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The "PTB Ex Proficiency Testing Scheme" - Interlaboratory Comparisons in the Field of Explosion Protection

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The requirement of participation in interlaboratory comparisons was not sufficiently fulfilled by laboratories in the field of explosion protection (Ex-testing laboratories) due to a lack of proficiency testing programs. The reasons were the extensive effort, the complexity of the relevant measurands- and characteristics of interest and difficulties with the selection of appropriate test samples.
The present paper introduces the "PTB Ex Proficiency Testing Scheme" as the first comprehensive proficiency testing program in explosive protection. Furthermore, a detailed look into the program "Explosion Pressure" is presented with a discussion about the reasons for differences in the results of the participants. It is shown that the scheme can improve the performance of the participated Ex-testing laboratories which generates additional confidence for the whole community related to the topic explosion protection..

1. Introduction

The international standard ISO/IEC 17025 (2005) describes the general requirements for the competence of testing and calibration laboratories and is, therefore, the basis for Ex-testing laboratories worldwide. An essential requirement is the proof of competence through participation in interlaboratory comparisons or proficiency tests. In addition to the requirements of the standard the steady increase in international networking of industry and progressing economic integration have also increased the necessity.
The international networking in the field of explosion protection is handled by the IECEx system (International Electrotechnical Commission System for Certification to Standards Relating to Equipment for Use in Explosive Atmospheres). It is a worldwide standardised test and certification system for equipment and services for use in explosive atmospheres which is recognised by numerous countries with its numbers growing continuously. The tests are conducted on the basis of the international standards series IEC 60079-0 (2011) and the following and the certificates issued accordingly. These certificates are recognised in whole or in part by the participating countries and save the manufacturers of Ex equipment the additional expense of multiple approvals. This growing harmonisation in the conformity assessment in the field of explosion protection can only work if all those involved operate with the same fundamentals and deliver comparable quality. To ensure this, there are standardised regulations based on IEC Standards on the one hand, and now the additional active participation in interlaboratory comparisons. The "PTB Ex Proficiency Testing Scheme" serves as proof of competence and offers the test laboratories a complete system for performance assessment.
The programs performed already have shown, that although the laboratories using the same standards and conducting the tests in accordance to predefined procedure instructions, the results for the measurands and characteristics of interest have been different. The reasons for this are manifold and are partial rooted in the testing method, the mistakes in performing the tests and the scope for interpretation in the standards.

2. Proficiency Testing

Proficiency testing is the evaluation of participant performance against pre-established criteria by means of interlaboratory comparisons (ISO/IEC, 2010). Next to the need to fulfil the requirements of the ISO/IEC 17025 (2005) and the IECEx system proficiency testing is also of decisive importance for:

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- proving the competence and provision of additional confidence to customers, regulators and end users.
- the identification and avoidance of problems within and among the test laboratories and the initiation of measures for improvement in matters, for example, of inadequate test or measurement equipment and procedures, effectiveness of staff training and supervision, interpretation of standards and calibration of measurement equipment.
- the establishment of the effectiveness and comparability of the applied testing and measurement methods.
- the avoidance of distortions of competition between the manufacturers as the customers of the test laboratories.
- the identification of interlaboratory differences.
- the education of participating laboratories based on the outcomes of such comparisons.
- the further promotion of the "fair play" culture within the global community of Ex laboratories.

3. PTB Ex Proficiency Testing Scheme

3.1 Scheme design

The PTB Ex Proficiency Testing Scheme is developed in accordance with the requirements of standard ISO/IEC 17043 (2010) which specifies general requirements for the competence of providers of proficiency testing schemes. It consists of different PTB Ex Proficiency Testing Programs with regard to different areas of testing in the field of explosion protection. To have a clear indication each testing performance of a program is unambiguously assigned to a unique test round depending on the date of the program rollout. For each test round a workshop takes place. The workshops are an essential element of the programs operated by the coordinator and are especially addressed to the laboratory technicians in order to start an experience exchange for further alignment of procedures and technologies, by the opportunity to meet face to face. The structure of the scheme is visualized in Figure 1.

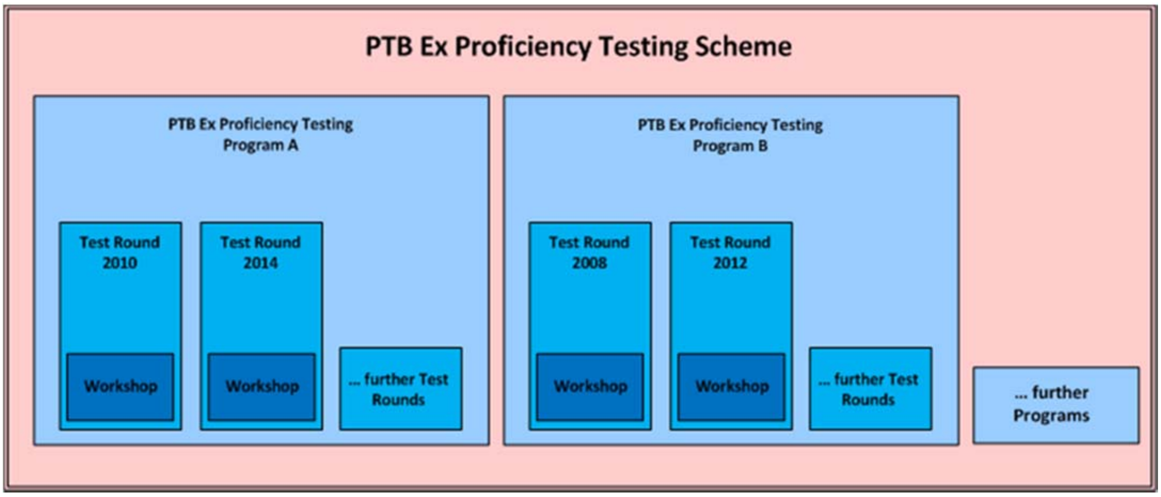

Figure 1: Principle design of the PTB Ex Proficiency Testing Scheme

3.2 Programs

For conducting the programs, the individual routine procedure of each test laboratory needs to be applied (used every day for achieving the test results for real projects). Supplementary framework conditions for conducting the respective programs are given in the form of task descriptions, the so-called "Procedure Instructions". The general routine procedure is described by the basic standards of the applicable type of protection. This means that the basic standard of the respective type of protection must also be used as a basis when the quantities to be compared (measurands or characteristics of interest) are selected.
The programs are divided into two phases. For Phase I the analysis of the results as well as the preparation of the interim report are in accordance to ISO/IEC 17043 (2010) and ISO 13528 (2005). The interim report provides a summary of all results and (hidden to other laboratories) the specific results of each individual participant. Furthermore it includes first aspects for discussion and interpretation. After interim report and

workshops Phase II (improvement loop) allows the participant to repeat the tests after improvement of their procedures and instrumentation, if they are not satisfied with their position regarding the difference with the reference value. During this phase the participants are invited to individual and confidential discussion of their results with experts from the coordinator. After the improvement loop a final report is released, which provides, in addition to the analysis of the participants results, an overview of the improvement in results from Phase I to Phase II.
Each program refers to a certain measurand or characteristic of interested typically for the type of protection and has an allocated test sample. The test samples are developed as similarly as possible to those explosion protection devices routinely tested by participating laboratories in daily work. The development of the test samples is based on the same principle as the development of a program, the test sample is as simple as possible and as complex as necessary and it reflects the properties of a real explosion protection device. To date the PTB Ex Proficiency Testing Scheme consists of six different programs.

Program 1 "Explosion Pressure":
The explosion pressure (reference pressure) is an essential characteristic for the testing and assessment of safety for the type of protection flameproof enclosures, described by the standard IEC 60079-1 (2014). The test sample (see Figure 2) consists of a small pipe section (Chamber A, 250 mm length) and a large pipe section (Chamber B, 500 mm length) closed by flanges on both sides. The inner diameter is 161.5 mm for both pipe sections. To increase the variability of the configurations an orifice with a 15 mm hole is used which can be installed between the pipe sections. The explosion pressure has to be measured for each of both pipe sections (Configuration a) & b)) and for a combination of both pipe sections together with the orifice (Configuration c) & d)) for two explosive mixtures in accordance to the standard IEC 60079-1 (2014). On the basis of four configurations of the test sample and of two different explosive mixtures and five ignitions each, a total of 40 explosion tests must be performed by each participant.

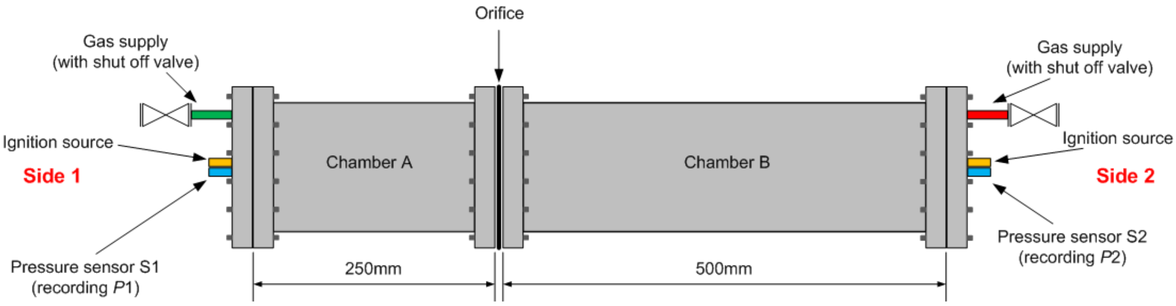

Figure 2: Test sample for PTB Ex PT Program “Explosion Pressure”

Program 2 "Spark Ignition":
The ignition probability of circuits is a decisive criterion for the testing and the assessment for the type of protection intrinsic safety described by the standard IEC 60079-11 (2011). In the program, the ignition probability of twelve different circuits is compared by ignition tests using a spark test apparatus. The twelve circuits (resistive, inductive, capacitive and mixed) are permanently installed in a “black box” and represent the test sample. For each one of the twelve circuits, the ignition probability is determined with an explosive mixture in accordance with IEC 60079-11 (2011). To do so the number of contacts until ignition are determined for each circuit, and this test is repeated 20 times. The overall effort for the performance of the program thus results from the achievement of a total of 240 ignitions for all tested circuits of the test sample.

Program 3 "Flame Transmission":
The general routine procedure for program “Flame Transmission” is described by the standard IEC 60079-1 (2014). The characteristic of interest is the test for non-transmission of an internal ignition. The test sample consists of two pipe sections of differing lengths, identical to the test sample from the "Explosion Pressure" programme (Chamber A & Chamber B, see Figure 2). In addition, it consists of a further prepared flange and three different nozzles (diameters 0.7 mm, 0.8 mm and 0.9 mm) instead of the orifice. After ignition in Chamber A the participant observes if there is a flame transmission through the nozzle into Chamber B or not. On the basis of three configurations of the test sample, one explosive mixture and ten ignitions each, a total of 30 explosion tests must be performed by each participant for the program.

Program 4 "Temperature Classification":
In this program the highest surface temperatures are determined for a test sample in accordance with IEC 60079-0 (2011). The test sample consists of a steel heating block with four heating cartridges as well as three different surface materials, copper, plastic (polycarbonate) and glass. The test sample is heated with the four heating cartridges until the thermal state of equilibrium is reached. In the program, the maximum surface temperature corresponds to the end temperature of the surfaces. The end temperature is regarded as being reached once a temperature increase of max. 2 K/h is not exceeded. Once the end temperature is reached, the temperature is to be determined at the hottest points of the prepared surfaces.

Program 5 "Electrostatic Charge":
The program consists of two measurands of interest, the surface resistance in accordance to IEC 60079-0 (2011) and IEC 60079-32-2 (2015) and the test for transferred charge in accordance to IEC 60079-32-2 (2015). The test sample is a collection of material samples of different substances with various properties for surface resistance and transferred charge. Per material sample, two surface resistance tests are performed in accordance to the above mentioned standards. Furthermore the test for transferred charge is performed for three of the material samples. Thus, a total of three test series are performed for the program.

Program 6 "Intrinsic Safety":
During the program “Intrinsic Safety” an assessment of Intrinsic Safety has to be performed based on a safety barrier for Ex ia Ga IIC in accordance with the standard IEC 60079-11 (2011). Safety barriers are used in a broad application area to separate intrinsically safe (Ex i) circuits from non-intrinsically safe circuits. The barriers limit the power supply (electrical power/energy) to the hazardous area, providing an intrinsically safe output circuit with level of protection “ia”. In the program no practical tests or measurements are necessary. During their assessment the participants shall uncover non-conformance, where the requirements of the standards are not fulfilled. These non-conformances are the characteristics of interest.

4. Results of program “Explosion Pressure”

4.1 Methods for analysis of the results

Because of the unknown “real value”, the assigned value has been calculated as the robust average x^* and the robust standard deviation s^* in accordance to standard ISO 13528 (2005) of the results reported by all participants.

4.2 Presentation and evaluation of the results

The diagram in Figure 3 shows the results of Configuration a) (Chamber A, 250 mm length, see Figure 2) for Phase I of program “Explosion Pressure” with an assigned value of $x^* = 7.02$ bar and the standard deviation of $s^* = 0.84$ bar. In the diagram of Figure 4 the results of the same configuration but for Phase II with an assigned value of $x^* = 7.24$ bar and the standard deviation of $s^* = 0.67$ bar can be seen. The program was performed by 37 participants in total. Six of those participants had only performed Phase II which explains the difference of the number of anonymized participants in the diagrams and the slight difference in the assigned value. The ethylene-air mixture with a concentration of 8 % ± 0.5 % C_2H_4 was ignited by a spark plug at one of the flanges. At the opposite flange of the spark plug a piezoelectric pressure transducer was installed to measure the explosion pressure (see Figure 2).
For evaluation and interpretation of laboratory biases the calculated standard deviation s^* of the assigned value in accordance with ISO 13528 (2005) was used. When a participant reports a result that gives rise to a laboratory bias greater than 3,0 s^* or less than −3,0 s^* then the result shall be considered to give an “action signal”. Likewise, a laboratory bias above 2,0 s^* or below −2,0 s^* shall be considered to give a “warning signal”. An “action signal” shall be taken as evidence that an anomaly has occurred that requires investigation.

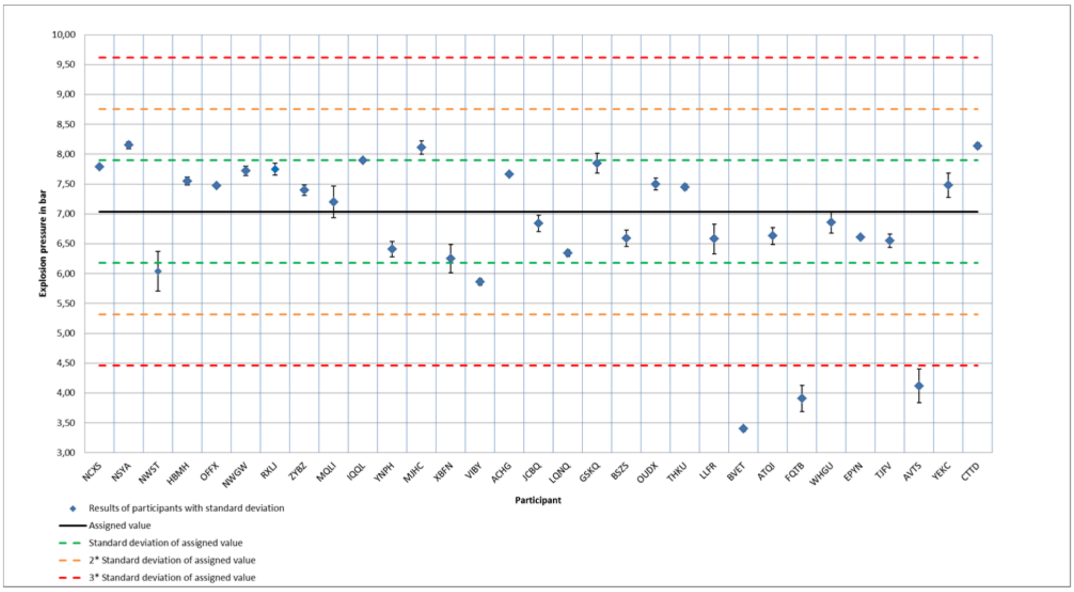

Figure 3: Anonymized participants' results for Phase I of Configuration a) of program "Explosion Pressure"

It can be seen on the diagram in Figure 3 that three participating laboratories have a bias less than −3,0 *s** and therefore an action signal.

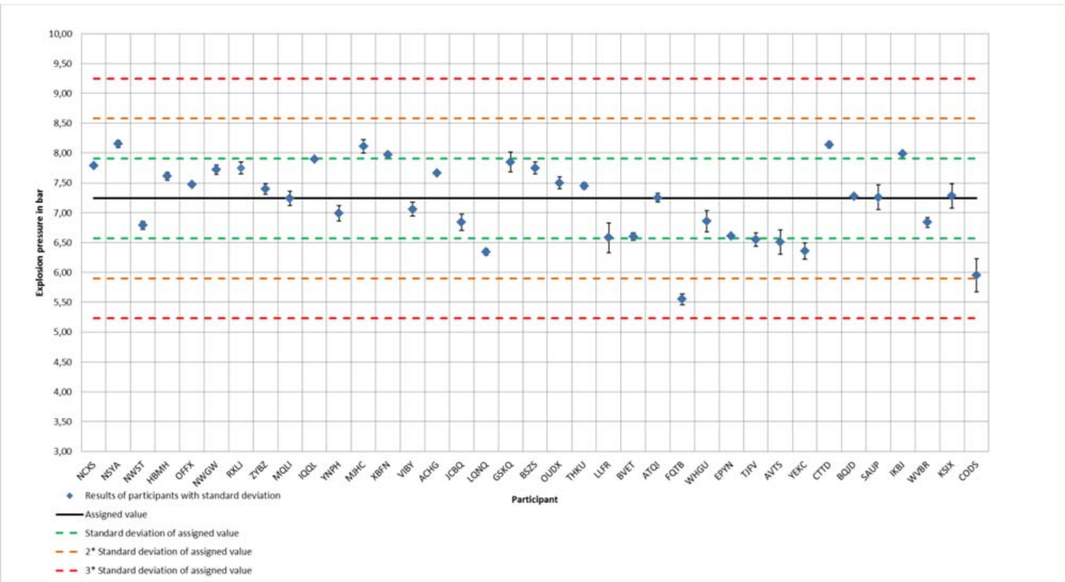

Figure 4: Anonymized participants' results for Phase II of Configuration a) of program "Explosion Pressure"

In the diagram in Figure 4 there is no participating laboratory with an action signal (bias greater than 3,0 *s** or less than −3,0 *s**).

5. Influencing factors

A deep investigation of the results, an analysis of the progressions of the explosion pressure curves and the discussion with the participating laboratories reveals the reasons for the differences in the results of program "Explosion Pressure":

- Most important is the critical analysis and plausibility check of all measured results (including pressure curves).

- To avoid temperature influences on pressure transducers, the transducer face (diaphragm) has to be temperature compensated. The background is that almost all pressure transducers are sensitive to thermal influences. The heat of the explosion process can cause an expansion of the housing of the internal crystal of the diaphragm. That expansion causes a pressure discharge of the crystal and simulates a low explosion pressure.

- Individual measuring ranges (for time base and amplitude) depending on the test sample and the explosive mixture should be used. Predefined settings are inadvisable. The focus should be on recording the rise time and the maximum amplitude. The reason is that the precision of measurement depends on the sample rate, the memory depth and the measuring range of the data acquisition system. Measuring ranges which are too wide could cause less precision and low details of the measuring result. Because of this it could happen that the data acquisition system doesn‘t record the highest measuring value and important peaks could be missed.

- When using digital oscilloscopes or other measuring devices, DC coupling should always be selected. The background is that AC coupling places a capacitor in line to the measuring input of the measuring system. This works like a high pass filter and blocks DC and low frequency AC signals which can result in lower measured explosion pressures than expected.

- Shut off valves of the test facility (see Figure 2) should be located close to the test sample. The reason is that the volume of the gas connection lines could influence the explosion pressure.

- Pressure transducers should be tightened to the torque recommended by the pressure transducer manufacturer. Incorrect torque could causes side loading of the transducers diaphragm which results in distortions in the output signal and different pressure values than expected.

- Pressure transducer faces should be flush with the inside wall of the enclosures in which they are mounted to avoid turbulences in front of the diaphragms which could influence the measured explosion pressures.

- To prevent pre-pressure inside of the test sample a delay time for shut off valves after purging with the explosive mixture should be used. If shut off valves close immediately after purging with the gas air mixture the pressure inside of the sample could be higher than atmospheric pressure. Pre-pressure of the gas air mixture inside of the sample could cause higher explosion pressures than expected.

6. Conclusions

The analysis of the results for program “Explosion Pressure” shows that the main factor for differences in the results is the human factor. The problems could be identified and solved with the help of the PTB Ex Proficiency Testing Scheme. For example, this can be seen in detail in the improvement of participant results for Configuration a) described in this present paper. The number of action signals was reduced from three to zero laboratories. An indication for the general improvement of results overall is the comparison of the standard deviation s^* (as measure of variability) for both phases of the same configuration of program “Explosion Pressure”. There was a reduction of about 20 % from $s^*_{\text{Phase I}}$ = 0.84 bar to $s^*_{\text{Phase II}}$ = 0.67 bar. These examples are transferable to the other results and aren’t limited to program “Explosion Pressure”. Finally the success of the scheme is highlighted by the decision of IECEx to make proficiency testing mandatory for all accepted and applicant IECEx Ex-testing laboratories.

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