European Metrology Programme for Innovation and Research

Delivering Impact

The first international standard for vacuum gauges

Research into fundamental physics, the manufacture of advanced pharmaceuticals, semiconductors or electronics are all linked by a common factor. They require an environment free of atmospheric contaminants, provided by high or ultra-high vacuums. However, in the first few decades of the 21st century, instruments that measured high vacuum lacked standardisation and had significant measurement uncertainties.

Europe's National Measurement Institutes working together

The European Metrology Programme for Innovation and Research (EMPIR) has been developed as part of Horizon 2020, the EU Framework Programme for Research and Innovation. EMPIR funding is drawn from 28 participating EURAMET member states to support collaborative research between Measurement Institutes, academia and industry both within and outside Europe to address key metrology challenges and ensure that measurement science meets the future.

Challenge

High (10^{-1}-10^{-6} Pa) and ultra-high (10^{-6}-10^{-9} Pa) vacuum are indispensable in a range of high-technology industries including preventing atmospheric contamination during integrated circuit fabrication or the deposition of thin films for solar cell or electronic manufacturing.

Vacuum levels are measured by "ionisation gauges" (IG's) but at the start of 2020 these instruments were not standardised, and commercial gauges differed in materials and geometries. These lacked long-term and transport stability and were mainly only calibrated for nitrogen gas. To quantify other gases, "sensitivity factors" were applied to measurements but this led to measurement uncertainties of 10 - 20%. This meant IGs were unable to comply with international standard ISO 21360-1 which requires an uncertainty of 3% on pressure measurements with these instruments.

Working with the company INFICON, the EMPIR project Ion Gauge (2017-2020) resolved these issues and produced a "standardised" IG which could measure vacuum pressure from 10^{-2} down to 10^{-6} Pa, with a 1% measurement uncertainty for nitrogen and only 2 - 3% for other gas types.

Standardisation bodies indicated that industry would benefit from a new technical specification on this new gauge design. This would allow conformity not only to ISO 21360-1 but also improve calibration uncertainty according to ISO 3567, and to ISO 27893.

Solution

In 2021, the ISO Gauge project started to develop a new technical standard for IGs and, in conjunction to the International Standards Organisation Technical Committee 112 (ISO TC 112), launched ISO NP TS 6737 and appointed the coordinator of ISO Gauge as project leader.

In June 2021, three partners from the previous Ion Gauge project, including INFICON, further optimised the new IG's design for reliable operation. This included refining the influence of apertures, the effects of external magnetic fields, and the suitability of the cathodes to generate the electrons that ionise residual gases. The gaps between electrodes were sized to conform with IEC 61010 standards on safety requirements for electrical equipment and machining and welding tolerances were also defined to conform with standards ISO 2768-1 and ISO 13920.

After addressing further comments the final draft was approved and published in November 2023 as ISO/TS 6737 *Vacuum technology — Vacuum gauges — Characteristics for a stable ionisation vacuum gauge*.

Impact

INFICON is a leading company in vacuum instrumentation, gas analysis, thin film technology and protective particle coatings. The company's expertise in vacuum instrumentation was integral to the development of the prototype standardised IG in the Ion Gauge project and the technical standard in the subsequent ISO Gauge project.

In 2022, INFICON has introduced the new IG to the market as the IRG080. This is the first gauge on the market that conforms to the ISO/TS6737 specification. Along with the low measurement uncertainties and wide measurement range (10^{-2} - 10^{-6} Pa) of the original prototype, it also has a high repeatability (<1 %), reproducibility (<1 %), and stability to storage and transport (<1 %). It can calibrate vacuum gauges or other instruments, such as quadrupole mass spectrometers - that analyse gas composition in industrial processes, environmental monitoring or research applications.

The IRG080 has been adopted by several National Metrology Institutes worldwide and had been selected by numerous R&D and calibration laboratories across industry and research, such as at CERN in Switzerland and ITER in France (international organisations which study fundamental physics and nuclear fusion respectively) to provide an accurate, stable and reliable reference. Outside the laboratory, industry is recognising the gauge as a reliable tool for in-situ calibration of vacuum-based coating processes.

The new ISO/TS6737 standard, and the freely released design of the standardised IG, will allow European industry to optimise a range of processes, including coating, semiconductor and EUV lithography, via the provision of a new traceable and more robust measurement tool.

Developing a new ISO technical standard

In 2021, within the International Standards Organisation Technical Committee 112 (ISO TC 112), the project ISO NP TS 6737 was initiated. A first draft of the new document was created and presented in June 2021 with a second draft accepted following this meeting.

Partners from the previous Ion Gauge project performed additional experiments to refine the ion gauge (IG) and a third working draft submitted in February 2022, with a fourth refined draft submitted and accepted after a workshop in April 2022.

Following voting within ISO TC112, the draft was registered as a DIS standard in April 2023 and in September 2023 a final draft was sent to the ISO secretariat. In November 2023, the document was published as ISO/TS 6737.

The ISO/TS 6737 is the first international standard for a robust and accurate ion gauge that will allow improvements in both time and energy for a wide range of industrial and scientific fields.

EMPIR EURAMET

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