Using the Windows Program, EDMCheq.exe, (EDM Calibration)

Introduction

EDMCheq.exe is a NCDOT stand-alone Windows program that will create, edit and process EDM Calibration data files. The purpose of an EDM calibration is to determine the scale and constant error of an EDM using a NGS calibration baseline based upon measured raw data.

All algorithms and formulas used in the EDMCheq.exe came from the National Geodetic Survey technical memorandum entitled "NOAA Technical Memorandum NOS NGS-10: Use of Calibration Base Lines, by Fronczek, December 1977, reprinted 1980, 38 pp." Some additional formulas were obtained from the NGS program calibrat.bas source code.

One of the best resources for EDM calibration information is the NGS website http://www.ngs.noaa.gov/CBLINES/calibration.html.

For information on North Carolina EDM Calibration baselines go the following website http://portal.ncdenr.org/web/lr/geodetic/maps/edm.

Preparing Data Files

When processing an EDM calibration session using the NGS file format, both the published and measured data sets need to be used.

EDMCheq .exe uses the same data input file format as the NGS program calibrat. The published data consists of the horizontal distances between baseline monuments defined from either a user-defined data file or from one of the predefined NC calibration baselines. Another data file contains the reduced horizontal distances between baseline monuments measured in the field.

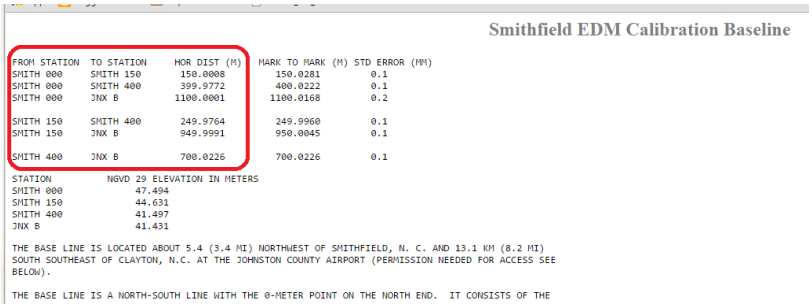
All the data for the published baselines in North Carolina are built into to program. Both the published and the measured data files use the same type records and format. Data records consist of three fields, The EDM station name, the prism station name, and the horizontal distance, either published or measured. The fields are separated by either commas or spaces.

Following is an example of a data file containing the published data for a baseline. The station names in the following example are alphanumeric. There are no naming restrictions other than not using spaces or commas in the station names. Every station name must exist in both the published and measured files.

```
SMITH_0,SMITH_150,150.0008
SMITH_0,SMITH_400,399.9772
```

```
SMITH_0,JNX_B,1100.0001
SMITH_150,SMITH_400,249.9764
SMITH_150,JNX_B,949.9991
SMITH_400,JNX_B,700.0226
```

Following is a portion of the data sheet for the Smithfield NC NGS Baseline. Notice that the published horizontal distances match the distances in the above listing. The NC EDM calibration data sheets can be found at the following website: http://www.ncgs.state.nc.us/Pages/edm.aspx.



Smithfield EDM Calibration Baseline

FROM STATION	TO STATION	HOR DIST (M)	MARK TO MARK (M)	STD ERROR (MM)
SMITH 000	SMITH 150	150.0008	150.0281	0.1
SMITH 000	SMITH 400	399.9772	400.0222	0.1
SMITH 000	JNX B	1100.0001	1100.0168	0.2
SMITH 150	SMITH 400	249.9764	249.9960	0.1
SMITH 150	JNX B	949.9991	950.0045	0.1
SMITH 400	JNX B	700.0226	700.0226	0.1

STATION	NGVD 29 ELEVATION IN METERS
SMITH 000	47.494
SMITH 150	44.631
SMITH 400	41.497
JNX B	41.431

THE BASE LINE IS LOCATED ABOUT 5.4 (3.4 MI) NORTHWEST OF SMITHFIELD, N. C. AND 13.1 KM (8.2 MI) SOUTH SOUTHEAST OF CLAYTON, N.C. AT THE JOHNSTON COUNTY AIRPORT (PERMISSION NEEDED FOR ACCESS SEE BELOW).

THE BASE LINE IS A NORTH-SOUTH LINE WITH THE 0-METER POINT ON THE NORTH END. IT CONSISTS OF THE

If not using one of the predefined baselines, the published data file needs to be created using an ASCII text editor such as Notepad or UltraEdit, The published data can alternately be input using the EDMCheq.exe user interface.

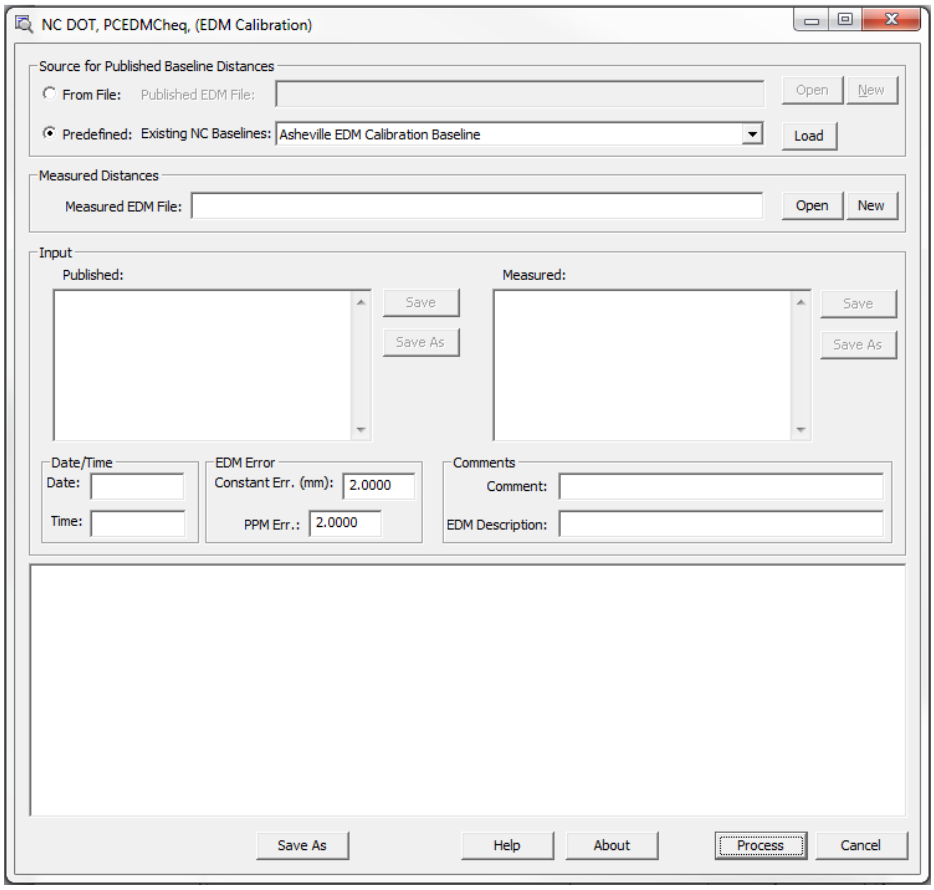
Following is an example of a data file containing the measured data. All the station names found in the measured file need to exist in the published data file. There needs to be a minimum of three baseline stations and three baseline measurements. All distances, both published and measured, need to be horizontal distances. As with all least squares problems, the more redundant measurements that are taken the more confidence you will have in the solution.

```
SMITH_0,SMITH_150,150.0048
SMITH_0,SMITH_400,399.9773
SMITH_0,JNX_B,1100.0032
SMITH_150,JNX_B,950.0025
SMITH_400,JNX_B,700.026
SMITH_150,SMITH_400,249.9762
SMITH_0,SMITH_400,399.9819
```

NGS publishes the baseline data in metric units. EDMCheq.exe is currently set up to only work in meters. When collecting the baseline distances collect them in meters or convert the distances to metric before processing.

Running EDMCheq.exe

EDMCheq.exe is part of the NCDOT workspace. If you are running a NCDOT computer you should find the program EDMCheq.exe in the following folder, C:\NCDOT_V8_WORKSPACE\LOCATION_STDS\Standards\appl. There should also be a file called baselines.dat in the same folder. Baselines.dat contains the data for all the published baselines in North Carolina. This file needs to be in the same folder as EDMCheq.exe file. Double-click EDMCheq.exe to start the program. A short cut could be created for convenience. The program consists of a single dialog box as shown.



Designating Data Files

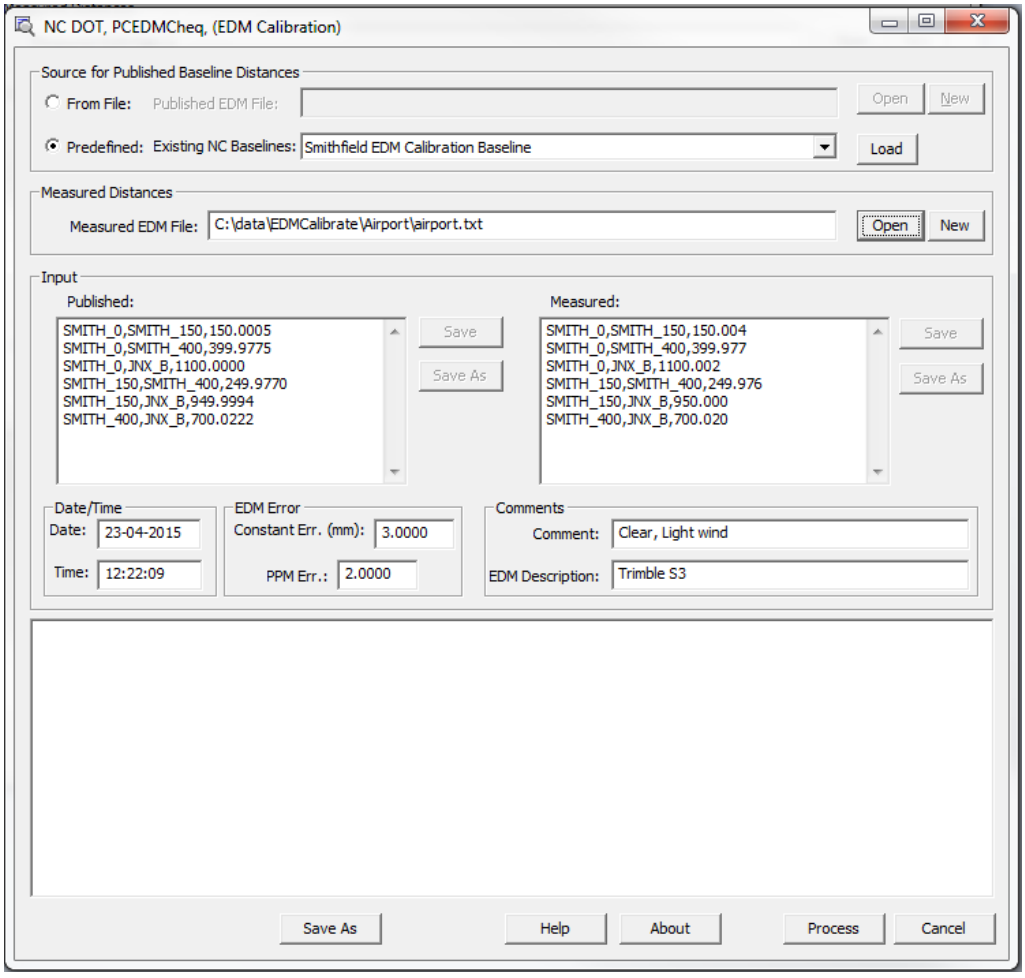
Both the published data and the measured data need to be designated:

> **Published EDM File**: The published data contains the station names and published horizontal distances for the calibration baseline being used. For NC DOT users the baseline being used should be available as one of the predefined baseline options. Alternately, the user can create a data file containing the published distances. If you are using one of the predefined baselines you will need to use the same point naming scheme as the predefined baselines. If the user needs to

create a published baseline file he can use the ‘Open’ button to designate an existing file, or he can use the ‘New’ button to create a new data file. One of the conveniences of the NGS format is that most users will always return to the same calibration baseline. So the user typically only has to define the ‘Published EDM File:’ once.

Measured EDM File: The Measured EDM file contains the station names and the measured horizontal distances between the baseline monuments. Use the ‘Open’ button to designate an existing data file .Use the ‘New’ button to create a new data file. This file can be manually created or it could have been created using a total station using the NCDOT TSC3 program EDMCheq.

Following is the EDM Calibration dialog box after both the published and the measured data source have been chosen. If choosing one of the predefined baselines, first pick the ‘Predefined’ radio button. Then choose the correct baseline from the combo box list. Then press the ‘Load’ button. After choosing the data source the contents are displayed in the edit fields. These values can be edited and saved to the same file using the ‘Save’ button or another file using the ‘Save As’ option. If a new calibration is being performed, use the ‘New’ button to designate the new data file name and then enter the data into the edit box and ‘Save’ the data once input is completed. The data file can alternately be created using any ASCII text editor.

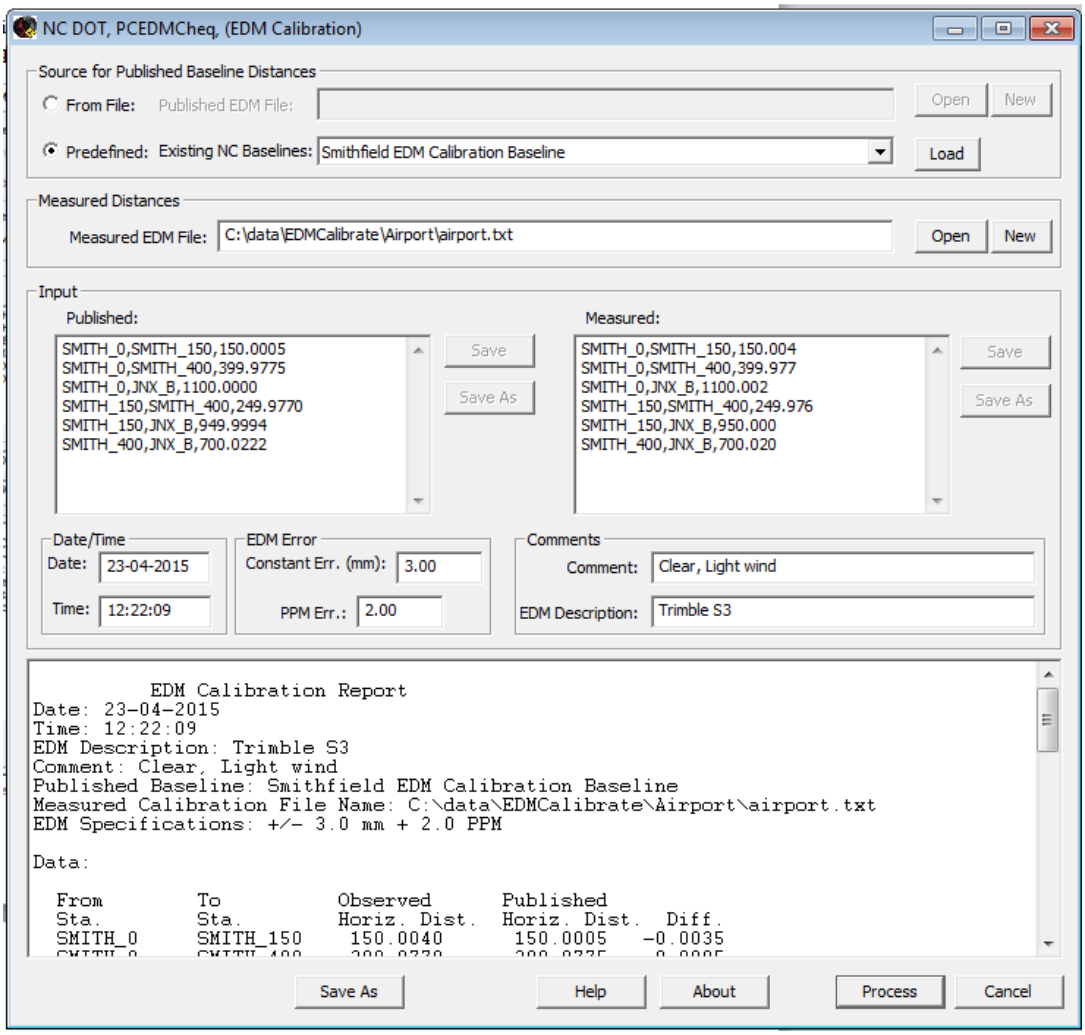


Date/Time, EDM Error, Comments

In addition to the published and measured data there are six fields that need to be filled out. The fields, Comment, EDM Description, Date, and Time are all text fields that have no impact on any computations or processing. These fields only become part of the final report. The Constant Err. and PPM Err. define the predicted accuracy of the EDM being tested. EDM specifications as published by the EDM manufacturers are commonly entered here. These values are used in the computation of covariance, correlation, variance of Unit weight and standard error of unit weight. Additionally these values are used by the program to compute the standardized residual column in the output report.

Processing the Data

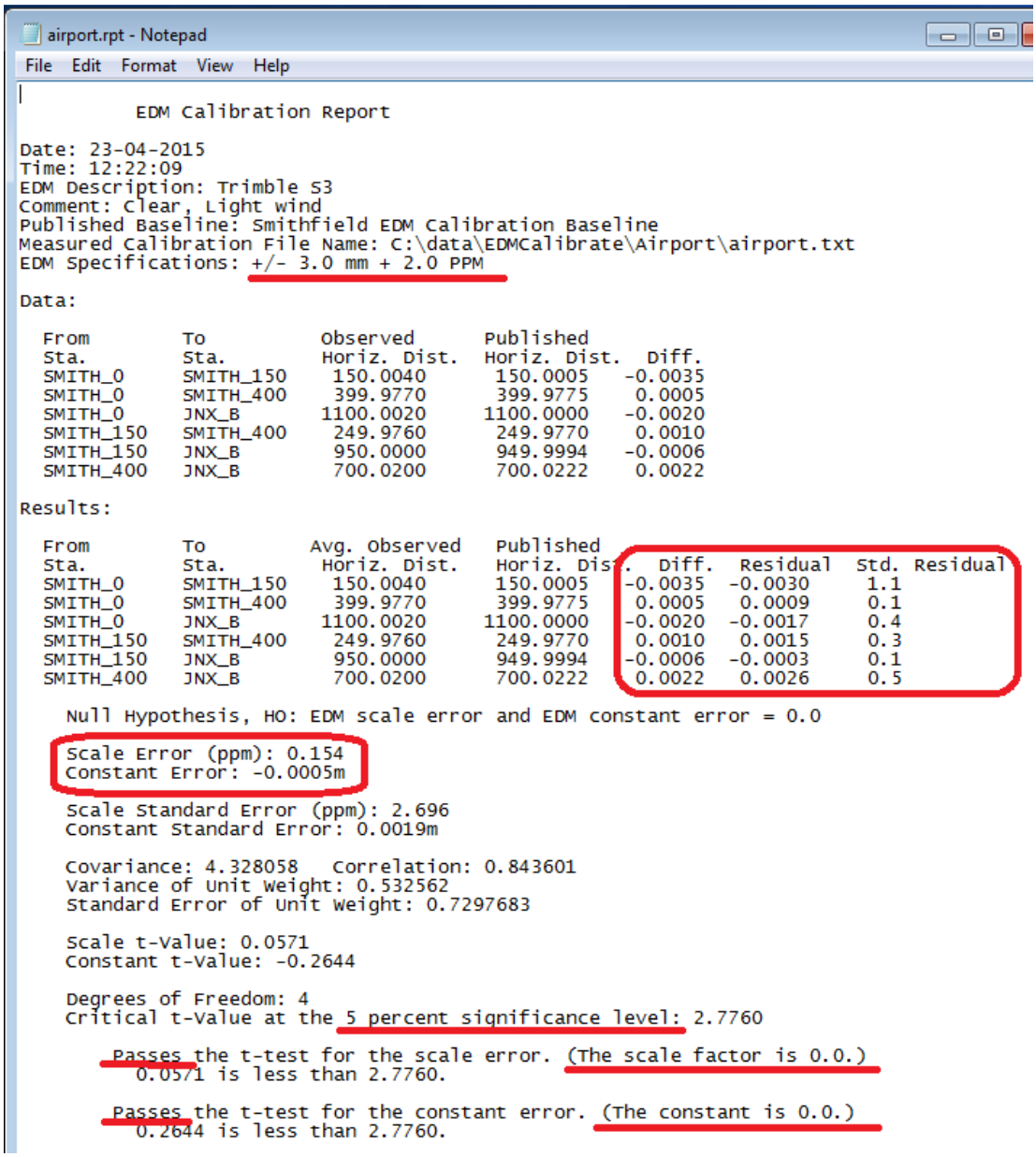
After both the published and measured data have been created and designated the **'Process'** button is pressed, and an output report is created. The report is displayed in the lower portion of the dialog box.



To save the report to an ASCII text file press the ‘Save As’ button found on the bottom of the dialog box and enter a file name.

The Report File

Following is a more complete view of the report as viewed in an ASCII text editor. The key items to review are marked in red.



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 .154 ppm.

2) Statistically speaking you cannot distinguish those computed errors from 0.0 indicating that the EDM is operating well within its specifications. This is shown from the results of the t-test. Note that the test is being performed to a 5% confidence level.

   Surveyors are probably more familiar with the chi-square test than the t-test. But the two tests serve a similar purpose. The t-test is used to test whether the computed scale error and constant error differ significantly from 0.0 scale and constant error. If the results of the t-test indicate that the scale and constant error is significantly different from 0 that is an indication that the EDM is not working properly.

   Be careful of treating the results of the t-test as a measure of the absolute correctness of the EDM. There can be instances where a passing t-test result is obtained when the scale and constant error are too large. There also can be instances though less common when you fail the t-test yet have perfectly acceptable scale and constant error results.

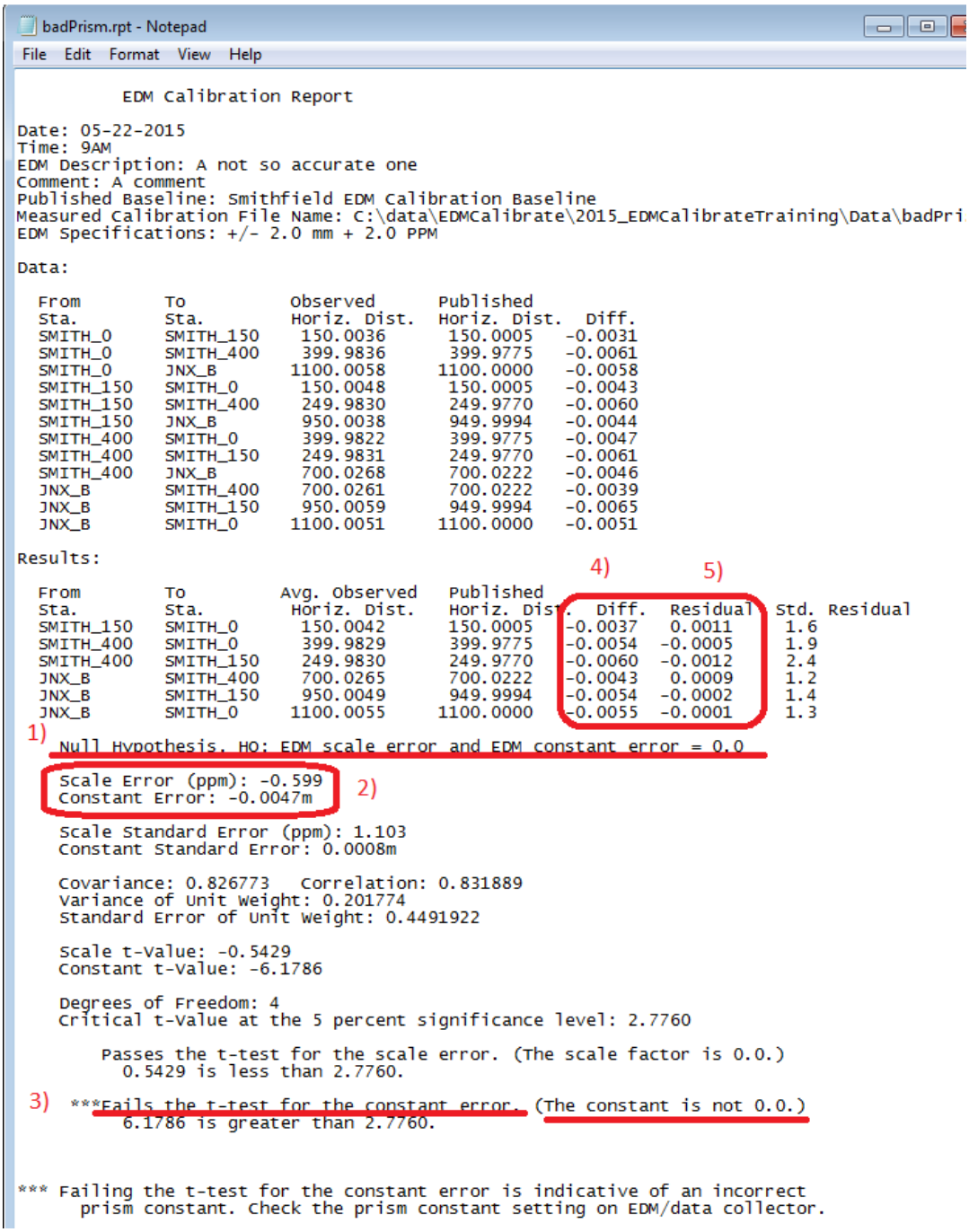
   The results of the t-test are dependent on the Scale Standard Error and the Constant Standard Error. If the standard errors are very large you may pass the t-test when the scale and/or constant error are actually too large. Also, if the standard errors are very small the t-test may fail when the scale and/or constant error are perfectly acceptable.

   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.

3) The values in the “Diff.” column cluster around 0.0 without positive or negative values predominating indicating there is no systematic error.

4) The standardized residual is comparing whether the expected distance error is the same as the measured distance error. The measured distance error is the values in the ‘Diff.’ column. The expected distance error is computed from each measured distance and the expected error, 3mm & 2ppm, in our example. The standardized residual is computed by dividing the measured error by the expected error. Since we are hoping that the measured errors and expected errors be the same, we are expecting the standardized residuals to be close to one. In the above report all the standardized residuals are less than one indicating that the measured errors were less than what we were expecting. If any of the standardized residuals were greater than three, they would have been marked with an ‘*’ indicating a potential problem.

A Report File with a Constant Error



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)
  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 assumption that we are testing. Our assumption is: The EDM we are testing is well adjusted and has no systematic error with a constant error of 0.0 and a PPM error of 0.0. Another way of phrasing this is that we are testing whether the measured distances are the same as the published distances. We are using statistics to determine whether this is a statistically valid assumption.

2) The computed constant error is -4.7mm's or -.015'. Modern EDM's are certainly capable of measuring better than this. The ppm error is -.6, well within capabilities of modern EDM's. The most common cause of an excessive constant error is an incorrect prism offset. This is noted in the report.

3) Notice that the results of the t-test indicate that the null hypothesis is rejected for the constant error, i.e. the EDM has a systematic constant error.

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. For the above example the residual is computed as follows:

$$\left((-0.599 \times measuredDist \div 1000000.0 + \ -0.0047) + measuredDist\right) - publishedDist$$

This value is the (corrected measured distance – the published distance). If distances are corrected using the computed scale and ppm error then good results are obtained.

6) 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.

A Report File with a PPM Error

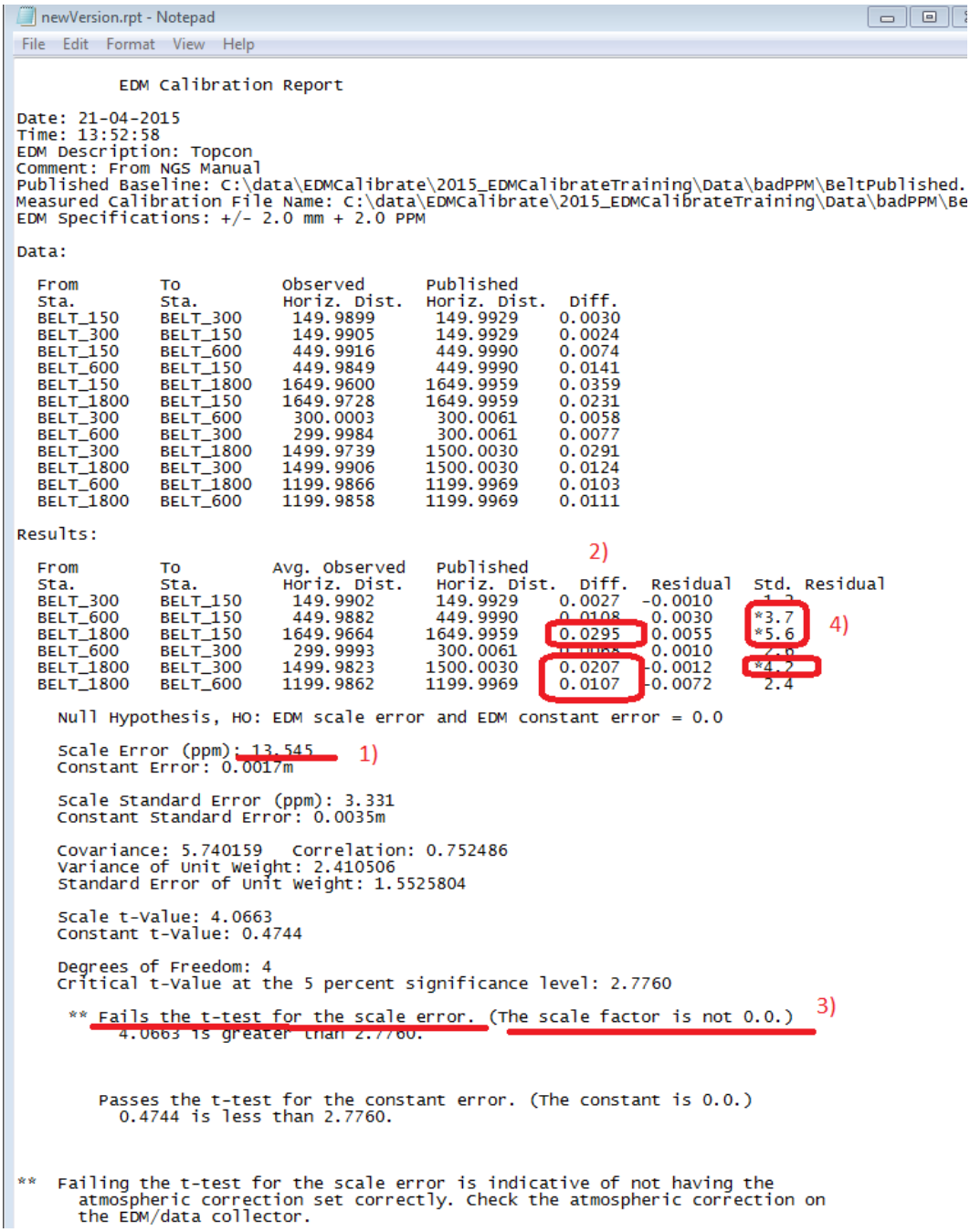
The following report is from the example found in the NGS manual, NOS NGS-10: Use of Calibration Base Lines.

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. The most common cause of a PPM error is not accounting for the atmospheric correction correctly. This is noted in the report.

2) In the 'Diff' column notice the 150m distance has a difference of .003m while the 1650m distance has a 'Diff' error of .02m. Also notice that all the 'Diff' distances are positive indicating a positive 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 is marked with an '*' 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        To          Observed      Published
  Sta.        Sta.        Horiz. Dist.  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        To          Avg. Observed   Published
  Sta.        Sta.        Horiz. Dist.    Horiz. Dist.  Diff.   Residual  Std. Residual
  BELT_300    BELT_150     149.9902       149.9929    0.0027   -0.0010     1.3
  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   4)
  BELT_600    BELT_300     299.9993       300.0061    0.0068    0.0010     1.0
  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

    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.
```