
TOC (ppb)
A PUMP1 OP
PMP STAT
A PUMP2 OP
PMP STAT
PUMP3 OP
PMP STAT
A OP
PRES (PSI)
LPCF
n_h=288
23-Aug
24-Aug
25-Aug
26-Aug
27-Aug
28-Aug
29-Aug
30-Aug


StationA 2007-08-23 00:00:00 to 2007-08-29 23:55:00
A Cl2
CLM (NTU)
A PH
PH (pH)
A TEMP
TEMP (°C)
A COND
OND (μS/cm)
A TURB
TURB (NTU)
A TOC
TOC (ppb)
A PUMP1 OP
PMP STAT
A PUMP2 OP
PMP STAT
PUMP3 OP
PMP STAT
A OP
PRES (PSI)
LPCF
n_h=300
23-Aug
24-Aug
25-Aug
26-Aug
27-Aug
28-Aug
29-Aug
30-Aug

Creating a Composite Signal

- In the GUI configuration editor, create a new signal
- Give the signal a new name and make up a SCADA tag that will not conflict with any other tag
- Set the signal type as appropriate (usually a water quality, operations or calibration signal)
- Click on the "Composite Signal" check-box
- Now, save the configuration file, and open it with "Word Pad" or your favorite text editor
  - Currently, there is no expected date on when a GUI form of the composite signal editor will be available
  - It is possible to view a signal in the GUI, but it is not editable

Creating a Composite Signal

- The composite signal is defined using a simple coding mechanism. This mechanism is similar to that which is used in a reverse polar notation (RPN) calculator.
  - Briefly, the RPN format operates on a stack and a current value
  - An entry can:
    - Push a value to the stack from the current value
    - Pop a value off the stack into the current value
    - Perform an operation on the current value and the value on the top of the stack
  - For example, the following would result in a value of 2.5
    - 5
    - 2
    - /

Creating a Composite Signal

- There are three types of "<Entry>" tags in a <CompositeSignal> program
  - <Entry var="*signal_id*" shift="*uint*"/>
  - <Entry const="*value*" />
  - <Entry cmd="*operation*" />
- The entries are processed from first to last, with a command removing one (or two) values from the stack, and then adding the result back to the stack
- By definition, shift of 0 is the current time step value, and a shift of 1 is the previous time step value, etc
- A shift of 0 is implied if the *shift="0"* property is omitted

Commands Recognized by CANARY

- +
- -
- /
- *
- ** *or* ^ *or* pow
- abs
- >
- <
- >=
- <=
- ==

- sqrt
- log10
- log *or* ln
- e *or* exp
- max *(of 2 values)*
- min *(of 2 values)*

- Other commands may or may not work, and will only operate on the top of the stack

- Commands that take two arguments operate on the stack as:

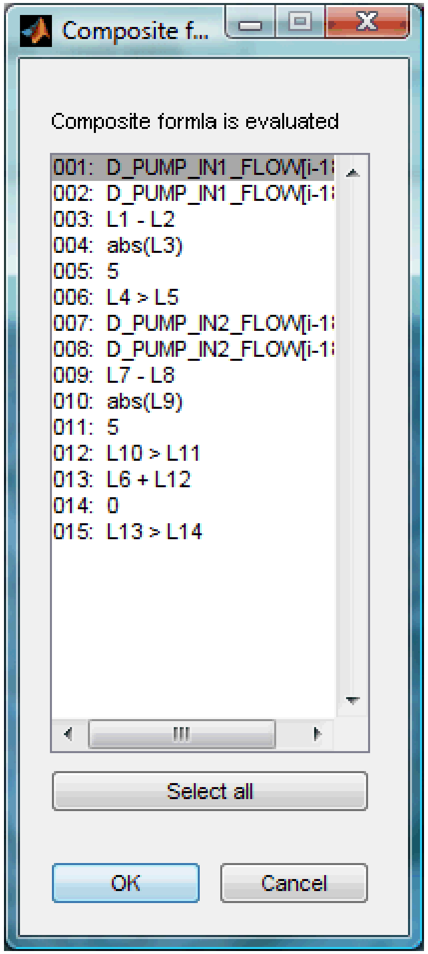
Top-1 [OP] Top

- The code to check if the flow in inlet IN1 or IN2 has changed by more than 5 gpm

```
<Signal name="TEST_PUMPS" scada-tag="D_TEST_PUMPS"
  signal-type="op" parameter="FLOW" ignore-
  changes="none" >
   <CompositeSignal>
    <Entry var="D_PUMP_IN1_FLOW" shift="180" />
    <Entry var="D_PUMP_IN1_FLOW" shift="182" />
    <Entry cmd="-" />
    <Entry cmd="abs" />
    <Entry const="5" />
    <Entry cmd=">" />
    <Entry var="D_PUMP_IN2_FLOW" shift="180" />
    <Entry var="D_PUMP_IN2_FLOW" shift="182" />
    <Entry cmd="-" />
    <Entry cmd="abs" />
    <Entry const="5" />
    <Entry cmd=">" />
    <Entry cmd="+" />
    <Entry const="0" />
    <Entry cmd=">" />
   </CompositeSignal>
</Signal>
```

Example of a Composite Signal

As viewed in the editor



Other Composite Signal Notes

- Don't do too much in one signal
  - You can always combine two composite signals into a third – just don't create a self-referencing loop
  - Calibration signals in particular can be overly complicated – it's better to create an operations signal first, and then do only the calibration comparison in the calibration signal
- If in doubt, plot it out
  - Add the signals in to the station, then run in batch mode without an algorithm; graphing the data can really help make sure that the combined signal is doing what you want it to do
- Use shifts carefully
  - Make sure the shifts make sense operationally – just because you can look at data from 5 hours ago doesn't mean it's a good idea