SYMMETRON
ELECTRONIC APPLICATIONS

# Symmetron VeriVane

## Version 2.1.2.2

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ELECTRONIC APPLICATIONS

**CONTENTS**

# 1. INTRODUCTION

VeriVane is an instrument which is used to verify the correct operation of wind vanes. That is to say, the vane's actual (geometrical) angles are compared to the measured ones (the ones that are read in the instrument's output). In its current version, VeriVane is suitable for wind vanes with analog output, either potentiometric ones, or with an analog voltage output without a reference voltage, or with an analog current output, which will be terminated with a resistor. According to certain parameters (tolerances) the user defines in VeriVane's accompanying software, the vane succeeds or fails. These data are stored in a verification (test) report, in an Excel file (actual angles compared to the measured ones, their deviation, measurement uncertainties, max deviation, along with graphs with these values).

VeriVane consists of mechanical and electronic parts.

# 2. CONNECTION METHOD OF MECHANICAL-ELECTRONIC PARTS

VeriVane consists of its **mechanical** and **electronic** part.

The first part of the mechanical part is a metallic construction, which consists of two 'H' shape pieces and 4 bars which are screwed in the 4 ends of the two 'H's, as you can see in the figure below. On the structure's upper part (on the upper 'H'), a cubic step motor is screwed via 4 screws in the appropriate connectors. Right below, a special bar is screwed, which the motor will turn, with a 0.9 angle step. By adapting the vane's wing on this bar, it will rotate exactly with the motor's step. On the lower side, a base for the vane is screwed, via a big screw. Symmetron company provides the appropriate bases for NRG, Vector and 2EN vanes. Appropriate bases can be constructed for most vanes, and even the entire structure can be reconstructed, if the vane's size is too big, such as Young 05103 and Thies First Class. The final form of the mechanical part (with an NRG vane connected) can be seen in the figure below.

The electronic part is enclosed in a box and is connected to the mechanical part (and specifically to the motor), via a cable, which you must connect to the left (circular) connector

on the box's front part. In the second connector from the left, connect VeriVane's power supply, which supplies both the electronic part and the motor. On the right part, there is a connector for a 4-pin screw terminal. Screw the wind vane's wires to this screw terminal. Specifically, the following pins are available: Ground (first from the left), Output signal (second from the left), Reference voltage (third from the left- for potentiometric vanes), and one additional 12V pin (the fourth from the left), for certain (non-potentiometric) sensors which require power supply (not a reference voltage), such as the 2EN vane. On the box's back side, there is a USB cable to connect VeriVane to the PC, so that it be recognized by its software.


## 3. SOFTWARE AND INITIALIZATION

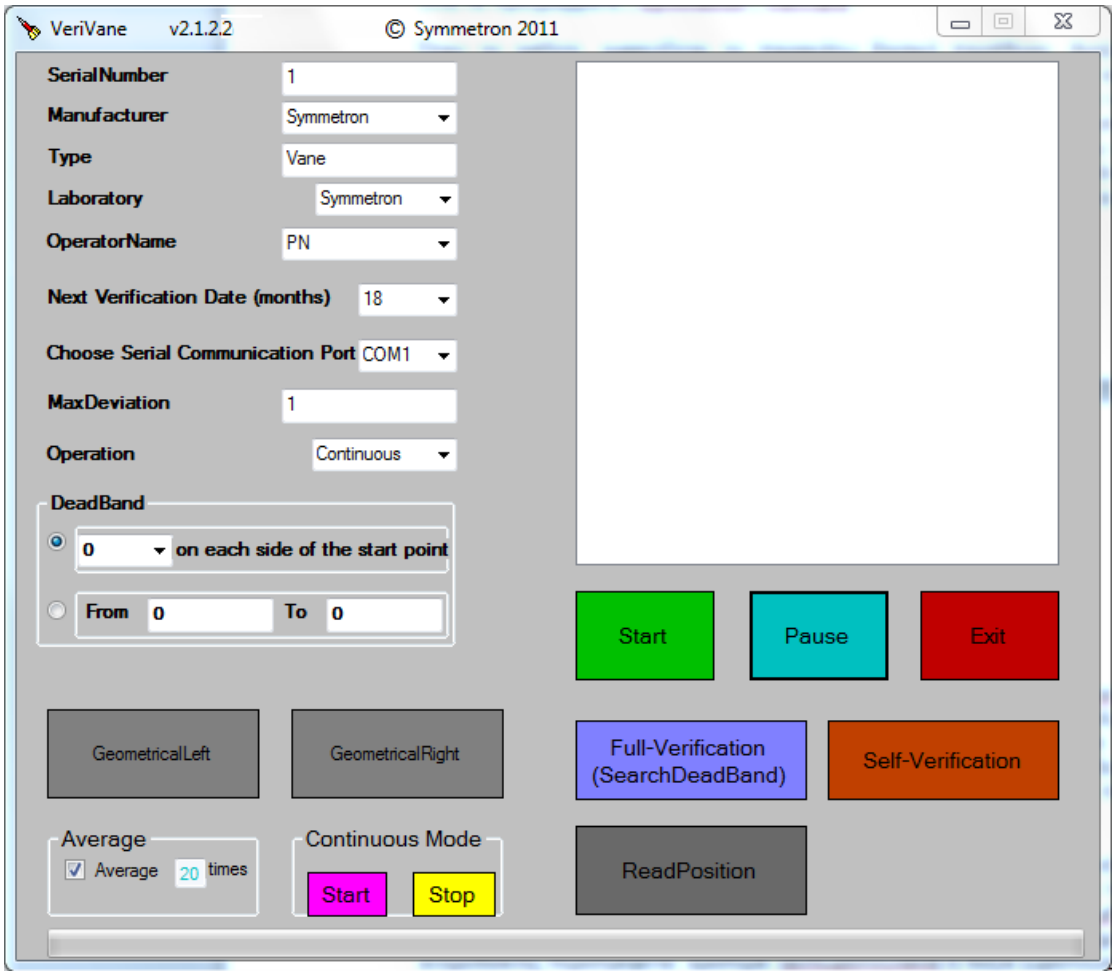
In order to start the verification process, you need the "VeriVane" software. In order to install it from the accompanying CD, follow the instructions of the file: 'VeriVane Readme (Version_2.1.2.2)_EN.txt'.

After you confirm that you have connected the vane correctly to VeriVane, that you have connected the motor's power supply and that you have connected the USB cable to a computer USB slot, you can run the software from the path: "Start | All programs | Symmetron | VeriVane".

When you start it, the main window below appears. It is not available immediately, because the software needs a few seconds to initialize. The appearing message box basically induces you to wait for the software to initialize. During the initialization, all the available (not open) computer COM ports (actual serial ones and USB ones) are being opened one by one. For each port it opens, the software checks if VeriVane is connected. When it is located, this port appears in the "Choose Serial Communication Port" field. After VeriVane is automatically located, the program locks this port and you cannot change it. The next message induces you to place the wind vane at the 0 position (the one at which its output is 0 degrees- "Geometrical 0"), which is usually indicated with two marks on its side, which must concur.

You can achieve that in three ways. Besides the obvious way, ie to move softly (in order not to harass the system) the vane to the 0 position by hand, you can click repeatedly the "Geometrical Left" or the "Geometrical Right" button until the vane reaches the 0 position.

With each click, the vane rotates to the left (anti-clockwise) or to the right (clockwise) by 0.9 degrees (the minimum measurement step). The third way, which is more user friendly, is to select "Start" from the right lower part of the window ("Continuous Mode" frame). This way, the vane rotates continuously (repeatedly) clockwise with a 0.9 degree step. When you click "Stop", the rotation stops. If with the first or the third way, you do not aim the 0 position exactly, approach it and then use the "Geometrical Left" or the "Geometrical Right" option to aim it exactly.




**NOTE**: If you have not connected VeriVane to a USB port of your computer or if you have not connected it to the power supply, the software will check all the COM ports and will not locate the device, no further action will be allowed. An error message will appear, that the device is not VeriVane and the program will close automatically. However, in case you start the program too quickly, the device may not have initialized in the USB port, and while the port is located, the software cannot communicate with the device. In any case, a message appears which induces you to check the device's connections (USB port and power supply) or to restart the program because the device did not have time to initialize.

## 4. SETTINGS ADJUSTMENT

After you have moved the vane to the "Geometrical 0" position via one of the methods described in a previous chapter, you can assign other parameters, related to the vane verification process.

The first parameter group is not related to the process's operation, but with the vane's features and the identification of the specific process. These features are apparent in the title and in the "General Data" sheet of the Excel file, which is saved as the vane's verification report in the 'C:\VeriVane_Version_2.0.0\CalReports\VerificationReports' folder. In the window's corresponding files, you can type the corresponding features which will appear in the report. Type the vane's Serial Number and Manufacturer in the corresponding fields, while in the "Type" field, besides its type (eg potentiometric), you can also type an identifying code which is indicated on the vane along with its Serial Number. In the "Laboratory" field, type the lab in which the verification was performed, while in the "Operator Name", type the name of the person which performed the test. In the "Next Verification Date" field, select after how many months you wish for the next verification date, from a drop-down list (select from 0 to 36 months).

The second parameter group is related to the process's method and deviations. Specifically, in the "Max Deviation" field, type the maximum deviation of the actual-geometrical angle and the measured angle, which will be allowed during the verification process. If the deviation in all the verification angles is not greater than this value (except for the values in the dead band), the vane passes the test, otherwise it fails. In the "Operation" field, the only available option is "Continuous", ie the wind vane's reference voltage (5V) is continuous. In a future version, the "Intermittent" option will also be available, so that it be pulsed, ie to be available only during each measurement. This has a meaning only for potentiometric vanes. In the **"Dead Band"** field, three options are available:

**i.** Select the vane's dead band via a drop-down list, as it is defined in its specifications. The exact specifications value may not be available, because, like the measuring step, multiples of 0.9 degrees (the rotation step of the motor) are available. This way, the measurements within the dead band (from 0 to x degrees and from 360-x to 360 degrees, where x the selected dead band) will appear in the report, but will not be taken into account. If measurements at x or at 360-x degrees occur, they will not be taken into account.

**ii.** Use the DeadBand values which have been found via the **'Full-Verification (SearchDeadBand)**' process (see **chapter 7**) and appear in the second option "From x To y", where x and y are the degrees found via the process mentioned and which declare that the dead band of the examined vane is between these degrees. In this case, the x and y degrees are not necessarily symmetrical to the Geometrical 0 point.

The "Average 20 times" check box on the lower left part of the window is always checked, so in each measuring position (which is defined by the measuring step), VeriVane performs 20 measurements of the angle and measures the average value.

On the right part of the software's main window, the flow of the current measurements and of the selected process, in general, appear, therefore you get a picture of the verification's flow in real time..

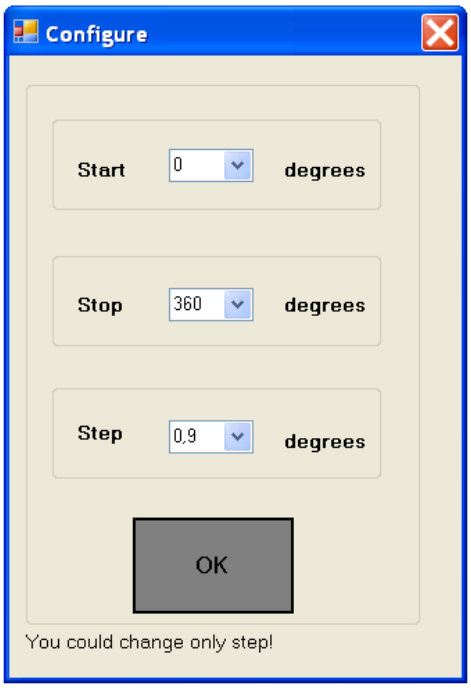
Finally, via the "Read Position" button, you can read and view the current measured angle. In case one of the verification processes (which will be discussed in the next 3 chapters) are executed at that time, this operation is not available.

After you have defined these parameters, there are 3 available verification methods, which will be discussed in the following chapters:

- **Simple verification** (chapter 5 and 6).
- **Full-Verification (Search Dead Band)** (chapter 7).
- **Self-Verification** (chapter 8).

## 5. SIMPLE VERIFICATION

Aftre you have defined the parameters you wish in the main window's fields, click the green "Start" button to start the verification process, The following window will appear.




In the "Step" field, select the measuring step via a drop-down list, which is a multiple of the motor's rotation step (0.9 degrees). During the wind vane's rotation, when it is at a measuring angle, it will pause for about 1 second to make the measurement, as described before, before it continues the rotation. It will also measure at the "Geometrical 0" position. It is worthy of note that the "Start" and "Stop" fields are not active in VeriVane's current version, as it is mentioned in the window's status bar.

If you click OK, the verification process begins, as described before, until a full circle is completed (the vane returns to the "0" position). Then, the measuring data (actual value, measured value, deviation, uncertainty) will be saved in the "Table Measures" sheet of the Excel report. However, you can also terminate the process, via the "Pause" button, before the full circle is completed. This way, only the data (angles) that have been measured up to that moment will be saved. This may be useful if you wish to have an unofficial indication if the vane operates correctly, via the first measurements, without waiting for the circle to be completed.

It must be noted that you can terminate a verification process only via the "Pause" button. The green "Start" button, the "Start" and "Stop" buttons of the "Continuous Mode" section, the "Geometrical Left" and "Geometrical Right", “ReadPosition”, “Full-Verification (SearchDeadBand)” and “Self-Verification” buttons are deactivated. Finally, the "Exit" button closes the program, therefore if you click it during the process, the data will be lost (no report will be created).

When the vane’s verification process will be completed or when you end it manually, the data of the verification report are stored in an Excel file in the "C:\VeriVane_Version_2.0.0\CalReports\VerificationReports" folder.

## 6. DATA-MEASUREMENT STORAGE

When the vane verification process is completed or when you terminated it manually, the verification data report is stored in the "C:\VeriVane_Version_2.0.0\CalReports\ VerificationReports" folder. The file name consists of the vane’s Serial Number, which you have typed in the corresponding field of the main window, and the date and time of the test’s completion.

In the "General Data" sheet, certain parameters defined in the main window appear, ie the Serial Number, the Manufacturer, the type, the laboratory, the next calibration date, the person who performed the test, the reference voltage operation (continuous or intermittent), the max deviation you have defined and the selected dead band. Moreover, the verification date, along with its start time and end time are mentioned. Finally, next to the "ITEM STATUS" cell, the verification’s result is mentioned: **PASS**, if the test was successful or **FAIL** if it was unsuccessful, according to the parameters (dead band and max deviation) you have assigned.

In the "Table Measures" sheet, there are analytical data in table form. Specifically, the data are presented in 5 columns. In the "GeometricalValue" one, the actual rotation angles of the motor are mentioned, therefore of the vane as well, in the "VaneValue" column, the angle which the vane outputs in each position is mentioned, in the "Deviation" one, the deviation between the two angles is mentioned (the difference between the column values), while in the next column, there are two fields: The "Max Deviation" one, which contains only one value, which is the maximum value of the third column, taking into account only the values for which the values of the first column (actual-geometrical values) are not in the dead band and the field “MaxDeviationFrom10To350Degrees” contains the maximum value of the third column “Deviation” for angles between 10 and 350 degrees. If the "Max Deviation" value is not greater than the max deviation you have defined in the "Max Deviation" field in the program’s main window, the verification is successful ("ITEM STATUS: **PASS**", in the ‘General Data’ sheet). Finally, in the “Uncertainty” column, the total uncertainty of each measurement appears, the calculation of which will be discussed analytically in Chapter 9.

NOTE: The reason why there is also the “MaxDeviationFrom10To350Degrees” column, besides the "Max Deviation" one is that usually the max deviation is located out of the dead band limits, but close enough to it. Moreover, the way the wind vane is supported causes its “active” part to be between these degrees, therefore with this value, we get a better picture and an additional piece of information about the most critical and interesting arc of the vane.

In the "Graph Output" sheet, the graph of the second vs the first column appears, in which the linearity of the measured vs the geometrical angle of the vane can be seen optically as well. Finally, in the "Graph Deviations" sheet, the graph of the third vs the first column appear, which also gives a picture about the linearity of the deviation between the geometrical and the measured angle.

## 7. FULL VERIFICATION (SEARCH DEAD BAND)

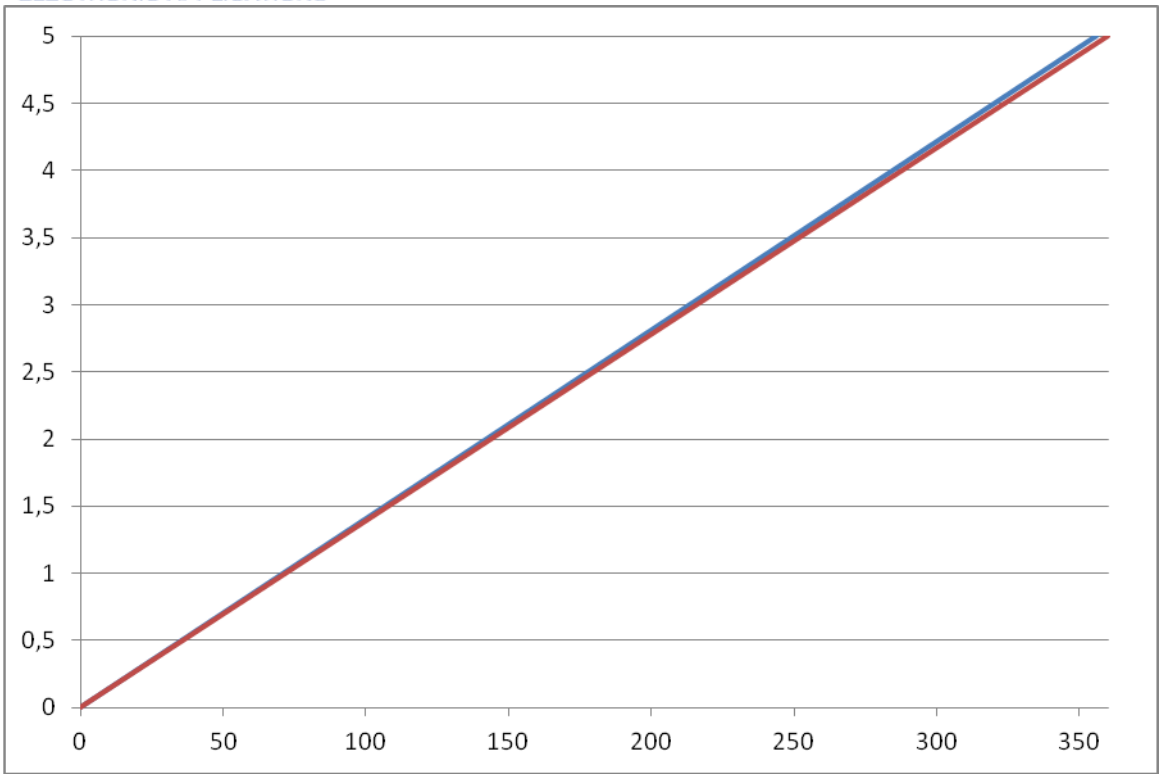
In the main window of VeriVane's accompanying software, if you click the "Full-Verification (SearchDeadBand)" button, a full calibration of the wind vane will take place. This means that besides the data acquired via the simple verification process, furthermore, the corresponding data (geometrical angle, measured angle, deviations, uncertainties, max deviation) are also acquired exactly, for counterclockwise rotation, ie rotation from 360 degrees to 0. Moreover, which degrees the vane's dead band consists of is found, in relation to the point of its initial installation- Geometrical 0. This process is performed with "Operation" = "Continuous", ie with continuous power supply, because, since the measuring step is 0.9 degrees (the only available option for this operation), there is no operational meaning to open and close the power supply for such a little time.

At first, having placed a wind vane to the "Geometrical 0" position, its clockwise rotation begins and measurements are being performed per 0.9 degrees (minimum step of the motor). In each measuring position, 20 measurements are being made, from which the average value is calculated, as the angle measurement of each position. Then, since a full rotation has been completed ($360^{o}$) and the vane returns to "Geometrical 0" position, another full rotation begins, this time counterclockwise. The measurements continue similarly. At the end of the rotation, the software finds between which angles the dead band of the vane under test is located, and it automatically appears in the fields of the second selection of Dead Band, on the left part of the main window. Based on this dead band, all calculations are made concerning which value causes the "MaxDeviation" for the normal and reverse rotation. Similarly to the simple Verification, the vane is characterized as Pass or Fail.

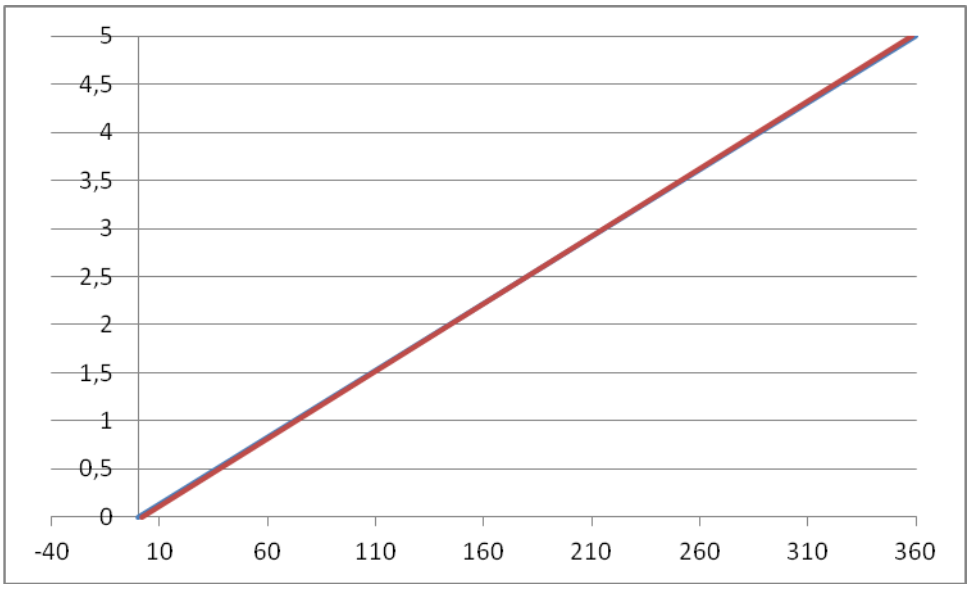
### MEASUREMENTS CORRECTION VIA SLOPE AND OFFSET PARAMETERS

However, before the verification is characterized as successful or unsuccessful, it must be noted that the linearity of the measurements calculated is not absolutely accurate, because the dead band is not located in the same degrees for all wind vanes.

- For instance, vanes such as **Young 05103** have their dead band between about 356 and 360 (or 0) degrees, therefore its linearity is located between about 0 and 356 degrees and the vane's output is changing linearly from 0 to 5V for these angles, as it appears in the graph below. The red line would be the ideal one (absolute linearity), if the wind vane had no dead band, while the blue one is the ideal one with the dead band (values in the dead band are not plotted). Therefore, in such a case, the deviation VeriVane measures is increasing as the angles are increasing, and it has a minimum value, just above 0 degrees.




- On the other hand there are vanes such as **NRG #200P**, the dead band of which is symmetrical about around 0 degrees, i.e. about between 358 and 2 degrees. Correspondingly, the graph below displays the difference between the desired linearities, with and without dead band. In this case, the deviation VeriVane measures is minimum around 180 degrees and it increases, drawing away from these angles.




In general, the dead band may not be located symmetrically around 0 (i.e. it may be between 357 and 2 degrees), therefore it is about an intermediate case.

In all these cases, VeriVane will actually measure greater deviation than the one given by the vane's manufacturer, because in the specifications, the linearity deviation tolerance outside

the dead band is mentioned (deviation concerning the blue lines), while VeriVane calculates the deviation from the linearity if there was no dead band (red line).

This problem can be solved by applying appropriate Slope and Offset factors to the vane measurements in retrospect, so that the graphs produced be rotated and moved, so that they can be compared to the red lines of the graphs above.

VeriVane, in combination with the dead band, also calculates these optimum Slope and Offset. Specifically, it calculates the deviation and the uncertainty of all values, during the correct and inverse direction of rotation, and via these, it calculates the dead band, while it mentions the max deviation in each direction. Via these deviations, it calculates the Slope and Offset which will optimize these deviations best. Therefore, there is the max deviation before and after applying the Slope and Offset. It is logical the first one not to be within specification, as explained before. The second one is the one that must be within specification.

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However, you can also terminate the process, via the “Pause” button, before the full circle is completed. This way, only the data (angles) that have been measured up to that moment will be saved, but no conclusion will be drawn, concerning the deviations and if the verification is successful, since the data are insufficient (neither has the dead band been calculated nor have the Slope and Offset been calculated and applied, since the process has not been completed). However, this may be useful if you wish to have an unofficial indication if the vane operates correctly, via the first measurements, without waiting for the process to be completed.

It must be noted that you can terminate a verification process only via the "Pause" button. The green "Start" button, the "Start" and "Stop" buttons of the "Continuous Mode" section, the "Geometrical Left" and "Geometrical Right", “ReadPosition”, “Full-Verification (SearchDeadBand)” and “Self-Verification” buttons are deactivated. Finally, the "Exit" button closes the program, therefore if you click it during the process, the data will be lost (no report will be created).

When the vane’s full verification process is completed or when you terminated it manually, the verification data report is stored in the "C:\VeriVane_Version_2.0.0\CalReports\ FullVerification(SearchDeadBand) Reports" folder. The file name consists of the vane’s Serial Number, which you have typed in the corresponding field of the main window, and the date and time of the Full-Verification’s completion.

In the "General Data" sheet, certain parameters defined in the main window appear, ie the Serial Number, the Manufacturer, the type, the laboratory, the next calibration date, the person who performed the test, the reference voltage operation (continuous or intermittent), and the max deviation you have defined. Moreover, the verification date, along with its start time and end time are mentioned. Furthermore, the brief results of the verification are mentioned, i.e. the Slope and Offset calculated, and the max deviation before and after applying them. Finally, next to the "Item Status" and “New Item Status” cells, the verification’s result is mentioned, before and after applying the Slope and Offset factors correspondingly: **PASS**, if the test was successful or **FAIL** if it was unsuccessful, according to the parameters (dead band and max deviation) you have assigned. The second result is the accurate one.

In the "Table Measures" sheet, there are analytical data in table form. Specifically, the data are presented in 16 columns. In the "GeometricalValue" one, the actual rotation angles of the motor are mentioned, therefore of the vane as well, in the "VaneValue (Right Direction)" column, the angle which the vane outputs in each position is mentioned, in the "Deviation (Right Direction)" one, the deviation between the two angles is mentioned (the difference between the column values) during the clockwise rotation, while in the next column ("Max

Deviation (Right Direction)"), which contains only one value, which is the maximum value of the third column, taking into account only the values for which the values of the first column (actual-geometrical values) are not in the dead band. In the fifth column “Uncertainty (Right Direction)” the total uncertainty of each measurement is mentioned, the calculation of which will be discussed thoroughly in Chapter 9, while the sixth column “MaxDeviationFrom10To350Degrees” contains the maximum value of the third column “Deviation” for angles between 10 and 350 degrees. In the next columns: "GeometricalValue (Inverse Direction)", "VaneValue (Inverse Direction)", "Deviation (Inverse Direction)", "Max Deviation (Inverse Direction)", “Uncertainty (Inverse Direction)”, “Max Deviation (Inverse Direction) From10To350 Degrees”, the corresponding data for the counterclockwise rotation are mentioned. Moreover, in the next column, below “Dead Band”, the calculated dead band appears, while right below, the optimum Slope and Offset calculated are mentioned. If the "Max Deviation" value is not greater than the max deviation you have defined in the "Max Deviation" field in the program’s main window, the verification is successful ("Item Status: **PASS**", in the ‘General Data’ sheet). However, as mentioned above, the final result, after the Slope and Offset application, is the one that matters. The “VaneValue (Right Direction)After Slope and Offset” column occurs after applying the Slope and Offset to the proper rotation measurements ("VaneValue (Right Direction)" column). In the ”Deviation (Right Direction) After Slope and Offset” column, the deviation of the previous column from the acual-geometrical values is calculated. Therefore, the “Max Deviation (Right Direction) From10To350 Degrees After Slope and Offset” column (the max deviation after applying the Slope and Offset, between 10 and 350 degrees) gives the final result, if the wind vane passes the test ("New Item Status: **PASS**", in the General Data sheet) or not.

In the "Graph_Output_Right_Direction", the graph of the second vs the first column appears, in which the linearity of the measured vs the geometrical angle of the vane can be seen optically as well. Similarly, for the counterclockwise rotation, there is also the graph of the eight vs the seventh column, in the "Graph_Output_Inverse_Direction" sheet. Finally, in the " Graph_Deviations_Right_Dir " sheet, the graph of the third vs the first column appear, which also gives a picture about the linearity of the deviation between the geometrical and the measured angle and the corresponding one for the counterclockwise rotation appears in the "Graph_Deviations_Inverse_Dir." Sheet, where the graph of the ninth vs the seventh column appears.

## 8. SELF VERIFICATION

In the main window of VeriVane’s accompanying software, via the “Self-Verification” button, a calibration of the VeriVane instrument itself is performed. Occasionally, you can check if the entire construction is working within the specifications.

The way this capability is handled relies on the usage of a potentiometric wind vane. Firstly, you are asked to place a wind vane of this type in “geometrical 0” position, then measurements are being performed per 0.9 degrees (minimum step of the motor). In each measurement, 20 measurements are performed, from which the average value is calculated to measure the angle of each position. Afterwards, provided that a full rotation ($360^{o}$) has been completed and that the vane returns to “Geometrical 0”, the user is asked to invert the vane’s power supply, via a message box: Invert the wires connected to the screw terminal’s first pin from the left (ground) and third pin from the left (the vane’s reference voltage-5V). The measurements continue similarly, until a full (inverse) rotation is completed. All the data are stored in an Excel file located in the path: “C:\VeriVane_Version_2.0.0\CalReports\ SelfVerificationReports” and its name is defined by the Serial Number of the vane used, and the date and time of the Self-Verification.

In the stored Excel file, in the "General Data" sheet, certain parameters defined in the main window appear, i.e. the Serial Number, the Manufacturer, the type, the laboratory, the next self-verification date, the person who performed the test and the selected dead band. Moreover, the verification date, along with its start time and end time are mentioned. Finally, next to the "ITEM STATUS" cell, the verification's result is mentioned: **ACCEPT**, if the results are within the 3 bit (1,0557 degrees) accuracy, which is a feature of the instrument, or **NOT ACCEPT**, if it is not within this specification.

In the "Table Measures" sheet, there are analytical data in table form. Specifically, the data are presented in 6 columns. In the "GeometricalValue" one, the actual rotation angles of the motor are mentioned, therefore of the vane as well, the "VaneValue (Right Polarity)" column contains the angle which the vane outputs in each position, during the first rotation, where the wiring of the reference voltage is properly connected. The "VaneValue (Inverse Polarity)" column contains the measurements deriving from the vane's output during the second rotation, where the reference voltage has been reversed, while the "Sum Positions (Right And Inverse Polarity)" column, contains the sum of the measurement during the proper and the inverse connection for each position (which ideally-theoretically should be 360 degrees), the "Average Sum Positions" column contains the average value of the values of the "Sum Positions (Right And Inverse Polarity)" column, and finally the "Difference Position with Average Sum Positions" column contains the deviations of the "Average Sum Positions" column, under which (except for the measurements made in the dead band) the conclusion if the instrument is ACCEPT or NOT ACCEPT is reached, since they are within the 3 bit (1.0557 degree) accuracy. ("ITEM STATUS: **ACCEPT or NOT ACCEPT**", in the "General Data" sheet).

In the "Graph_Output_Right_Polarity" sheet, the graph of the second vs the first column appears, in which you can also see optically the linearity of the measured vs the geometrical angle of the vane, during the proper wiring rotation. In the "Graph_Output_Inverse_Polarity" sheet, the graph of the third vs the first column appears, in which you can also see optically the linearity of the measured vs the geometrical angle of the vane, during the inverse wiring rotation.Finally, in the "Graph Deviations" sheet, the graph of the sixth vs the first column appear, which also gives a picture about the deviations measured and if they are within the instrument's accuracy specifications.

**NOTE**: If you wish to define how your Excel reports produced will be, you can modify the headers and footers of the files "CalForm Vane FullVerification.xls", "CalForm Vane SelfVerification.xls", "CalForm Vane Standar.xls", located in the path: "C:\VeriVane_Version_2.0.0\CalDocs" and refer to the corresponding procedures. From the files' main menu, via the option "View→Header and Footer…"). If you wish, you can change only the logo in the left part of the header ("View→Header and Footer…→Header/ Footer →Header Adjustment" and on the left part insert your company's logo, as an image). Do this for all the worksheets of all three Excel files mentioned. Moreover, in the "General Data" sheet of each of the three Excel files mentioned, you can remove the image which appears on the lower part of the sheet. You are advised not to make any changes other than the ones mentioned.

## 9. UNCERTAINTIES

The uncertainties (which appear in the "Uncertainty" column of the Excel file) have been separated and calculated, according to if they are Type A uncertainties, ie their evaluation is based on statistical methods, or if they are Type B uncertainties, ie their evaluation is based on non-statistical methods. Therefore, according to this precondition, you can see the uncertainties calculation method below.

### 9.1 TYPE A UNCERTAINTY

The type A uncertainty occurs according to the measurements made, therefore if we have one measurement it equals zero and if we have 20 measurements, such as in our case, it is calculated via the general formulas:

- $AV=\frac{\sum_{x=1}^{n} x}{n}$ which calculates the measurements' average, where $x$ is the measurement and $n$ is the number of measurements (in this case $n$=20).

- $SDV = \sqrt{\left(\frac{\sum x^2}{n} - AV^2\right)\frac{n}{n-1}}$ This formula calculates the measurement's standard deviation.

- $\sigma_A=\frac{SDV}{\sqrt{n}}$ This formula calculates the standard uncertainty.

We have considered that we have a normal or Gaussian distribution

### 9.2 TYPE B UNCERTAINTY

For the type B uncertainty, we take into account the following:

- The uncertainty caused by the LSB digit of the measurement because of distinctity, which is named SigmaLogRound and according to the type of the measurement executed, it is calculated via the following formula

$\sigma_{log\text{-}round} = u_{log\text{-}round} / \sqrt{3}$ where $u_{log\text{-}round}$=Resolution/ 2 .

Rectangular distribution has been considered.

The Resolution calculation is based on the fact that the 360 degrees correspond to the full scale 1023, given that we have a 10-bit AD Converter, which is used to perform each measurement.
Therefore: Resolution=360/1023=0.3519 $^{o}$.

- The uncertainty caused by the motor's step. It has been considered that it is 25% of its minimum step, which is 0,9$^{o}$ and it is named SigmaStepMotor. For this uncertainty, a rectangular distribution has also been considered. Therefore:

$\sigma_{stepmotor} = u_{stepmotor} / \sqrt{3}$ .

- The uncertainty caused by the accuracy of the VeriVane construction itself, which is named SigmaAccuracyVeriVane and it is calculated according to the following fact: Given that the

accuracy is 3 bits, therefore it is 1,0557 degrees (360 degrees correspond to 1023 bits). Having considered again a rectangular distribution, the following folrmula applies:

$\sigma_{accuracyverivane}=u_{accuracyverivane}/\sqrt{3}$ .

The type B uncertainty is totally calculated via the following formula:

$$\sigma_B = \sqrt{SigmaLogRound^2 + SigmaStepMotor^2 + SigmaAccuracyVeriVane^2}$$

### 9.3. TOTAL UNCERTAINTY

Finally, the total uncertainty for this category is calculated via the following formula:

$S_{EXP} = 2 \times \sqrt{\sigma_A{}^2 + \sigma_B{}^2}$ , where we have considered a normal distribution and our total uncertainty has occurred for coverage factor k=2, providing a trust level of about 95%.