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A program for conformity assessment of the calibration results with the specification

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Abstract —**This paper describes the procedure for calculating the conformance probability of the results of the calibration with the requirements or specifications (standards or manufactures), including borderline cases. An original program created in Excel was presented, which makes it easy to calculate in a Metrology Laboratory. During the development of this program, the recommendations of the European Accreditation Team (EA), as well as the requirements of ISO / IEC 17025: 2017, were taken into account. The goal of this program is to provide the customer with a certificate of calibration with the declared uncertainty as well as the compliance of the results of the calibration with the requirements or specifications. The program was developed for the needs of the Metrology Laboratory, which is located in the company ORAO a.d. Bijeljina. The accreditation body at the accreditation examination of the Metrology Laboratory checked the results of the program. The international standard ISO 10576-1: 2003 describes the procedure for calculating the conformance probability of the calibration results with the specification. According to the described procedure, each calibration result must first be graphically presented according to normal PDF (Gaussian distribution). Then, in order to determine the probability of occurrence of any measured value, use the z-value and the standard surface tables below with normal PDF. In metrology laboratories, this is a difficult and long-lasting process because the digital multimeter can be calibrated at even a hundred measuring points.**

Keywords - calibration; measurement uncertainty; specification; conformity assessment;

I. Introduction

The measuring instrument is correct not only when it is functionally correct, but also when its metrological characteristics are confirmed by the calibration. Calibration is a metrological activity in which the metrological characteristics of the measuring devices are checked. Calibration measurement equipment conducted by an accredited Metrology Laboratory provides the user with reliable measurement results with the expression of measurement uncertainty.

For the needs of customers accredited Metrology Laboratory, which is part of the company Orao a.d., upon completion of the calibration, issues one-page Calibration certificate and/or Calibration certificate with more pages, according to the Instructions for calibration record and certificate. Calibration certificate with more pages must contain the results of the calibration and the appropriate measurement uncertainty. Measurement uncertainty in our laboratory is usually given with a coefficient of coverage k = 2 (probability 95.46%) and assuming that the measurement results have a normal PDF (Gaussian distribution), shown in Fig. 1.

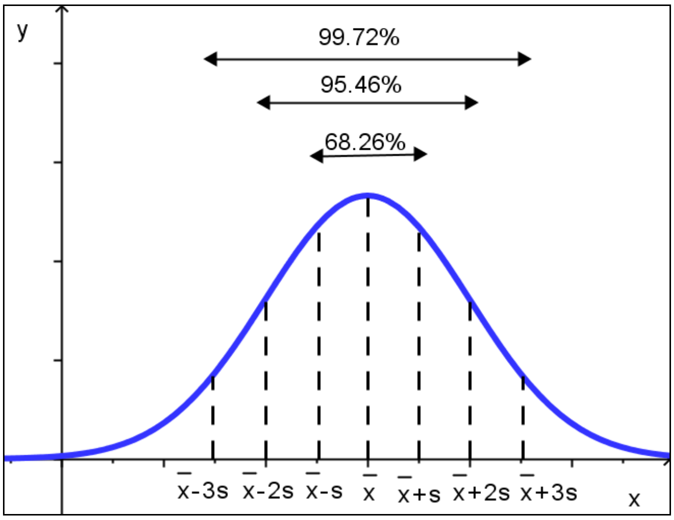

Figure 1. Intervals reliability for normal PDF.

In Fig. 1. ” $\overline{x}$ ” is the mean value of the measurements made, and ”*s*” is a standard deviation. For a theoretical, normal PDF, the percentage of the total number of data is calculated at certain intervals, that is:

- in the interval $\bar{x} \pm 1s$ there are 68.26% of data;
- in the interval $\bar{x} \pm 2s$ there are 95.46% of data;
- in the interval $\bar{x} \pm 3s$ there are 99.72% of data,

or, expressed in a different way:

- 50% of data is in the interval $\bar{x} \pm 0.674s$;
- 95% of data is in the interval $\bar{x} \pm 1.9605s$;
- 99% of data is in the interval $\bar{x} \pm 2.57s$.

The described intervals are called intervals of probability or confidence intervals with probability limits. The integral of -∞ to +∞ of the complete surface below the gauge curve yields probability 1 (that is, 100% of all data presented). In the interval of -∞ to "$\bar{x}$" there is 50% of the data, and the other 50 % of the data is in the interval from "$\bar{x}$" to +∞. To determine the probability of occurrence of any measured value of "x" (the area below the curve from -∞ to that value "x" if "$x < \bar{x}$" or the area is below the curve of that value "x" to +∞ if "$x > \bar{x}$"), which appears according to gauge distribution, can be used with *z - value* and standard table surface below the normal PDF (in Appendix 1). This *z-value* is the distance of the observed value "x" from the mean value "$\bar{x}$" expressed in the parts of the standard deviation "s" and calculated according to the formula:

$$z = \frac{x - \bar{x}}{s}. \tag{1}$$

It is created a program, which in a simpler and faster way calculates the surface (or probability) below the normal PDF, with the "NORM.DIST" statistical functions in Excel. The function "NORM.DIST(x; Mean; Standard_Dev; Cumulative)" has 4 required input arguments with the following meanings:

- x - value for which probability is sought (area under the curve from -∞ to this value);
- Mean - mean value for normal PDF;
- Standard_Dev - standard deviation for normal PDF;
- Cumulative - the cumulative factor to be TRUE.

The result of this function values from 0 to 1, and by multiplying the obtained value with 100%, the probability is obtained in percentages.

According to item 8.2. standard ISO/IEC 17025:2017 [1], a declaration of compliance of the calibration results with the requirements or specifications (manufacture or standard) must also be provided at the customer's request in the calibration certificate. In the Metrology Laboratory Orao a.d. is defined the decision rule on the conformity of individual calibration results with the specification, which we apply when issuing a calibration certificate (Table I). This decision rule is presented in Fig. 2. and it is shown in the following ways:

a) The calibration results that comply with the specification is not specifically marked (MV1 in Table I), and the same applies:

$$|Error| <= |Ls| - |U|. \tag{2}$$

For this calibration, results, it is said that 100% are in conformity with the specification.

b) The calibration results that do not accept the specification are marked with "**" (MV6 in Table I) and the same applies:

$$|Error| > |Ls| - |U|. \tag{3}$$

For these calibration results, it is said that 0% is in conformity with the specification (that is, 100% is incompatible with the specification, or risk is 100%).

c) The calibration results that is less than 100% conformity the specification is marked with "*" (MV2, MV3, MV4 and MV5 in Table I) and the same applies:

$$|Ls| - |U| < |\,Error\,| <= |Ls| + |U|. \tag{4}$$

For these calibration results, determining the conformance probability with the specification will be described in detail in this paper.

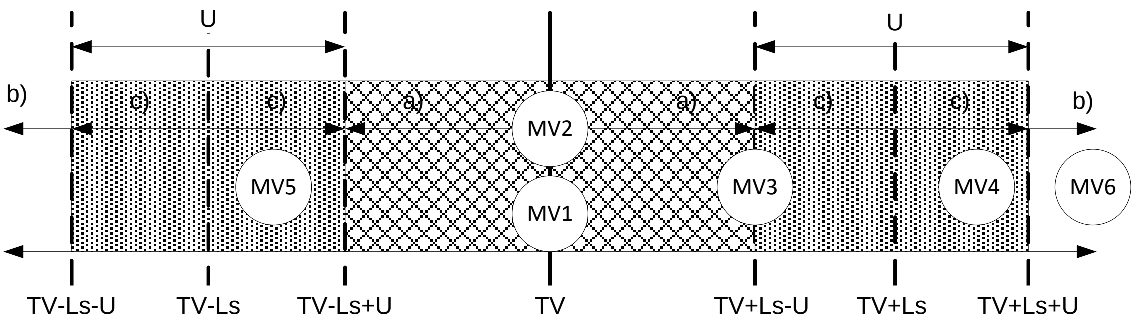

Figure 2. Decision-making rule on the conformity of individual calibration results with the specification.

In previous inconsistencies and Fig. 2. abbreviations have the following meaning:

TV – True Value measured on the standard;
MV - Measured Value on the item under calibration;
Error – Error of Measurement (*Error* = *MV* – *TV*);
Ls - Specification limit of error (accuracy);
U - Expanded uncertainty (k = 2).

Fig. 2. shows six measurement results (MV1, MV2, MV3, MV4, MV5, and MV6), whose numerical values are given in Table I. Each measurement has a manufacturer's specification with two-side tolerance interval. For these six calibration results, the next chapter of the paper describes the conformity

assessment with the specification. In the third chapter of the paper are shown measurement result with a single lower specification limit of error and describes the conformity assessment with the specification. In chapter IV of the paper, are shown measurement result with single upper specification limit of error and describes the conformity assessment with the specification.

II. MEASUREMENT WITH A TWO-SIDED TOLERANCE INTERVAL

This section will describe the procedure for indicating the conformance probability of the calibration results with the manufacturer's specification or standard, where each measurement has a lower specification limit and the upper specification limit of error [2], [3], [4]. Table I presents six possible measurement results of one digital voltmeter calibration, with associated extended measurement uncertainties. Based on these calibration measurement results in Fig 3., Fig. 4., Fig. 5., Fig. 6., Fig. 7. and Fig. 8., the corresponding probability graphs of the distribution of the calibration results are shown. These graphics will serve as the basis for calculating the conformance probability of the calibration results with the requirements or specifications (manufacture or standard). Above each graph, the corresponding table with parameters and their values, based on which the graph is drawn, is shown. On each graph, the center of the normal PDF (full vertical line) is a value that corresponds to the measured value of the instrument being calibrated. The lower and upper specification limits of permissible errors are represented by vertical interrupted lines and are located at values that are equally distant from the true value measured on standard (*TV*).

TABLE I. DC VOLTAGE MEASUREMENT WITH TWO-SIDE TOLERANCE INTERVAL IN THE CALIBRATION CERTIFICATE

	Standard	Calibrated Instrument		Error	Specification Limit	Expanded Uncertainty	Conformity Assessment
	True value *Utv*	Figure	Measured value U_{mv}	*Umv - Utv*	*Ls*	*U* (*k* = 2)	
	5 V	Fig. 2.	MV1 5 V	0 V	±3 V	1 V	100%
*	5 V	Fig. 3.	MV2 5 V	0 V	±3 V	3 V	95%
*	5 V	Fig. 4.	MV3 7.1 V	2.1 V	±3 V	1 V	98%
*	5 V	Fig. 5.	MV4 8.5 V	3.5 V	±3 V	1 V	16%
*	5 V	Fig. 6.	MV5 2.5 V	-2.5 V	±3 V	1 V	84%
**	5 V	Fig. 7.	MV6 9.1 V	4.1 V	±3 V	1 V	0%

First, in Table I, are shown the result of the calibration labeled MV1. For this result, the probability distribution chart for the measurement results is shown in Fig. 3.

TABLE II. INPUT VALUES FOR FIG. 3.

Parameter	**Value**
TV – True Value measured on standard	5
MV - Measured Value on instrument	5
± *Ls* - Specification Limit	3
Lsl – Lower Specification Limit	2
Lsu – Upper Specification Limit	8
U - Expanded Uncertainty (*k* = 2)	1
U/2 - Expanded Uncertainty (*k* = 1)	0.5
Total conformity	**100%**
Upper Limit Risk	0%
Lower Limit Risk	0%
Total Risk	0%

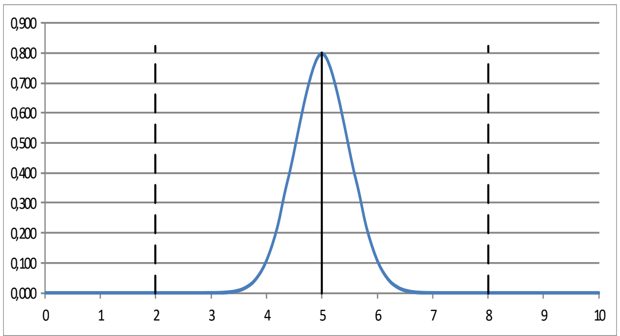

Figure 3. Determination of the conformance probability with the specification for the two-sided tolerance interval for MV1.

Table II shows the parameters on which the graph is drawn and the overall conformity with the specification is calculated. Based on these parameters we can say that this calibration result satisfies the condition from the equation (2) and that it is in the field a) in Fig. 2. Calculated the conformance probability with the specification in this example is 100%. This value of conformity is obtained by first calculating the percentage of the risk of the results with the specification at the lower limit of the allowed error. This percentage is determined based on the normal PDF surface, which is left to the lower limit of the allowed error (below 2 V). In our case, this area is equal to 0% and is calculated using the function in Excel "NORM.DIST". Then, the percentage of the risk of the results at the upper specification limit of the allowed error is calculated. This percentage is determined from the normal PDF surface, which is to the right of the upper specification limit of the allowed error (above 8 V). In our case, this area is also 0%. Then these two values are summed and the percentage of the total risk of the results in relation to the specification is obtained. In this case, this is 0% = 0% + 0%. The conformance probability with the specification is obtained through the formula:

$$\text{Total conformity} = 100\% - \text{Total Risk} \qquad (5)$$

Calculation of the risk with the specification measurement result over the *z-value*, in our example, is done using the following formula:

$$z = \frac{Ls - TV}{U/2} \qquad (6)$$

At the lower specification limit of the allowed error, *z – value* is $z = (2 - 5) / 0.5 = -6$. For this *z - value* from the table in the Appendix, a value of 0.0000 and 0% is obtained.

At the upper specification limit of the allowed error, *z - value* is $z = (8 - 5) / 0.5 = 6$. For this *z - value* from the table in the Appendix, the value of the area is 0.0000 and 0%. The total risk is then 0%, and the conformity with the specification is 100%.

Fig. 4. describes the procedure for determining the conformity assessment with the specification of the second calibration result (MV2), for which the equation (4) is valid, and which is marked with "*" in Table I. This result is marked with "*" although the error is 0 V, but in this case, the calibration results are associated with a large measurement uncertainty, which is equal to specification limit.

TABLE III. INPUT VALUES FOR FIG. 4.

Parameter	Value
TV – True Value measured on standard	5
MV - Measured Value on instrument	5
± *Ls* - Specification Limit	3
Lsl – Lower Specification Limit	2
Lsu – Upper Specification Limit	8
U - Expanded Uncertainty ($k = 2$)	3
U/2 - Expanded Uncertainty ($k = 1$)	1.5
Total conformity	**95.45%**
Upper Limit Risk	2.28%
Lower Limit Risk	2.28%
Total Risk	4.55%

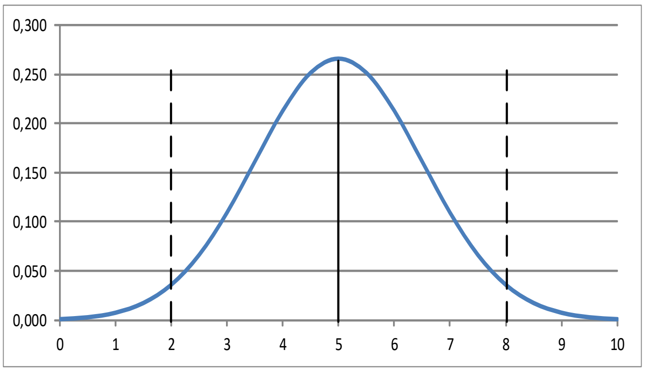

Figure 4. Determination of the conformance probability with the specification for the two-sided tolerance interval for MV2.

First, the percentage of risk of the results with the specification at the lower specification limit of the allowed error is calculated. This percentage is determined based on the normal PDF surface, which is left to the lower specification limit of the allowed error (below 2 V). In our case, this area is equal to 2.28%. Then, the percentage of the risk of the results at the upper limit of the allowed error is calculated. This percentage is determined from the normal PDF surface, which is to the right of the upper specification limit of the allowed error (above 8 V). In our case, this area is also 2.28%. Then, these two values are summed and the percentage of the total risk of the results with the specification is obtained. In this case it is 4.55% = 2.28% + 2.28%. The conformance probability with the specification is 95.45% = 100% - 4.55%. Although this measurement result is marked with "*", the obtained result indicates that the risk of non-compliance with the specification is relatively small.

Calculation of the risk with the specification via *z-value* is done in this example as follows. At the lower specification limit of the allowed error z – value is $z = (2 - 5) / 1.5 = -2$. For this z - value from the table in the Appendix, a value of 0.0228 or 2.28% is obtained.

At the upper specification limit of the allowed error, z – value is $z = (8-5) /1.5= 2$. For this value from the table in the Appendix, a value of 0.0228 and 2.28% is obtained. The total risk is then 4.55%, and the compliance with the specification is 95.45%.

Fig. 5. describes the procedure for determining the conformity assessment with the specification of the third calibration result (MV3), with the measured value close to the upper specification limit of the allowed error. Equation (4) is also valid for this result, and it is marked with "*" in Table I.

TABLE IV. INPUT VALUES FOR FIG. 5.

Parameter	Value
TV – True Value measured on standard	5
MV - Measured Value on instrument	7.1
± *Ls* - Specification Limit	3
Lsl – Lower Specification Limit	2
Lsu – Upper Specification Limit	8
U - Expanded Uncertainty ($k = 2$)	1
U/2 - Expanded Uncertainty ($k = 1$)	0.5
Total conformity	**96.41%**
Upper Limit Risk	3.59%
Lower Limit Risk	0%
Total Risk	3.59%

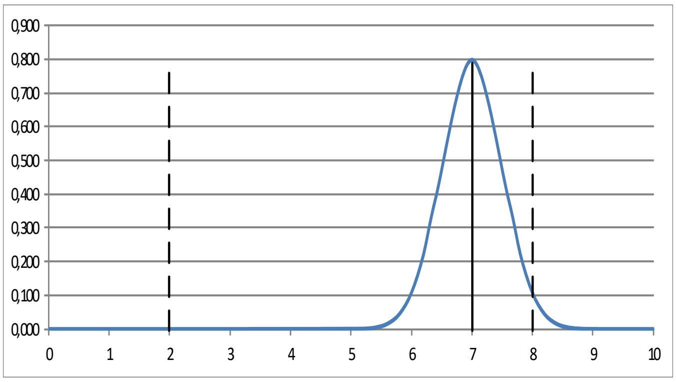

Figure 5. Determination of the conformance probability with the specification for the two-sided tolerance interval for MV3.

First, the percentage of risk of the results with the specification at the lower specification limit of the allowed error is calculated. This percentage is 0%. Then, the percentage of the risk of the results at the upper specification limit of the allowed error is calculated. This percentage is 3.59%. The total risk of calibration result with the specification is 3.59%. The conformance probability with the specification is 96.41%. Although this calibration result is marked with a single star, the obtained result shows that the risk of non-compliance with the specification is relatively small.

Calculation of the risk with the specification via *z-value* is done as follows. At the lower specification limit of the allowed error *z – value* is $z = (2 - 7.1) / 0.5 = -10.2$. For this *z - value* from the table in the Appendix, a value of 0.0000 and 0% is obtained.

At the upper specification limit *z – value* is z = (8 - 7) / 0.5 = 1.8. For this value from the table in Appendix, a value of 0.0359 or 3.59% is obtained. The total risk is then 3.59%, and the conformity with the specification is 96.41%.

Fig. 6. describes the procedure for determining the conformity assessment with the specification of the fourth calibration result (MV4), in which the measured value is greater than the upper specification limit of the allowed error. This result is marked in Table I with "*". The calculation method is similar to the one in the previous example. The conformance probability with the specification is only 15.87%. This is expected because the measured value is higher than the upper specification limit of the allowed error.

Calculation of conformity (and not risk, because in this case, the mean value is greater than the upper specification limit of the allowed error) with specification over *z - value*, is done as follows. At the upper specification limit of the allowed errors *z – value* is z = (8 - 8.5) / 0.5 = -1. For this *z - value* from the table in the Appendix, a value of 0.1587 or 15.87% is obtained. The total conformity is then 15.87%, and the total risk with the specification is 84.13%.

TABLE V. INPUT VALUES FOR FIG. 6.

Parameter	Value
TV – True Value measured on standard	5
MV - Measured Value on instrument	8.5
± *Ls* - Specification Limit	3
Lsl – Lower Specification Limit	2
Lsu – Upper Specification Limit	8
U - Expanded Uncertainty (*k* = 2)	1
U/2 - Expanded Uncertainty (*k* = 1)	0.5
Total conformity	**15.87%**
Upper Limit Risk	84.13%
Lower Limit Risk	0%
Total Risk	84.13%

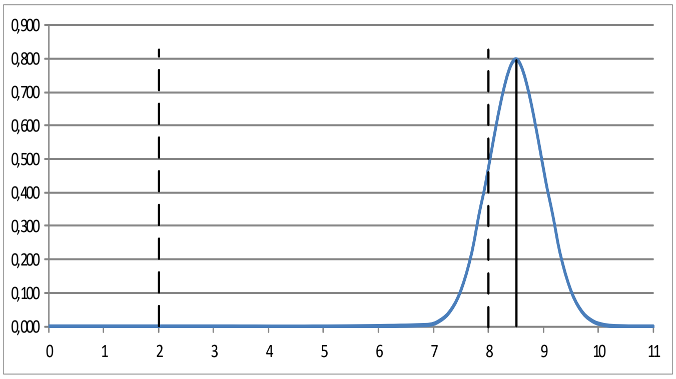

Figure 6. Determination of the conformance probability with the specification for the two-sided tolerance interval for MV4.

Fig. 7. describes the procedure for determining the conformity assessment with the specification of the fifth calibration result (MV5), which is marked in Table I with "*". The calculation method is similar to the one in the preceding example, only here there is a percentage of the risk of the lower specification limit of the error, and there is no percentage of the risk of the upper error limit. The conformance probability with the specification is 84.13%.

Calculation of the risk with the specification via *z-value* is done as follows. At the lower specification limit of the allowed error *z – value* is z = (2 - 2.5) / 0.5 = -1. For this *z - value* from the table in the Appendix, a value of 0.1587 or 15.87% is obtained. The total risk is then 15.87%, and the conformity with the specification is 84.13%.

TABLE VI. INPUT VALUES FOR FIG. 7.

Parameter	Value
TV – True Value measured on standard	5
MV - Measured Value on instrument	2.5
± *Ls* - Specification Limit	3
Lsl – Lower Specification Limit	2
Lsu – Upper Specification Limit	8
U - Expanded Uncertainty (*k* = 2)	1
U/2 - Expanded Uncertainty (*k* = 1)	0.5
Total conformity	**84.13%**
Upper Limit Risk	15.87%
Lower Limit Risk	0%
Total Risk	15.87%

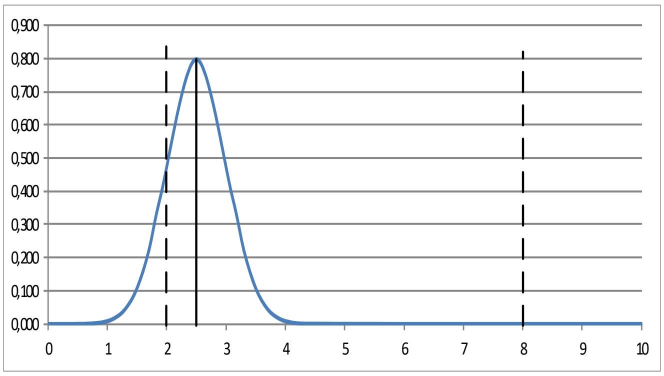

Figure 7. Determination of the conformance probability with the specification for the two-sided tolerance interval for MV5.

Fig. 8. describes the procedure for determining the conformity assessment with the specification of the sixth calibration result (MV6), which is marked with "**" in Table I, because it satisfies the equation (3). The calculation method is similar to the previous examples, only here is a percentage of the risk of the upper specification limit of error, and there is no percentage of the risk of the lower specification limit. The conformance probability with the specification is only 1.39%. That's why we can rightly say that the correct assumption is that the results marked with two stars have 0% conformity with the specification.

Calculation of conformity (and not risk because the mean value is greater than the upper specification limit of the allowed error) with the specification via *z-value* is done as follows. At the upper specification limit of the allowed error *z – value* is z = (8 - 9.1) / 0.5 = -2.2. For this *z-value* from the table in the Appendix, a value of 0.0139 and 1.39% is obtained. The total conformity is then 1.39%, and the risk with the specification is 98.61%.

TABLE VII. INPUT VALUES FOR FIG. 8.

Parameter	Value
TV – True Value measured on standard	5
MV - Measured Value on instrument	9.1
± *Ls* - Specification Limit	3
Lsl – Lower Specification Limit	2
Lsu – Upper Specification Limit	8
U - Expanded Uncertainty (*k* = 2)	1
U/2 - Expanded Uncertainty (*k* = 1)	0.5
Total conformity	**1.39%**
Upper Limit Risk	98.61%
Lower Limit Risk	0%
Total Risk	98.61%

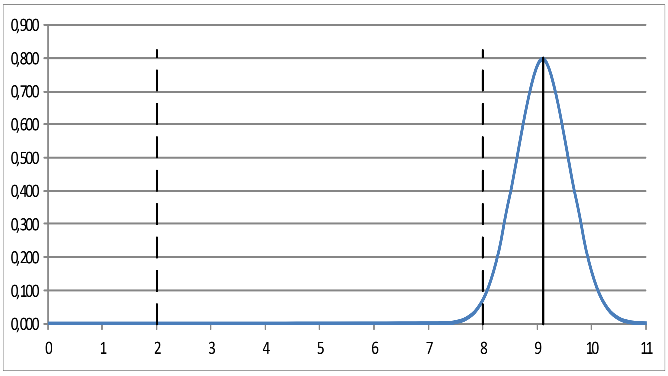

Figure 8. Determination of the conformance probability with the specification for the two-sided tolerance interval for MV6.

In order to facilitate the process of calculating compliance with the specification of the results of the calibration of instruments that have declared the lower and upper specification limit of the allowed error, a program has been created in Excel in the document named "ProracunUskladjenosti.xls". The first worksheet contains a calculation when the measurer is calibrated (Figure 9. a)), and on the second worksheet there is a calculation when calibrators (generators) are calibrated (Figure 9. b)). In the program, four values are entered from the calibration certificate: the value of the indication of the standard (*TV*), the value indicated by the instrument to be calibrated (*MV*), the permissible error specification limit (*Ls*), and the expanded measurement uncertainty (k = 2). The conformance probability of the calibration results with the specification is obtained in the order of Total conformity. The other auxiliary cells, which show how the final result has arrived, are not shown in this image. The Excel document that is used is set to be Read-only, to prevent the user from accidentally changing the name and content of this document. All cells with formulas are password protected so the user can not change them.

Calibration measurement instrument	Measure 1
TV – True Value on standard	5
MV - Measured Value on instrument	7.1
± Ls - Specification Limit	3
U - Expanded Uncertainty (k = 2)	1
Total conformity	96.41%

a)

Calibration calibrator (generator)	Measure 1
MV - Measured Value on instrument	5
TV – True Value on standard	8.5
± Ls - Specification Limit	3
U - Expanded Uncertainty (k = 2)	1
Total conformity	15.87%

b)

Figure 9. The appearance of the program made in Excel for calculation conformance probabilities with the specification, for measurement with a two-sided tolerance interval. The program in Figure a) is used when the measurer is calibrated, and in Figure b) when calibrating the calibrator (generator).

III. MEASURE WITH A SINGLE LOWER SPECIFICATION LIMIT

This section will describe the procedure for indicating the conformance probability of the calibration results with the manufacturer's specification or standard, where each measurement has only a lower specification limit of error, and the upper specification limit of error is not defined [2], [3], [4]. Table VIII presents the result of the cast iron strength test, based on which the probability distribution graph of the measurement results shown in Fig. 9. is presented. Table IX shows the parameters based on which the graph is plotted and the conformity assessment with the specification is calculated. On the graph, the center of the normal PDF (full vertical line) is at a value that corresponds to the measured value of the standard. The lower specification limit of the allowed error is represented by a vertical dashed line. The equation (4) is valid for this result, and it is marked with "*" in Table VIII.

TABLE VIII. THE MEASURE OF TENSIONAL STRENGTH WITH A SINGLE LOWER SPECIFICATION LIMIT IN A TEST REPORT

	Tested part	Standard		Lower Specification Limit *Lsl*	Expanded Uncertainty *U* (*k* = 2)	Conformity Assessment
	Nominal value	Figure	Measured value P_{izm}			
*	300 MPa	Fig. 10.	300 MPa	> =260 MPa	60 MPa	91%

Fig. 10. describes the procedure for determining the conformity assessment with the specification of the calibration results. The percentage of risk calibration results, with the specification at the lower specification limit of the allowed error, is calculated. This percentage is 9.12% and it is also the overall percentage of risk. Since there is no upper specification limit of the allowed error, then there is no calculation of the percentage of upper risk. The conformance probability with the specification is 90.88%.

TABLE IX. INPUT VALUES FOR FIG. 10.

Parameter	Value
TV – True Value measured on standard	300
Lsl – Lower Specification Limit	260
U - Expanded Uncertainty (k = 2)	60
U/2 - Expanded Uncertainty (k = 1)	30
Total conformity	**90.88%**
Lower Limit Risk	9.12%

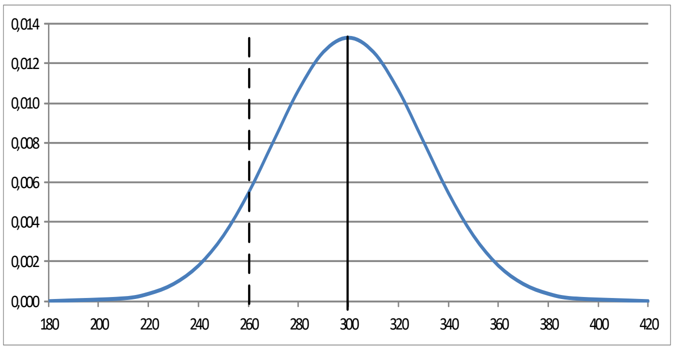

Figure 10. Determination of the conformance probability with the measurement specification that has only the lower specification limit of error.

Calculation of the risk with the specification via *z-value* is done as follows. At the lower specification limit of the allowed error *z – value* is *z* = (260 - 300) / 30 = -1.333. For this *z-value* from the table in Appendix, approximately (for *z* = 1.33) the value of the area is 0.0918 and 9.18% is obtained. The total risk equal lower risk is then 9.18%, and the compliance with the specification is 90.82%.

In order to facilitate the process of calculating conformity with the specification of the measurement results of the calibration of instruments that have declared the lower and upper specification limit of the allowed error, a program has been created in Excel in the document named "ProracunUskladjenosti.xls". On the third worksheet, there is a calculation when the measurer is calibrated (Figure 11. a)), and on the fourth worksheet there is a calculation when the calibrators are calibrated (Figure 11. b)). In the program, three values are entered from the calibration certificate: the measured value of the instrument being calibrated (MV); the lower specification limit of the error; extended measurement uncertainty (k = 2). The conformance probability of the calibration results with the specification is obtained in the order of total conformity.

Calibration measurement instrument	Measure 1
TV – True Value on standard	300
MV - Measured Value on instrument	300
Lsl – Lower Specification Limit	260
U - Expanded Uncertainty (k = 2)	60
Total conformity	90,88%

a)

Calibration calibrator (generator)	Measure 1
MV - Measured Value on instrument	290
TV – True Value on standard	300
Lsl – Lower Specification Limit	250
U - Expanded Uncertainty (k = 2)	80
Total conformity	89,44%

b)

Figure 11. The appearance of the program made in Excel for calculation conformance probabilities with the specification, for measurement with single lower specification limit of the error. The program in Figure a) is used when the measurer is calibrated, and in Figure b) when calibrating the calibrator (generator).

IV. MEASUREMENT WITH A SINGLE UPPER SPECIFICATION LIMIT

This section will describe the procedure for indicating the conformance probabilities of the calibration results with the manufacturer's specification or standard, wherein each measurement has only the upper specification limit of error, and the lower specification limit of error is not defined [2], [3], [4]. In Table X, the calibration results of a gage block are presented, based on which the probability distribution graph of the measurement results shown in Fig. 12. is presented.

Table XI shows the parameters on the basis of which the graph is plotted and the total conformity with the specification is calculated. On the graph, the center of the normal PDF (full vertical line) is at a value that corresponds to the measured value of the standard. A vertical dashed line represents the upper specification limit of the allowed error. The equation (4) is valid for this calibration result, and it is marked with "* " in Table X.

TABLE X. CALIBRATION CERTIFICATE GAGE BLOCKS WHICH HAVE SINGLE UPPER SPECIFICATION LIMIT

	Calibrated Instrument	Standard		Upper Specification Limit	Expanded Uncertainty	Conformity Assessment
	Nominal value	Figure	Measured value P_{izm}	*Lsu*	*U* (k=2)	
*	4 μm	Fig. 12.	4 μm	<=5 μm	2 μm	84%

Fig. 12. describes the procedure for determining the conformity assessment with the specification of the calibration measurement result. The percentage of risk results with the specification at the upper specification limit of the allowed error is calculated. This percentage is 15.87% and it is also the total risk. Since there is no lower specification limit of the allowed error, then there is no calculation of the percentage of lower risk. The conformance probability with the specification is 84.13%.

Calculation of the risk with the specification via *z-value* is done as follows. At the upper specification limit of the allowed error *z – value* is *z* = (5 - 4) / 1 = 1. For this *z-value* from the table in the Appendix, a value of 0.1587 or 15.87% is obtained. The total risk is then 15.87%, and the conformance probability with the specification is 84.13%.

TABLE XI. INPUT VALUES FOR FIG. 12.

Parameter	Value
TV – True Value measured on standard	4
Lsl – Upper Specification Limit	5
U - Expanded Uncertainty (k = 2)	2
U/2 - Expanded Uncertainty (k = 1)	1
Total conformity	**84.13%**
Upper Limit Risk	15.87%

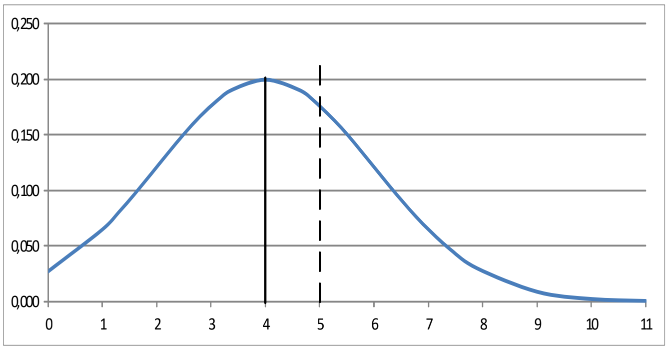

Figure 12. Determination of the conformance probability with the measurement specification that has only the upper specification limit of the error.

In order to facilitate the process of calculating conformity with the specification of the calibration results of the instruments that have a declared lower and upper specification limit of the allowable error, a program has been created in Excel in the document named "ProracunUskladjenosti.xls". The fifth worksheet contains a calculation when the measurerer is calibrated (Figure 13a)), and on the sixth worksheet there is a calculation when calibrators are calibrated (Figure 13b)).

In the program, three values are entered in the certificate of calibration: the measured value of the instrument being calibrated (*MV*), the upper specification limit of error (Lsu), and extended measurement uncertainty (k = 2). The conformance probability of the measurement results with the specification is obtained in the order of total conformity.

Calibration measurement instrument	Measure 1
TV – True Value on standard	2
MV - Measured Value on instrument	2
Lsu – Upper Specification Limit	3
U - Expanded Uncertainty (k = 2)	2
Total conformity	84,13%

a)

Calibration calibrator (generator)	Measure 1
MV - Measured Value on instrument	4
TV – True Value on standard	4
Lsu – Upper Specification Limit	5
U - Expanded Uncertainty (k = 2)	3
Total conformity	74,75%

b)

Figure 13. The appearance of the program made in Excel for calculation conformance probabilities with the specification, for measurement with single upper specification limit of the error. The program in Figure a) is used when the measurer is calibrated, and in Figure b) when calibrating the calibrator (generator).

V. CONCLUSION

According to the new requirements of ISO / IEC 17025: 2017, when measuring instruments are calibrated, each calibration result is accompanied by appropriate measurement uncertainty, but at the request of the user, conformity assessment with the specification should also be performed. According to the international standard ISO 10576-1: 2003, the *z-value* and standard tables under the normal PDF are to be used to calculate the conformance probability of the calibration results with the specification. However, this is a rather complex and slow method of calculation. That is why a program was created that, based on four inputs from the calibration certificate, calculates the conformity of the calibration results with the specification. Through several examples, they were processed with three characteristic cases in the calibration of measurement instruments: when the instrument has a two-sided tolerance band, a single lower tolerance limit, and a single upper tolerance limit.

VI. APPENDIX

The standard table of the surface below the normal PDF is shown in Table XII [5]. The first column of this table contains z - values expressed with one decimal, and the second decimal is found in the top row at the top of the table.

TABLE XII. THE TABLE OF THE SURFACE BELOW THE NORMAL PDF

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.5000	.4960	.4920	.4880	.4840	.4801	.4761	.4721	.4681	.4641
.1	.4602	.4562	.4522	.4483	.4443	.4404	.4364	.4325	.4286	.4247
.2	.4207	.4168	.4129	.4090	.4052	.4013	.3974	.3936	.3897	.3859
.3	.3821	.3783	.3745	.3707	.3669	.3632	.3594	.3557	.3520	.3483
.4	.3446	.3409	.3372	.3336	.3300	.3264	.3228	.3192	.3156	.3121
.5	.3085	.3050	.3015	.2981	.2946	.2912	.2877	.2843	.2810	.2776
.6	.2743	.2709	.2676	.2643	.2611	.2578	.2546	.2514	.2483	.2451
.7	.2420	.2389	.2358	.2327	.2296	.2266	.2236	.2206	.2177	.2148
.8	.2119	.2090	.2061	.2033	.2005	.1977	.1949	.1922	.1894	.1867
.9	.1841	.1814	.1788	.1762	.1736	.1711	.1685	.1660	.1635	.1611
1.0	.1587	.1562	.1539	.1515	.1492	.1469	.1446	.1423	.1401	.1379
1.1	.1357	.1335	.1314	.1292	.1271	.1251	.1230	.1210	.1190	.1170
1.2	.1151	.1131	.1112	.1093	.1075	.1056	.1038	.1020	.1003	.0985
1.3	.0968	.0951	.0934	.0918	.0901	.0885	.0869	.0853	.0838	.0823
1.4	.0808	.0793	.0778	.0764	.0749	.0735	.0721	.0708	.0694	.0681
1.5	.0668	.0655	.0643	.0630	.0618	.0606	.0594	.0582	.0571	.0559
1.6	.0548	.0537	.0526	.0516	.0505	.0495	.0485	.0475	.0465	.0455
1.7	.0446	.0436	.0427	.0418	.0409	.0401	.0392	.0384	.0375	.0367
1.8	.0359	.0351	.0344	.0336	.0329	.0322	.0314	.0307	.0301	.0294
1.9	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0239	.0233
2.0	.0228	.0222	.0217	.0212	.0207	.0202	.0197	.0192	.0188	.0183
2.1	.0179	.0174	.0170	.0166	.0162	.0158	.0154	.0150	.0146	.0143
2.2	.0139	.0136	.0132	.0129	.0125	.0122	.0119	.0116	.0113	.0110
2.3	.0107	.0104	.0102	.0099	.0096	.0094	.0091	.0089	.0087	.0084
2.4	.0082	.0080	.0078	.0075	.0073	.0071	.0069	.0068	.0066	.0064
2.5	.0062	.0060	.0059	.0057	.0055	.0054	.0052	.0051	.0049	.0048
2.6	.0047	.0045	.0044	.0043	.0041	.0040	.0039	.0038	.0037	.0036
2.7	.0035	.0034	.0033	.0032	.0031	.0030	.0029	.0028	.0027	.0026
2.8	.0026	.0025	.0024	.0023	.0023	.0022	.0021	.0021	.0020	.0019
2.9	.0019	.0018	.0018	.0017	.0016	.0016	.0015	.0015	.0014	.0014
3.0	.0014	.0013	.0013	.0012	.0012	.0011	.0011	.0011	.0010	.0010
3.1	.0010	.0009	.0009	.0009	.0008	.0008	.0008	.0008	.0007	.0007
3.2	.0007	.0007	.0006	.0006	.0006	.0006	.0006	.0005	.0005	.0005
3.3	.0005	.0005	.0005	.0004	.0004	.0004	.0004	.0004	.0004	.0003
3.4	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0002
3.6	.0002	.0002	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
3.9	.0000									

For example, if z = 1.23 the value is read from the table at the place where they are being cut: the line beginning with value 1.2 and the column with value 0.03, which is the surface then 0.1093. This means that 10.93% of the input data is larger than the data whose z - value is 1.23.

For z = -0.57, the value is read from the table at the place where they are being cut: the order beginning with value 0.5 and the column with value 0.07, which is the surface then 0.2843. This indicates that 28.43% of the data is less than the data expressed in z = -0.57. Negative z - *value* means that the table value refers to the percentage of data $\boldsymbol{x}$ in the part of the curve to the left of the value $\overline{x}$ (less than $\overline{x}$), while the positive z - *value* means that the table value refers to the percentage of data $\boldsymbol{x}$ in the part of the curve to the right of the value $\overline{x}$ (greater than $\overline{x}$).

In Table XII for all z values equal to or higher than 3.9, risk is 0.

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