## Document Control Sheet

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<th>Version</th>
<th>Date</th>
<th>Description</th>
<th>Author</th>
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<td>2014-01-15</td>
<td>Initial Draft</td>
<td>G. Proskurowski</td>
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<td>G. Proskurowski</td>
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<td>1-00</td>
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<td>Initial release</td>
<td>E. Chapman</td>
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Signature Page

This document has been reviewed and approved for release to Configuration Management.

OOI Senior Systems Engineer: ____________________________
Date: 2014-05-09

This document has been reviewed and meets the needs of the OOI Cyberinfrastructure for the purpose of coding and implementation.

OOI CI Signing Authority: ____________________________
Date: ____________________________
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1 Abstract
This document describes the computations used to calculate the OOI Level 1 Vent Fluid Temperature data products from the THSPH instrument. The THSPH instrument outputs hexadecimal voltage and resistance data from a series of sensors that is converted off-instrument, using the algorithms described here, to temperatures and chemical species concentrations. This data product specification is specific to two “final” environmental temperature measurements made by the THSPH instrument using a combination of high-temperature thermocouples and reference thermistors, and four “intermediate” temperature products that are particularly useful for tracking instrument health and data quality control. The two temperature measurements are separate from each other, but may be collocated, depending on the deployment. This data product specification includes definition of the raw THSPH hexadecimal output line, and all of the data manipulations to calculate temperature products from the raw data.

2 Introduction

2.1 Author Contact Information
Please contact Giora Proskurowski (giora@uw.edu) or the Data Product Specification lead (DPS@lists.oceanobservatories.org) for more information concerning the computation and other items in this document.

2.2 Metadata Information

2.2.1 Data Product Name
The OOI Core Data Product Name for this product is
- THSPHTe

The OOI Core Data Product Descriptive Name for this product is
- Vent Fluid Temperature from THSPH

2.2.2 Data Product Abstract (for Metadata)
The OOI Level 1 Vent Fluid Temperature core data product is the measured temperature at the sample inlet of the THSPH instrument.

2.2.3 Computation Name
Not required for data products.

2.2.4 Computation Abstract (for Metadata)
This algorithm parses the OOI Level 1 Vent Fluid Temperature core data product, from the instrument data string.

2.2.5 Instrument-Specific Metadata
See Section 4.4 for instrument-specific metadata fields that must be part of the output data.

2.2.6 Data Product Synonyms
Synonyms for this data product are
- Fluid temperature

2.2.7 Similar Data Products
Similar data products that may be confused with this data product by users or CI include: “Seafloor Temperature”, “Vent Fluid Temperature from TRHPH”, and/or “Vent Fluid Temperature from RASFL”.

While all of these products measure temperature at seafloor hydrothermal vents, they use different methodologies.

2.3 Instruments
For information on the instruments from which the L1 Vent Fluid Temperature core data product inputs are obtained, see the THSPH Data Processing Flow document (DCN 1342-00120). This document contains information on instrument classes and make/models; it also describes the flow of data from the instrument through all of the relevant QC, calibration, and data product computations and procedures.

Please see the Instrument Application in the SAF for specifics of instrument locations and platforms.

2.4 Literature and Reference Documents
Not applicable.

2.5 Terminology
2.5.1 Definitions
Not Applicable.

2.5.2 Acronyms, Abbreviations and Notations
General OOI acronyms, abbreviations and notations are contained in the Level 2 Reference Module in the OOI requirements database (DOORS).

2.5.3 Variables and Symbols
The following variables and symbols are defined here for use throughout this document. Because there are two independent thermocouple ("tc") temperature measurements made, the "_H" or "_L" is appended to the appropriate variables to associate them with the "High" or "Low" thermocouple. The deployment strategy is to place one thermocouple ("_H") in the high temperature fluid, with the other thermocouple ("_L") out of the strong flow. Both thermocouples are referenced to a thermistor ("ts") at the cold-junction reference ("ts_r") inside the sensor wand. Additionally, there is an onboard thermistor inside the electronics pressure housing that serves as a good check for bench-testing data quality and for in-situ housing health.

\[
\begin{align*}
tc_{rawhexH} & = \text{raw hexadecimal "H" thermocouple output} \\
tc_{rawdecL} & = \text{raw decimal "L" thermocouple output} \\
ts_{rawhexr} & = \text{raw hexadecimal reference thermistor output} \\
ts_{rawhexb} & = \text{raw hexadecimal board thermistor output} \\
ts_{rawdecH} & = \text{raw decimal "H" thermocouple output} \\
ts_{rawdecL} & = \text{raw decimal "L" thermocouple output} \\
ts_{rawdecr} & = \text{raw decimal reference thermistor output} \\
ts_{rawdecb} & = \text{raw decimal board thermistor output} \\
v_{tc\_engH} & = \text{engineering "H" thermocouple output, V} \\
v_{tc\_engL} & = \text{engineering "L" thermocouple output, V} \\
r_{ts\_engr} & = \text{engineering reference thermistor output, \Omega} \\
r_{ts\_engb} & = \text{engineering board thermistor output, \Omega} \\
v_{tc\_actualH} & = \text{calibrated "H" thermocouple voltage, V} \\
v_{tc\_actualL} & = \text{calibrated "L" thermocouple voltage, V} \\
r_{ts\_actualr} & = \text{calibrated reference thermistor resistance, \Omega} \\
r_{ts\_actualb} & = \text{calibrated board thermistor resistance, \Omega} \\
T_{tc\_H} & = \text{thermocouple "H" temperature, °C} \\
T_{tc\_L} & = \text{thermocouple "L" temperature, °C} \\
T_{ts\_r} & = \text{reference thermistor temperature, °C} \\
T_{ts\_b} & = \text{board thermistor temperature, °C}
\end{align*}
\]
T_H_uncal = uncalibrated temperature, °C, at the sample inlet ("H")
T_L_uncal = uncalibrated temperature, °C, near vent ("L")
T_H = temperature, °C, at the sample inlet ("H")
T_L = temperature, °C, near vent ("L")

(c4,c3,c2,c1,c0)_e2l_H = correction coefficients applied to thermocouple "H" "engineering to lab"
(c4,c3,c2,c1,c0)_e2l_L = correction coefficients applied to thermocouple "L" "engineering to lab"
(c4,c3,c2,c1,c0)_e2l_r = correction coefficients applied to reference thermistor "engineering to lab"
(c4,c3,c2,c1,c0)_e2l_b = correction coefficients applied to board thermistor "engineering to lab"
(c5,c4,c3,c2,c1,c0)_l2s_H = correction coefficients applied to thermocouple "H" "lab to scientific"
(c5,c4,c3,c2,c1,c0)_l2s_L = correction coefficients applied to thermocouple "L" "lab to scientific"
(c4,c3,c2,c1,c0)_l2s_r = correction coefficients applied to reference thermistor "lab to scientific"
(c4,c3,c2,c1,c0)_l2s_b = correction coefficients applied to board thermistor "lab to scientific"
(c1,c0)_s2f_H = correction coefficients applied to absolute temperature "H" "scientific to final"
(c1,c0)_s2f_L = correction coefficients applied to absolute temperature "L" "scientific to final"

Correction coefficients applied to the general formula c5*x^4+c4*x^3+c3*x^2+c2*x+c1*x+c0.

3 Theory

3.1 Description
Temperature is measured at the sample inlet using a thermocouple referenced to a thermistor at the electrical cold-junction in the sensor wand. The raw measurements are each calibrated using a linear correction, and then converted to °C using equations associated with the measurement technique. Finally the thermocouple and thermistor measurements are combined to yield an absolute temperature. Four temperature measurements are being made: Tc_H (thermocouple in high temperature fluid), Tc_L (thermocouple in low temperature near vent), Ts_r (reference thermistor at cold-junction), Ts_b (thermistor inside electronics pressure housing).

3.2 Mathematical Theory
Not Applicable.

3.3 Known Theoretical Limitations
Not Applicable.

3.4 Revision History
No revisions to date.

4 Implementation

4.1 Overview
Thermocouple and thermistor outputs are parsed from the full response string, and converted to decimal. The raw decimal output is converted to engineering units of volts (V) or ohms (R, units of Ω), and then to calibrated units of volts or ohms. Each sensor output is then converted to temperature, °C, and then the thermocouple and reference thermistor values are combined to yield an absolute temperature, °C, at the vent and near vent measurement sites.

4.2 Inputs
- Raw THSPH hexadecimal string

Input Data Formats:
The raw THSPH data output is a 35 character hexadecimal string, initiated by “aH” and terminated by “#”. The 32 remaining characters represent 8 data channels each a 4-character hexadecimal string:

- **CH1**: High temperature ceramic electrode
- **CH2**: Low T Reference electrode
- **CH3**: \( \text{H}_2 \) electrode
- **CH4**: \( \text{S}_2^- \) electrode
- **CH5**: thermocouple 1
- **CH6**: thermocouple 2
- **CH7**: reference thermistor
- **CH8**: on board thermistor input

Example THSPH data output:

```
6b1C11C12C13C14C21C22C23C24C31C32C33C34C41C42C43C44C51C52C53C54C61C62C63C64C71C72C73C74C81C82C83C84#
```

CH1 is the data of CH1, C21-C24 is the data of CH2, etc.

For the calculation of Vent Fluid Temperature from THSPH channels 5, 6, 7 and 8 must be ingested.

### 4.3 Processing Flow

The specific steps necessary to create all calibrated and quality controlled data products for each OOI core instrument are described in the instrument-specific Processing Flow document (DCN 1342-00120). This processing flow document contains flow diagrams detailing all of the specific procedures (data product and QC) necessary to compute all levels of data products from the instrument and the order in which these procedures.

The processing flow for the temperature computation is as follows:

**Timestamp to be associated with all THSPH data products is the timestamp from the Digiport.**

**Step 1:**
Parse the following raw hexadecimal outputs from the THSPH data string:

```plaintext
tc_rawhex_H = CH51-CH54
tc_rawhex_L = CH61-CH64
ts_rawhex_r = CH71-CH74
ts_rawhex_b = CH81-CH84
```

**Step 2:**
Convert hex strings to decimal

```plaintext
tc_rawdec_H = hex2dec(tc_rawhex_H)
tc_rawdec_L = hex2dec(tc_rawhex_L)
ts_rawdec_r = hex2dec(ts_rawhex_r)
ts_rawdec_b = hex2dec(ts_rawhex_b)
```

**Step 3:**
Transform raw decimal output to engineering values, units of Volts (units V for the “tc”) and ohms (Ω for the “ts”)

```plaintext
V_{tc\_eng\_H} = (tc\_rawdec\_H * 0.25 - 1024) / 61606
V_{tc\_eng\_L} = (tc\_rawdec\_L * 0.25 - 1024) / 61606
R_{ts\_eng\_r} = (10000 * ts\_rawdec\_r * 0.125) / (2048 - ts\_rawdec\_r * 0.125)
R_{ts\_eng\_b} = (10000 * ts\_rawdec\_b * 0.125) / (2048 - ts\_rawdec\_b * 0.125)
```

**Step 4:**
Transform engineering values to lab calibrated values, units of Volts (units V for the “tc”) and ohms (Ω for the “ts”), a polynomial correction

\[ V_{tc\_actual\_H} = c_4\_e2l\_H*(V_{tc\_eng\_H})^4 + \ldots + c_1\_e2l\_H*(V_{tc\_eng\_H}) + c_0\_e2l\_H \]
\[ V_{tc\_actual\_L} = c_4\_e2l\_L*(V_{tc\_eng\_L})^4 + \ldots + c_1\_e2l\_L*(V_{tc\_eng\_L}) + c_0\_e2l\_L \]
\[ R_{ts\_actual\_r} = c_4\_e2l\_r*(R_{ts\_eng\_r})^4 + \ldots + c_1\_e2l\_r*(R_{ts\_eng\_r}) + c_0\_e2l\_r \]
\[ R_{ts\_actual\_b} = c_4\_e2l\_b*(R_{ts\_eng\_b})^4 + \ldots + c_1\_e2l\_b*(R_{ts\_eng\_b}) + c_0\_e2l\_b \]

Where \((c_4, c_3, c_2, c_1, c_0)_x\) are operator supplied coefficients for polynomial in the form of \(c_4*x^4+c_3*x^3+c_2*x^2+c_1*x+c_0\). The coefficients are unique to the sensor deployed, must be settable by the marine operator (e.g. in a version controlled lookup table), and preserved in the metadata.

Step 5:
Transform calibrated engineering values to scientific values, units of temperature in °C (unnecessary parentheses are provided as a visual aid). These equations are subject to change, so it may be wise to set them up as a lookup tables similar to Step 4.

Initially the following constants can be used with the thermocouple and thermistor materials supplied for the 2014 deployments:

\((c_5, c_4, c_3, c_2, c_1, c_0)\) for thermocouple:
\((0.000000932483,-0.000122268,0.00702,-0.23532,17.06172,-0.00444,)\)

\((c_4, c_3, c_2, c_1, c_0)\) for thermistor:
\((1.38009E-4,-0.01432,0.53886,-9.58863,79.12599)\)

\[ T_{tc\_H} = (c_5\_l2s\_H * ((V_{tc\_actual\_H} * 1000)^5)) + (c_4\_l2s\_H * ((V_{tc\_actual\_H} * 1000)^4)) + (c_3\_l2s\_H * ((V_{tc\_actual\_H} * 1000)^3)) + (c_2\_l2s\_H * ((V_{tc\_actual\_H} * 1000)^2)) + (c_1\_l2s\_H * ((V_{tc\_actual\_H} * 1000))) + c_0\_l2s\_H \]

\[ T_{tc\_L} = (c_5\_l2s\_L * ((V_{tc\_actual\_L} * 1000)^5)) + (c_4\_l2s\_L * ((V_{tc\_actual\_L} * 1000)^4)) + (c_3\_l2s\_L * ((V_{tc\_actual\_L} * 1000)^3)) + (c_2\_l2s\_L * ((V_{tc\_actual\_L} * 1000)^2)) + (c_1\_l2s\_L * ((V_{tc\_actual\_L} * 1000))) + c_0\_l2s\_L \]

\[ T_{ts\_r} = (c_4\_l2s\_r * (R_{ts\_actual\_r})^4) + (c_3\_l2s\_r * (R_{ts\_actual\_r})^3) + (c_2\_l2s\_r * (R_{ts\_actual\_r})^2) + (c_1\_l2s\_r * R_{ts\_actual\_r}) + c_0\_l2s\_r \]

\[ T_{ts\_b} = (c_4\_l2s\_b * (R_{ts\_actual\_b})^4) + (c_3\_l2s\_b * (R_{ts\_actual\_b})^3) + (c_2\_l2s\_b * (R_{ts\_actual\_b})^2) + (c_1\_l2s\_b * R_{ts\_actual\_b}) + c_0\_l2s\_b \]

Step 6:
Calculate absolute temperature at thermocouple measurement sites, units of temperature in °C:
\[ T_{H\_uncal} = T_{ts\_r} + T_{tc\_H} \]
\[ T_{L\_uncal} = T_{ts\_r} + T_{tc\_L} \]

Step 7:
Apply final linear calibration to the \(T_{H\_uncal}\) and \(T_{L\_uncal}\) data
\[ T_{H} = c_1\_s2f\_H*(T_{H\_uncal}) + c_0\_s2f\_H \]
\[ T_{L} = c_1\_s2f\_L*(T_{L\_uncal}) + c_0\_s2f\_L \]

4.4 Outputs

The outputs of the parsing and calculations are

Scientific L1 Data Products
• **T_H**: Temperature at high temperature location (position of thermocouple “H”), °C, %.2f. (Digi timestamp—this will be used for timestamping for all data lines); this Scientific L1 Data Product THSPHTE-TH.

• **T_L**: Temperature at low temperature location (position of thermocouple “L”), °C, %.2f. (Digi timestamp); this Scientific L1 Data Product THSPHTE-TL.

• **T_ts_r**: Reference thermistor Temperature, °C, %.2f. (Digi timestamp); this is Scientific L1 Data Product THSPHTE-REF

• **T_tc_H**: Thermocouple temperature position “H” (high temperature vent fluid), °C, %.2f. (Digi timestamp); this is Scientific L1 Data Product THSPHTE-TCH

• **T_tc_L**: Thermocouple temperature position “L” (low temperature near vent), °C, %.2f. (Digi timestamp); this is Scientific L1 Data Product THSPHTE-TCL

• **T_ts_b**: Board thermistor Temperature, °C, %.2f. (Digi timestamp); this is Scientific L1 Data Product THSPHTE-INT

The metadata that must be included with the output are

- calibration coefficients used
- Description of position of thermocouple sensors H, and L

See Appendix B for a discussion of the accuracy of the output.

Time stamp should be the time from the Digiport, rather than from the data string, the OMS or OOInet.

### 4.5 Computational and Numerical Considerations

#### 4.5.1 Numerical Programming Considerations

There are no numerical programming considerations for this computation. No special numerical methods are used.

#### 4.5.2 Computational Requirements

Not Applicable.

### 4.6 Code Verification and Test Data Set

The code will be verified using the test data set provided, which contains inputs and their associated correct outputs. CI will verify that the code is correct by checking that the output, generated using the test data inputs, is identical to the test data output.

The test data set below provides a few data points, see THSPHTE_Test_Data_Set_v4.xls for full set.

Input:

```
aH200B200720C420A1108D3E8C22421FFC#
aH200B200720C420A1108D3E8C22421FFC#
aH2009200820C2220A01088C3E8922361FF9#
```

Assuming the following calibration coefficients \((c5,c4,c3,c2,c1,c0)_{(e2l,l2s)} x\) where
\[ c5 \times x^5 + c4 \times x^4 + c3 \times x^3 + c2 \times x^2 + c1 \times x + c0 \] and \((c1,c0)_{s2f} x\) where \(c1 \times x + c0\).

<table>
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<tr>
<th>(c4,c3,c2,c1,c0)_{e2l_H}</th>
<th>c5</th>
<th>c4</th>
<th>c3</th>
<th>c2</th>
<th>c1</th>
<th>c0</th>
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<td>(c4,c3,c2,c1,c0)_{e2l_H}</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>-0.00055</td>
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</table>

<table>
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<th>(c4,c3,c2,c1,c0)_{e2l_L}</th>
<th>c5</th>
<th>c4</th>
<th>c3</th>
<th>c2</th>
<th>c1</th>
<th>c0</th>
</tr>
</thead>
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<tr>
<td>(c4,c3,c2,c1,c0)_{e2l_L}</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>-0.00055</td>
</tr>
</tbody>
</table>
Data Product Specification for Vent Fluid Temperature from THSPH

(c4,c3,c2,c1,c0)_e2l_r  0   0   4.54486E-13   3.82028E-10   0.00099151  0.05935
(c4,c3,c2,c1,c0)_e2l_b  0   0   4.54486E-13   3.82028E-10   0.00099151  0.05935
(c5,c4,c3,c2,c1,c0)_l2s_H  9.32483E-07  -0.00444  17.06172  -0.23532  0.00702  -0.000122268
(c5,c4,c3,c2,c1,c0)_l2s_L  9.32483E-07  -0.00444  17.06172  -0.23532  0.00702  -0.000122268
(c4,c3,c2,c1,c0)_l2s_r  0   79.12599  -9.58863   0.53886  -0.01432  0.000138009
(c4,c3,c2,c1,c0)_l2s_b  0   79.12599  -9.58863   0.53886  -0.01432  0.000138009
(c1,c0)_s2f_H  0   0   0   0   0.95567  1.68019
(c1,c0)_s2f_L  0   0   0   0   0.95567  1.68019

H thermocouple directly in Diva vent fluid
L thermocouple in seawater at end of sensor wand

Output:

(Digi timestamp = DTS)

\[
[DTS \ T_H \ T_L \ T Ts_r \ T tc_H \ T tc_L \ T Ts_b]
\]

<table>
<thead>
<tr>
<th>DTS</th>
<th>T_H</th>
<th>T_L</th>
<th>T Ts_r</th>
<th>T tc_H</th>
<th>T tc_L</th>
<th>T Ts_b</th>
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</thead>
<tbody>
<tr>
<td>DTS</td>
<td>20.54</td>
<td>630.89</td>
<td>19.36</td>
<td>0.37</td>
<td>639.04</td>
<td>23.06</td>
</tr>
<tr>
<td>DTS</td>
<td>20.54</td>
<td>630.89</td>
<td>19.36</td>
<td>0.37</td>
<td>639.04</td>
<td>23.06</td>
</tr>
<tr>
<td>DTS</td>
<td>20.54</td>
<td>630.80</td>
<td>19.43</td>
<td>0.30</td>
<td>638.87</td>
<td>23.08</td>
</tr>
</tbody>
</table>

L1 product includes the High Temperature and Low Temperature products (T_H, T_L), the reference thermistor (T Ts_r), the thermocouple temperatures (T tc_H, T tc_L) and the electronics housing thermistor (T Ts_b) merged with the time stamp information. The 6 temperature values can be stored in an array, but should have the full functionality during plotting and downloads of 6 different parameters.

In addition, the output should have metadata fields containing the 6 sets of correction coefficients, and a short description of the position of the sensors T_H and T_L.
Appendix A  Example Code

def parse(self, sample):
    ch1hex = sample[2:6]
    ch2hex = sample[6:10]
    ch3hex = sample[10:14]
    ch4hex = sample[14:18]
    ch5hex = sample[18:22]  #tc_rawhex_H
    ch6hex = sample[22:26]  #tc_rawhex_L
    ch7hex = sample[26:30]  #ts_rawhex_r
    ch8hex = sample[30:34]  #ts_rawhex_b
    ch5dec = int(ch5hex, 16)  #tc_rawdec_H
    ch6dec = int(ch6hex, 16)  #tc_rawdec_L
    ch7dec = int(ch7hex, 16)  #ts_rawdec_r
    ch8dec = int(ch8hex, 16)  #ts_rawdec_b

    vch5 = (ch5dec * 0.25 - 1024) / 61606    #V_tc_eng_H
    vch6 = (ch6dec * 0.25 - 1024) / 61606    #V_tc_eng_L
    rch7 = (10000 * ch7dec * 0.125) / (2048 - ch7dec * 0.125)  #R_ts_eng_r
    rch8 = (10000 * ch8dec * 0.125) / (2048 - ch8dec * 0.125)  #R_ts_eng_b
    vch5act = vch5 - 0.00055    #V_tc_actual_H
    vch6act = vch6 - 0.00055    #V_tc_actual_L
    rch7act = 0.05935 + 0.00099151 * rch7 + 3.82028e-13 * rch7 ** 3
    rch8act = 0.05935 + 0.00099151 * rch8 + 3.82028e-13 * rch8 ** 3

    Tch5 = -0.00444 + 17.06172 * vch5act * 1000 - 0.23532 * (vch5act * 1000) ** 2 +
          0.00702 * (vch5act ** 1000) ** 3 - 0.000122268 * (vch5act ** 1000) ** 4 +
          0.000000932483 * (vch5act ** 1000) ** 5  #T_tc_H
    Tch6 = -0.00444 + 17.06172 * vch6act * 1000 - 0.23532 * (vch6act * 1000) ** 2 +
          0.00702 * (vch6act ** 1000) ** 3 - 0.000122268 * (vch6act ** 1000) ** 4 +
          0.000000932483 * (vch6act ** 1000) ** 5  #T_tc_L
    Tch7 = 79.12599 - 9.58863 * rch7act + 0.53886 * rch7act ** 2 - 0.01432 * rch7act ** 3 +
           1.38009e-4 * rch7act ** 4  #T_ts_r
    Tch8 = 79.12599 - 9.58863 * rch8act + 0.53886 * rch8act ** 2 - 0.01432 * rch8act ** 3 +
           1.38009e-4 * rch8act ** 4  #T_ts_b

    TH = Tch5 + Tch7    #T_H_uncal
    TL = Tch6 + Tch7    #T_L_uncal
    THcal = 1.68019 + 0.95567 * TH    #T_H
    TLcal = 1.68019 + 0.95567 * TL    #T_L

    print "%.2f TH %.2f TL %.2f THcal %.2f board" % (Tch5, Tch7, Tch8, TH, THcal)

    return THcal
Appendix B  Output Accuracy

The accuracy of the L1 product, which includes a linear correction step, is similar to the accuracy of the thermistor and thermocouple component sensors.

The OOI-RSN requirements for the accuracy and precision of the Vent Fluid Temperature from TSHPH measurement, as represented in DOORS are:

   The vent fluid pH-H2S-H2-T chemistry instrument shall measure temperature with an accuracy of 1°C.  
   <L4-RSN-IP-RQ-728>

Factory reported accuracy for NTC thermistor is 0.2°C, and for Type E thermocouple is 1.0°C. When used in combination and calibrated in lab accuracy is closer to that of the thermistor.
Appendix C  Sensor Calibration Effects

The three temperature sensors are calibrated in ice water and boiling water and compared to a laboratory Hg thermometer. Data were collected over the network. The standard deviation of all probes was less than 0.1 °C at zero and 100, and the accuracy was within 0.5 °C.