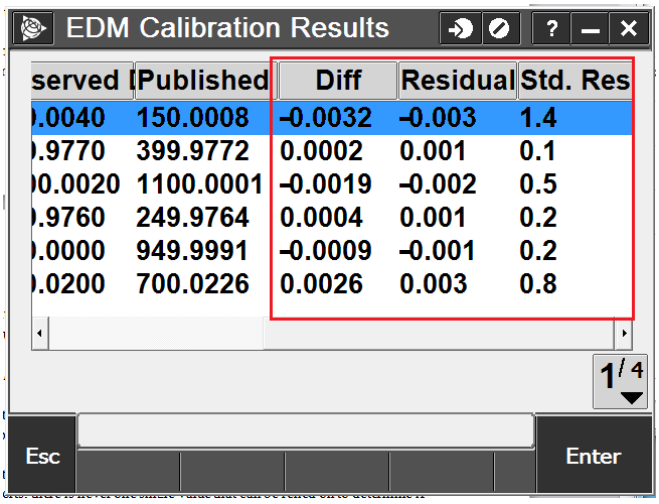
Review of EDMCheq Results

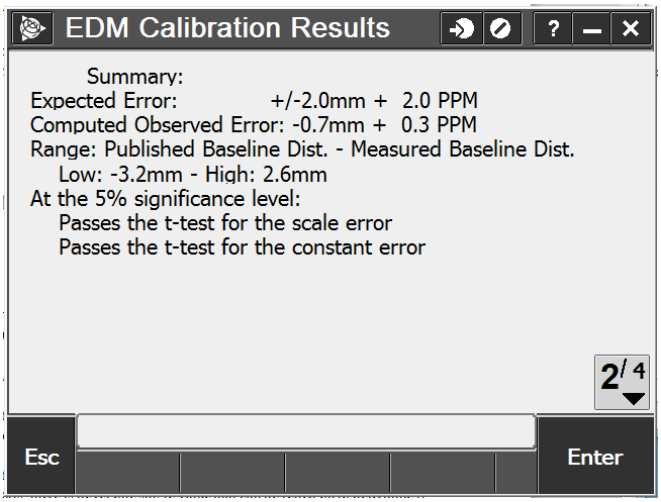
The following pages describe the reports and data generated after processing an EDM calibration field file. Like most least squares reports there is initially an overwhelming amount of data shown. But once you are accustomed to reviewing the report you will see that there are a few key items that need to be reviewed and checked to be assured that the EDM is working properly.

Notice the last three columns, the 'Diff' column, the 'Residual' column and the 'Std. Res.' column. The 'Diff' column is the difference between the observed distance and the published distance. This column is one of the most important columns to review. With a well-adjusted EDM there should be an equal distribution of positive and negative values, and any one value should not exceed three or four millimeters. If the 'Diff' column is consistently positive or negative this is an indication of a systematic error, either scale or constant error in the EDM. The 'Residual' column is the difference between the adjusted distance and the published distance. Even if an EDM is out of adjustment and has an excessive constant or scale error the 'Residual' column may still have only small values since they represent adjusted values. The 'Std. Res' is the standardized residual. The standardized residual is the 'Diff' value divided by the expected error for a distance. The expected error for a distance is computed from the measured distance and the expected constant and PPM error as entered when the project files were created. Since the Diff value and expected error should be approximately the same, the standardized residual should be around 1.0. If a standardized residual is 3.0 or greater the column entry will be marked with an '*' and the calibration should be reviewed carefully. If the standardized residual is consistently less than one then this indicates that the results are better than expected.

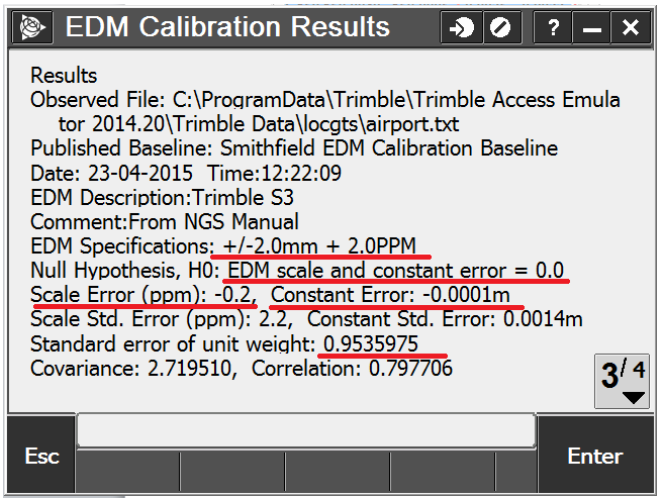


The second page of the results report shows a summary of the important items to review. Look at the Computed Observed Error. These are probably the two most important numbers to review. These numbers should be equal to or less than the Expected Error. The following example shows very good

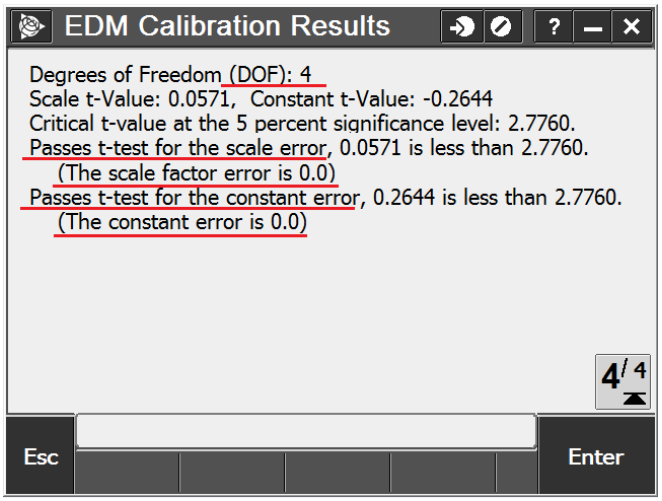
results .7mm and .3PPM. The 'Range: Published Baseline Dist. – Measured Baseline Dist.' is just the high and low range of the 'Diff' column from page one. Lastly, the results of the T-tests are displayed. Do not assume that if the T-test is passed that no further review is necessary. I have seen cases where I had questionable results yet still passed the T-test.



Pages three and four contain a more complete report than the summary on page one. The EDM Specifications are the expected error and are the values entered by the user when the project was created. Our statistical Null Hypothesis is that the EDM contains no error, i.e. the constant and scale error is 0.0 or there is no difference between measured distances and the published distances. The standard error of unit weight should be close to one. The closer the value is to one the more consistent the results are to the expected values i.e., the EDM Specification of +-2mm + 2PPM.

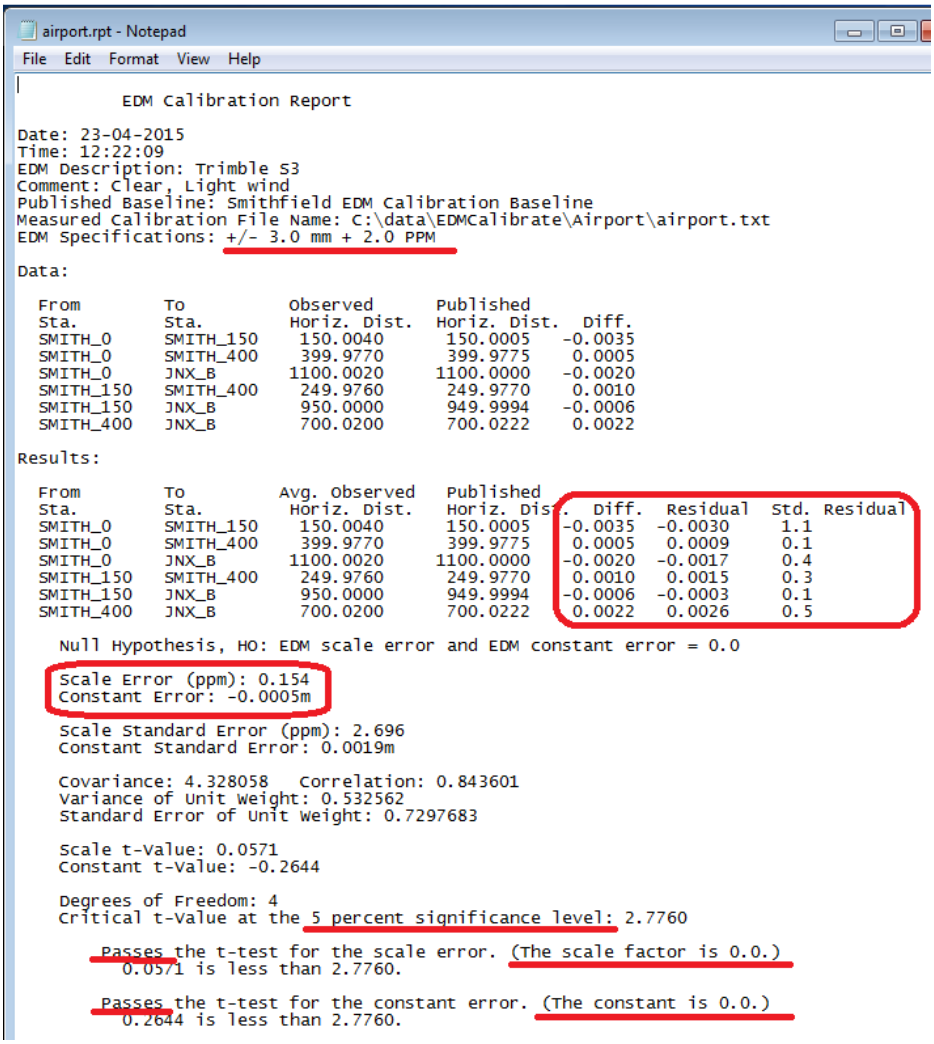


Page 4/4 shows degree of freedom, DOF, which is a measure of the redundancy. Since we are solving for two unknown values, the constant error and the PPM error, DOF equals the number of measurements minus 2. The results of the t-test are displayed. In this example the T-test was passed.



Reviewing the Report File: Calibration Using a Properly Adjusted EDM

Whenever an EDM calibration project is processed an ASCII .rpt file is created. This file will be located in the same folder as the measurement file and will have the same name as the measurement file except it will have an extension of .rpt. Following is an .rpt file of an EDM calibration using a well-adjusted EDM.



airport.rpt - Notepad

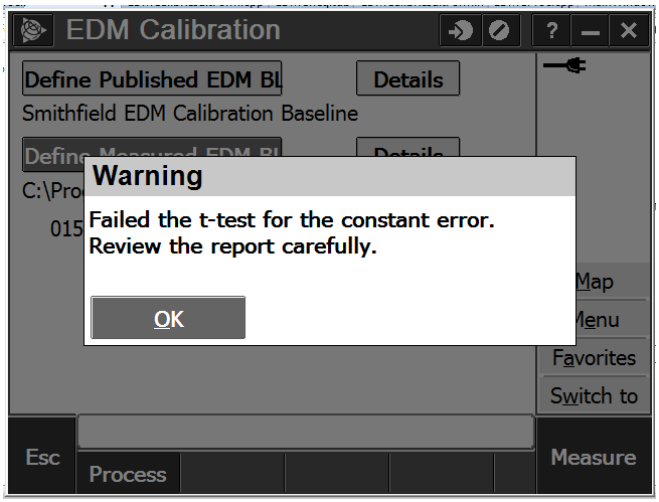
File Edit Format View Help

```
          EDM Calibration Report

Date: 23-04-2015
Time: 12:22:09
EDM Description: Trimble S3
Comment: Clear, Light wind
Published Baseline: Smithfield EDM Calibration Baseline
Measured Calibration File Name: C:\data\EDMCalibrate\Airport\airport.txt
EDM Specifications: +/- 3.0 mm + 2.0 PPM

Data:

  From        To          Observed      Published
  Sta.        Sta.        Horiz. Dist.  Horiz. Dist.   Diff.
  SMITH_0     SMITH_150    150.0040      150.0005    -0.0035
  SMITH_0     SMITH_400    399.9770      399.9775     0.0005
  SMITH_0     JNX_B       1100.0020     1100.0000    -0.0020
  SMITH_150   SMITH_400    249.9760      249.9770     0.0010
  SMITH_150   JNX_B        950.0000      949.9994    -0.0006
  SMITH_400   JNX_B        700.0200      700.0222     0.0022

Results:

  From        To          Avg. Observed   Published
  Sta.        Sta.         Horiz. Dist.   Horiz. Dist.  Diff.  Residual  Std. Residual
  SMITH_0     SMITH_150    150.0040       150.0005    -0.0035  -0.0030     1.1
  SMITH_0     SMITH_400    399.9770       399.9775     0.0005   0.0009     0.1
  SMITH_0     JNX_B       1100.0020      1100.0000    -0.0020  -0.0017     0.4
  SMITH_150   SMITH_400    249.9760       249.9770     0.0010   0.0015     0.3
  SMITH_150   JNX_B        950.0000       949.9994    -0.0006  -0.0003     0.1
  SMITH_400   JNX_B        700.0200       700.0222     0.0022   0.0026     0.5

    Null Hypothesis, HO: EDM scale error and EDM constant error = 0.0

    Scale Error (ppm): 0.154
    Constant Error: -0.0005m

    Scale Standard Error (ppm): 2.696
    Constant Standard Error: 0.0019m

    Covariance: 4.328058   Correlation: 0.843601
    Variance of Unit Weight: 0.532562
    Standard Error of Unit Weight: 0.7297683

    Scale t-Value: 0.0571
    Constant t-Value: -0.2644

    Degrees of Freedom: 4
    Critical t-Value at the 5 percent significance level: 2.7760

        Passes the t-test for the scale error. (The scale factor is 0.0.)
          0.0571 is less than 2.7760.

        Passes the t-test for the constant error. (The constant is 0.0.)
          0.2644 is less than 2.7760.
```

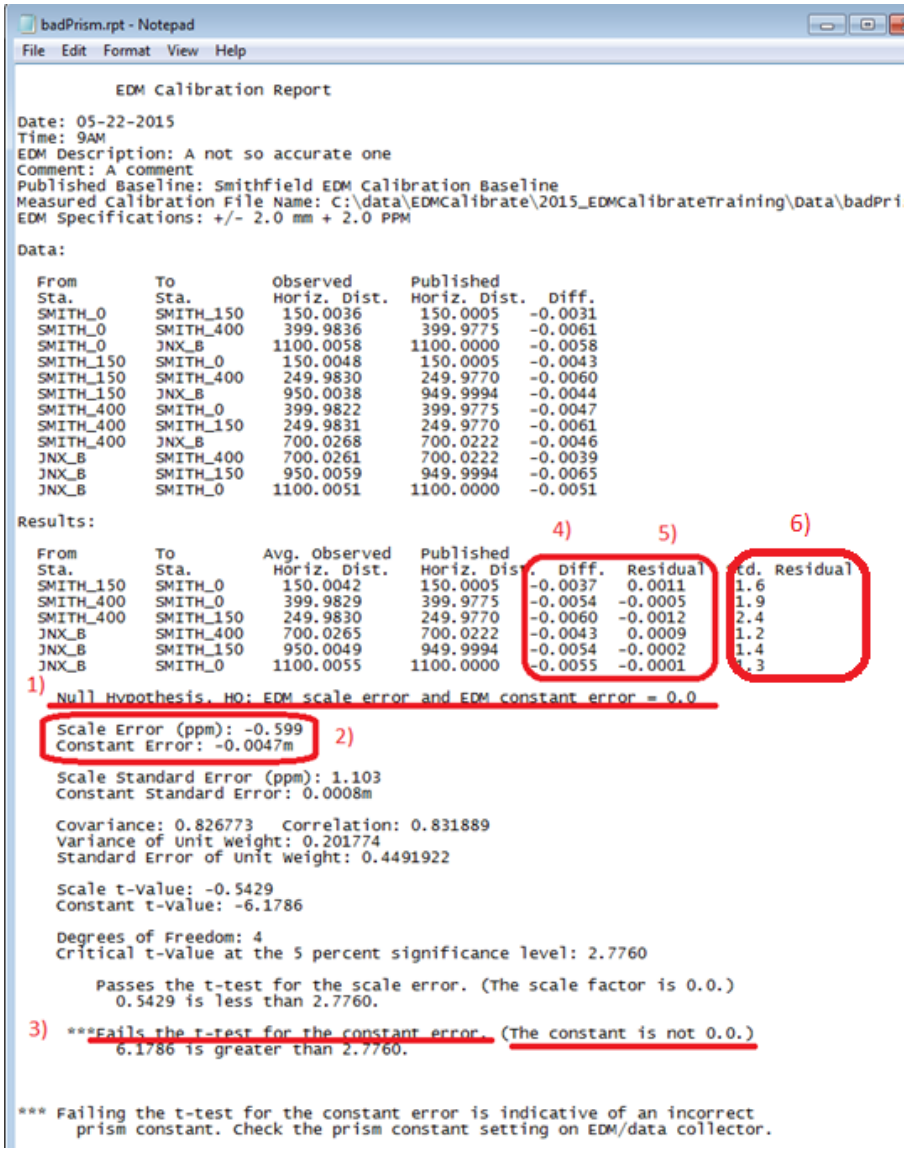
1) The above report shows that the EDM has a constant error of -0.5 mm and 0.154 ppm. Statistically speaking you cannot distinguish those computed errors from 0.0 indicating that the EDM is operating within its specifications.
2) The values in the “Diff.” cluster around 0.0 without positive or negative values predominating indicating there is no systematic error.
3) All but one of the standardized residuals is less than one.
4) The t-test is passed for both the scale and the constant value.

Reviewing the Report File: Calibration Where the Wrong Prism Constant Was Used

If you fail the t-test for the constant error you will first be warned after pressing the ‘Process button’. In most cases if you fail the t-test there is something wrong with the calibration. In a few instances the calibration passes the t-test when there is still something questionable with the calibration. Do not rely only on the t-test as an indicator of a good calibration. Review the entire report.



The following report is from an EDM calibration where the surveyor used a mismatched prism and total station.



badPrism.rpt - Notepad

File Edit Format View Help

```
          EDM Calibration Report

Date: 05-22-2015
Time: 9AM
EDM Description: A not so accurate one
Comment: A comment
Published Baseline: Smithfield EDM Calibration Baseline
Measured Calibration File Name: C:\data\EDMCalibrate\2015_EDMCalibrateTraining\Data\badPri
EDM Specifications: +/- 2.0 mm + 2.0 PPM

Data:

  From        To          Observed      Published
  Sta.        Sta.        Horiz. Dist.  Horiz. Dist.  Diff.
  SMITH_0     SMITH_150    150.0036      150.0005   -0.0031
  SMITH_0     SMITH_400    399.9836      399.9775   -0.0061
  SMITH_0     JNX_B       1100.0058     1100.0000   -0.0058
  SMITH_150   SMITH_0      150.0048      150.0005   -0.0043
  SMITH_150   SMITH_400    249.9830      249.9770   -0.0060
  SMITH_150   JNX_B        950.0038      949.9994   -0.0044
  SMITH_400   SMITH_0      399.9822      399.9775   -0.0047
  SMITH_400   SMITH_150    249.9831      249.9770   -0.0061
  SMITH_400   JNX_B        700.0268      700.0222   -0.0046
  JNX_B       SMITH_400    700.0261      700.0222   -0.0039
  JNX_B       SMITH_150    950.0059      949.9994   -0.0065
  JNX_B       SMITH_0     1100.0051     1100.0000   -0.0051

Results:                                                    4)        5)        6)

  From        To          Avg. Observed   Published
  Sta.        Sta.         Horiz. Dist.   Horiz. Dist.   Diff.    Residual  Std. Residual
  SMITH_150   SMITH_0      150.0042       150.0005   -0.0037   0.0011    1.6
  SMITH_400   SMITH_0      399.9829       399.9775   -0.0054  -0.0005    1.9
  SMITH_400   SMITH_150    249.9830       249.9770   -0.0060  -0.0012    2.4
  JNX_B       SMITH_400    700.0265       700.0222   -0.0043   0.0009    1.2
  JNX_B       SMITH_150    950.0049       949.9994   -0.0054  -0.0002    1.4
  JNX_B       SMITH_0     1100.0055      1100.0000   -0.0055  -0.0001    1.3
1)
  Null Hypothesis. HO: EDM scale error and EDM constant error = 0.0

  Scale Error (ppm): -0.599
  Constant Error: -0.0047m    2)

  Scale Standard Error (ppm): 1.103
  Constant Standard Error: 0.0008m

  Covariance: 0.826773   Correlation: 0.831889
  Variance of Unit Weight: 0.201774
  Standard Error of Unit Weight: 0.4491922

  Scale t-Value: -0.5429
  Constant t-Value: -6.1786

  Degrees of Freedom: 4
  Critical t-Value at the 5 percent significance level: 2.7760

      Passes the t-test for the scale error. (The scale factor is 0.0.)
        0.5429 is less than 2.7760.

3)  ***Fails the t-test for the constant error. (The constant is not 0.0.)
        6.1786 is greater than 2.7760.


*** Failing the t-test for the constant error is indicative of an incorrect
    prism constant. Check the prism constant setting on EDM/data collector.
```

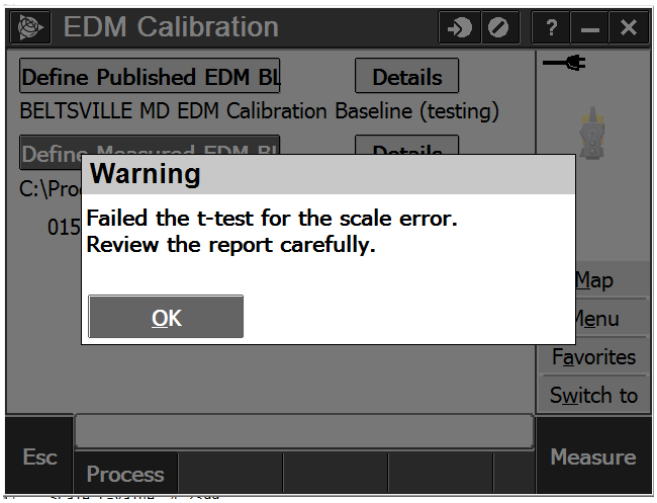
The preceding report was generated from data that was collected with an inappropriate prism. The user mistakenly used a prism that had the wrong offset for the total station that he was using. Note the following:

1) The Null Hypothesis is the default condition that we are testing. Our assumption is: The EDM we are testing has no systematic error, neither a constant error nor a PPM error. The measured distances should be the same as the published distances. We are using statistics to determine whether this is a statistically valid assumption.

2) The constant error is -4.7mm's or -.015'. Modern EDM's are certainly capable of measuring better than this. The ppm error is -0.6, well within capabilities of modern EDM's.
3) Notice that the t-test fails indicating there is a systematic constant error, i.e. the EDM probably has an incorrect prism constant.
4) Notice the 'Diff.' column and how there is a consistent negative value in the range of 3-6mm indicating a systematic error.
5) Notice the 'Residual' column. All the values are 1 mm or less with a roughly equal number of positive and negative values. This value is the corrected measured distance – the published distance. If distances are corrected using the computed scale and ppm error then decent results are obtained.
6) While all the standardized residuals are above 1, none are as high as 3.0. The key to analyzing this calibration is the consistent negative values in the Diff columns and a modern EDM should not have a 5mm constant error, and the t-test for the constant error failed.
7) Look at the entire report. Do not just look at the results of the t-test. Look at the computed scale error, the constant error, the differences, the residuals and the results of the statistical tests. As with all least squares reports, there is never one single value that can be relied on to determine if you have an adequate analysis. The report has to be reviewed in whole.

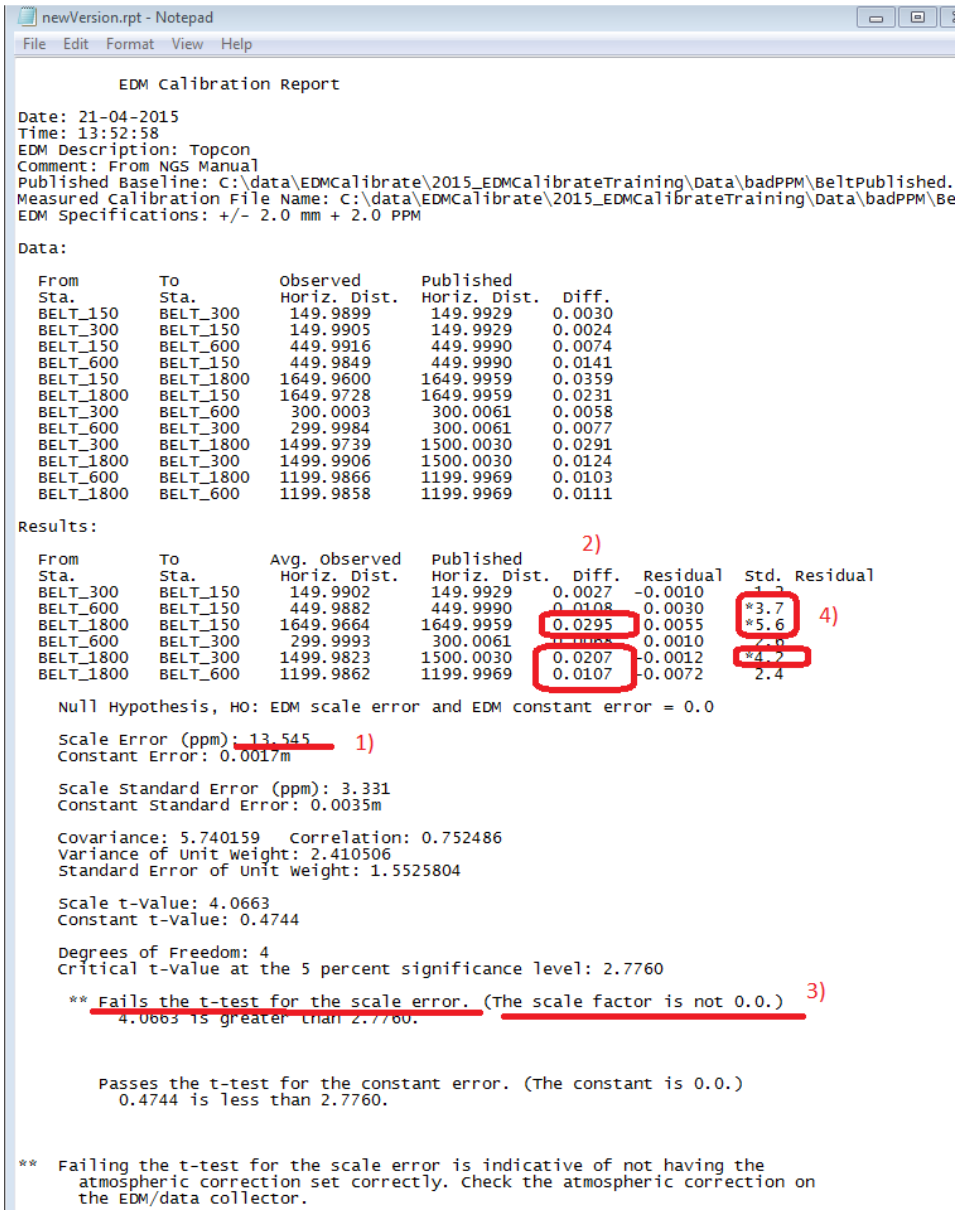
Reviewing the Report File: Calibration Where the Scale Factor is Incorrect

If you fail the t-test for the scale, PPM error, you will first be warned after pressing the 'Process button'. In most cases if you fail the t-test there is something wrong with the calibration. In a few instances the calibration passes the t-test when there is still something questionable with the calibration. Do not rely only on the t-test as an indicator of a good calibration. Review the entire report.



The following report is from the example found in the NGS manual, [NOS NGS-10: Use of Calibration Base Lines].

1) In this example the EDM has an excessive PPM error of 13.5 PPM. With a PPM error there is more error in longer distances than there are in shorter distances.
2) In the 'Diff' column notice the 150m distance has a difference of .002-.003m while the 1650m distance has a 'Diff' error of .02-.03m. Also notice that all the 'Diff' distances are positive indicating a systematic error.
3) Finally, note that the constant error passes the t-test but the PPM error does not pass the t-test.
4) Several values in the Standardized Residual columns have been flagged with an '*'. Any standardized residual above three is suspect and should be reviewed.



newVersion.rpt - Notepad

File Edit Format View Help

EDM Calibration Report

Date: 21-04-2015
Time: 13:52:58
EDM Description: Topcon
Comment: From NGS Manual
Published Baseline: C:\data\EDMCalibrate\2015_EDMCalibrateTraining\Data\badPPM\BeltPublished.
Measured Calibration File Name: C:\data\EDMCalibrate\2015_EDMCalibrateTraining\Data\badPPM\Be
EDM Specifications: +/- 2.0 mm + 2.0 PPM

Data:

From Sta.	To Sta.	Observed Horiz. Dist.	Published Horiz. Dist.	Diff.
BELT_150	BELT_300	149.9899	149.9929	0.0030
BELT_300	BELT_150	149.9905	149.9929	0.0024
BELT_150	BELT_600	449.9916	449.9990	0.0074
BELT_600	BELT_150	449.9849	449.9990	0.0141
BELT_150	BELT_1800	1649.9600	1649.9959	0.0359
BELT_1800	BELT_150	1649.9728	1649.9959	0.0231
BELT_300	BELT_600	300.0003	300.0061	0.0058
BELT_600	BELT_300	299.9984	300.0061	0.0077
BELT_300	BELT_1800	1499.9739	1500.0030	0.0291
BELT_1800	BELT_300	1499.9906	1500.0030	0.0124
BELT_600	BELT_1800	1199.9866	1199.9969	0.0103
BELT_1800	BELT_600	1199.9858	1199.9969	0.0111

Results:

2)

From Sta.	To Sta.	Avg. Observed Horiz. Dist.	Published Horiz. Dist.	Diff.	Residual	Std. Residual
BELT_300	BELT_150	149.9902	149.9929	0.0027	-0.0010	1.2
BELT_600	BELT_150	449.9882	449.9990	0.0108	0.0030	*3.7
BELT_1800	BELT_150	1649.9664	1649.9959	0.0295	0.0055	*5.6
BELT_600	BELT_300	299.9993	300.0061	0.0068	0.0010	2.0
BELT_1800	BELT_300	1499.9823	1500.0030	0.0207	-0.0012	*4.2
BELT_1800	BELT_600	1199.9862	1199.9969	0.0107	-0.0072	2.4

4)

Null Hypothesis, HO: EDM scale error and EDM constant error = 0.0

Scale Error (ppm): 13.545 1)
Constant Error: 0.0017m

Scale Standard Error (ppm): 3.331
Constant Standard Error: 0.0035m

Covariance: 5.740159 Correlation: 0.752486
Variance of Unit Weight: 2.410506
Standard Error of Unit Weight: 1.5525804

Scale t-Value: 4.0663
Constant t-Value: 0.4744

Degrees of Freedom: 4
Critical t-Value at the 5 percent significance level: 2.7760

** Fails the t-test for the scale error. (The scale factor is not 0.0.) 3)
4.0663 is greater than 2.7760.

Passes the t-test for the constant error. (The constant is 0.0.)
0.4744 is less than 2.7760.

** Failing the t-test for the scale error is indicative of not having the atmospheric correction set correctly. Check the atmospheric correction on the EDM/data collector.