Publishable Summary for 20SIP01 ISO Gauge
Developing an ISO Technical Specification "Characteristics for a stable ionisation vacuum gauge"

Overview

High and ultrahigh vacuum is indispensable for high-energy accelerators, plasma and fusion science, and also in industrial processes such as extreme ultraviolet (EUV) lithography, semiconductor and coating production. Monitoring high vacuums relies on calibrated ionisation vacuum gauges and general correction factors that relate calibration to process gas species, but this introduces significant measurement uncertainties. This project will promote the adoption of the stable and reliable ionisation gauge with known relative gas sensitivity factors developed in EMPIR JRP 16NRM05 through the drafting of an ISO Technical Specification (TS) document and its promotion to the wider industrial and scientific stakeholder ultra-high vacuum community.

Need

All manufacturers of ionisation gauges develop different products even if belonging to the same type of gauge. They differ in the selection of materials, potentials and, most important, geometry. For this reason, they also differ significantly in their relative sensitivity factors. In addition, all available ionisation gauge types are lacking long-term and transport stability, the instability being about 5 % over one year.

The pertinent technical committees ISO TC 112 "Vacuum Technology" and of the DIN NA 060-07 "Vacuum Technology" section have made it clear that the reliability and usefulness of ionisation vacuum gauges can be greatly improved by a technical specification and have encouraged work towards a standardised ionisation vacuum gauge.

ISO TC 112 has determined that several specific applications within its domain would benefit from the incorporation of the new ionisation vacuum gauge design. First, ISO 21360-1 requires a standard uncertainty of 3 % of pressure measurement with an ionisation vacuum gauge. This is possible for nitrogen, but at present not for any other gas. A suitable standardised ionisation vacuum gauge can provide this accuracy for many kinds of gases. The measurement of compression ratios according to ISO 21360-1 and ISO 21360-4 also requires an ionisation vacuum gauge with well-known relative gas sensitivity factors which are not available at present. Second, ISO TS 20175 and ISO TS 20177 will take advantage of a standardised ionisation vacuum gauge, when the calibration factors for relevant gas species will be known. Third, calibration laboratories for vacuum gauges in the High Vacuum (HV) and Ultra High Vacuum (UHV) ranges do not have reliable reference standards below 1 mPa. The present ionisation vacuum gauges lack long-term and transport stability. Also, it is too expensive to have them calibrated for other gases than nitrogen. The new ion gauge type developed in EMPIR JRP 16NRM05 will solve these problems and provide a stable ionisation vacuum gauge in order to apply ISO 3567 and ISO 27893.

Objectives

The overall aim of this project is to create impact from EMPIR JRP 16NRM05 "Ion Gauge", by casting the draft 'working' technical specification incorporating the important design characteristics for a stable ionisation vacuum gauge, as developed in the project, into an ISO Technical Specification, and to communicate the results to gauge manufacturers.

The specific objectives of this project are:

1. To incorporate the results of EMPIR JRP 16NRM05 Ion Gauge, including the design characteristics of a stable ionisation vacuum gauge, into an ISO Technical Specification within ISO TC 112.
2. To encourage manufacturers of ionisation vacuum gauges to produce the newly standardised gauge type.

Results

The results achieved so far in relation to the two objectives are:

Objective 1: To incorporate the results of EMPIR JRP 16NRM05 Ion Gauge, including the design characteristics of a stable ionisation vacuum gauge, into an ISO Technical Specification within ISO TC 112

As result of a ballot within the Technical Committee (TC) 112 of the International Standards Organisation ISO, the project ISO NP TS 6737 was initiated. The Working Group (WG) 2 "Vacuum Instrumentation" of ISO TC 112 was assigned with the project and with the development of the Technical Specification ISO TS 6737 "Characteristics for a stable ionisation vacuum gauge". The coordinator of this project 20SIP01 was nominated as project leader of the 6 project experts from 5 countries. The preparatory draft was accepted as first working draft as additional result of the ballot. A first meeting of the WG2 with the partners of 20SIP01 took place on June 29, 2021, as an online meeting due to the restrictions by the ISO Secretary General for the Covid-19 pandemic. In advance of this meeting the project partners prepared a second working draft which was accepted as new version of ISO TS/WD 6737 after the meeting. Four of the former partners in the preceding project developing the new gauge performed experiments and simulations with the new gauge. In the period until the following WG2 meeting in February 2022, the partners of 20SIP01 collected the new results by which the draft could be refined (for example tolerances, influence of openings in the anode cylinder, potentials and external magnetic fields, suitability of cathodes). Also comments from the WG2 and outside community were collected, and a third working draft was prepared by the partners of 20SIP01. This was discussed on February 7th, 2022, in an online workshop (36 participants from manufacturers, users, universities, research institutes and National Metrology Institutes) and on February 8th, 2022, in an ISO TC 112 WG2 online meeting and accepted as new working draft (WD). The new Online Standard Development (OSD) platform by ISO was used for commenting the third draft as online working group study. Outside of ISO TC 112 the draft was also circulated to the participants of the mentioned workshop for commenting until April 2022. After this period the 4th working draft was developed. The main issue in this phase were the tolerances of the gaps between the electrodes. It turned out that the gap sizes, which were used for the simulations, were too small in order to conform with the IEC 61010 series. This would inhibit conformity assessment and type approval of the gauge. Another issue were machining tolerances according to ISO 2768-1 and welding tolerances according to ISO 13920. These two issues were handled with the help of former project partners and external advice from a design engineer and an industrial partner who cared for the type approval for the commercial gauge which is designed according to ISO TS/WD 6737. This fourth draft was put to a vote within ISO TC 112 as ISO/CD TS 6737 between October 2022 and January 2023. It was accepted by ISO TC 112 but received 113 comments, mainly editorial. The comments were carefully considered and the revised CD was discussed and approved by the project partners at a project meeting in Ljubljana on 19/20 April 2023. The comment period for the CD closed on 28 April 2023 and was registered as a DIS. The responsible ISO Editorial Manager made comments, which were answered by the project leader and coordinator of 20SIP01. ISO TC 112 met with all its working groups in Berlin on 21-23 June 2023. The updated CD was discussed and approved. The final ISO DTS 6737 was formally initiated by ISO as a FDIS ballot on 7 July 2023, which will run until 1 September 2023. Final publication is expected before the end of 2023.

Objective 2: A series of presentations at conferences and to European manufacturers, to encourage production of the newly standardised gauge type.

An online video presentation was given at the XXIII IMEKO World Congress in September 2021 and a promotional leaflet for the new ionisation vacuum gauge has been designed. A list of manufacturers was compiled by the project partners and key users and manufacturers were informed of the newly developed ionisation vacuum gauge by emailing the publications on the gauge. Three talks were given at the sixteenth European Vacuum Conference EVC-16 in November 2021 in Marseille, which was a face-to-face meeting. The industrial exhibition during the EVC-16 was used to speak to manufacturers. Two manufacturers represented at this conference and the exhibition showed great interest. In addition, the industrial partner within this project developed a production line to sell the ionisation vacuum gauge developed in the preceding project. Presentations at the XXV Conference of the Italian Vacuum Society AIV, the 28th Croatian-Slovenian International Scientific Meeting on Vacuum Science and Technique (28-ISMVST), the 11th Vacuum symposium in UK and the 22nd International Vacuum Congress in Japan were used to arouse interest from the user's side, which then may ask manufacturers, if they are going to produce the new ISO gauge. The company INFICON presented its new gauge IRG080 according to ISO/CD TS 6737 at the industrial show of the 22nd International Vacuum Congress in Sapporo, Japan. The IRG080 with its associated controller IRC081 was displayed for the first time at an exhibit. As a consequence of the conference talk a great number of attendees came to the company booth to see the gauge. In the days following IVC-22 a few more formal inquiries were received. In particular a Japanese pump manufacturer was interested in IRG's good accuracy, as they want a precise gauge to measure their pump pressure. This is exactly in line with the goals of this and the former project 16NRM05. In general, academic or research institutes are more interested than industry in the gauge. The gauge was also displayed at the Japan Society of Applied Physics exposition. The new gauge

has attracted a great deal of interest, as evidenced by two invitations to present papers, one from the organisers of the 68th AVS Symposium in November 2022 in Pittsburgh, and the other from the 7th International CCM Conference on Pressure and Vacuum Metrology in conjunction with the 7th IMEKO TC-16 Conference in May 2023 in Rockville, Maryland. Two more papers were presented on these conferences by the project partners and another on the national Symposium of the German Physical Society in March 2023.

Impact

In order to promote the production of the newly standardised gauge type, project partners have participated in nine national and international events and made presentations to the end users. In addition, one paper has been published. Press releases and leaflets have been issued by the CNRS and CAO in France and the COMSOL company. INFICON is selling the newly standardised ionisation vacuum gauge as IRG080 optionally together with a controller IRC081 operating it.
The Technical Specification will enable manufacturers to produce an ionisation vacuum gauge ("ISO gauge") whose metrological characteristics are independent of the design of the product in detail. All ISO gauges will have the same operational parameters, the same sensitivities for nitrogen within a very small variation and the same relative gas sensitivity factors for other gas species compared to nitrogen. This allows a much broader application of the ISO gauge compared to existing ionisation vacuum gauges to characterise a vacuum environment. In the second half of 2022, INFICON succeeded to get a certificate of conformity with the IEC 61010 series for its IRG080 which is produced according to ISO/CD TS 6737. The gauge and a corresponding controller operating it, is now available for purchase from the company and several have been sold.

The direct impact of the project will be that ISO gauges without individual calibration can be offered with a much better accuracy (uncertainty of less than 2.5 %) than other ionisation vacuum gauges (10 % to 20 %). With individual calibration they can be used by calibration laboratories as reference gauges according to ISO 3567, which will be more long-term and transport stable than today's ionisation vacuum gauges. In addition, the calibration laboratories will be able to offer calibrations in high and ultrahigh vacuum not only for nitrogen, but for any other gas species where the ionisation probability by electrons is known.

With the ISO gauge, pumping speed measurements, performed according to the ISO 21360 series, for other gases than nitrogen will be much more accurate and pumping speed measurements can be extended to many more gases, because reliable relative gas sensitivity factors can be accumulated over time by National Metrological Laboratories or other calibration laboratories. This is important for the users of the pumps and for the design of vacuum systems in terms of energy saving and environmental protection (waste gas management), because no safety margins have to be added to the measured value. ISO TS 20175 will be able to be effectively implemented: The use of ionisation vacuum gauges to calibrate quadrupole mass spectrometers *in situ* will be much more accurate with a standardised ionisation vacuum gauge, because the relative gas sensitivity factors will be reliably known. ISO TS 20177 will benefit from a more accurate measurement of outgassing rate and the provisional use of nitrogen equivalent can be replaced by the true outgassing rate for a species.

In a wider impact the competitiveness of the European vacuum industry will be improved. The application of the TS will help to remove obstacles to achieve fundamental optimisation within the European coating and process tool industry, and the semiconductor and EUV lithography industries, via the provision of traceable and more robust measurement technical specifications. Large accelerator (e.g. CERN, ESRF, DESY) and fusion (ITER) facilities in Europe will greatly benefit from traceable vacuum pressure measurements. The application of the TS will also improve quality assurance procedures of European vacuum equipment manufacturers. National Metrology Institutes worldwide will have a reliable transfer gauge for high and ultrahigh vacuum to compare their primary standards.

List of publications

K. Jousten, S. Bechstein, M. Bernien, Frédéric Boineau, N. Bundaleski, C. Illgen, B. Jenninger, J. Setina, R.A.S. Silva, A. Stöltzel, O.M.N.D. Teodoro, , M. Wüest, *Evaluation and metrological performance of a novel ionisation vacuum gauge suitable as reference standard*, Measurement 2023, 112552, https://doi.org/10.1016/j.measurement.2023.112552.

This list is also available here: https://www.euramet.org/repository/research-publications-repository-link/

20SIP01 ISO Gauge

Project start date and duration:	01 May 2021, 36 months	
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Primary Supporter: Jürgen Eisenreich, ISO TC 112		
Internal Funded Partners: 1. PTB, Germany	External Funded Partners: none	Unfunded Partners: 2. IMT, Slovenia 3. INFICON LI, Liechtenstein