European Metrology Programme for Innovation and Research

Delivering Impact

Reducing aero-engine operational costs

Accurate air pressure measurements are essential for the safe and efficient operation of modern aircraft. The aero-engine environment is especially demanding for onboard sensors used to monitor and control important aircraft systems. Manufacturer blueprints of future, more fuel-efficient, engines specify operation at even higher temperatures, imposing tougher requirements for pressure sensor reliability. However, no calibration service could demonstrate long-term measurement stability for such sensors.

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

Responding to the international drive for improved fuel-efficiency, leading aircraft engine manufacturers are designing smaller, lighter engines, operating at higher temperatures and pressures than those currently in service. Such engines also 'bleed' hot, high-pressure air to support other important aircraft systems, typically extracted at over 200 °C.

In these harsh environments, multiple onboard sensing devices, including air pressure sensors, are relied on to maintain safe and efficient flight operations. For engine manufactures, the more precisely they can specify air pressure measurements, the more fuel-efficient they can specify their engines designs. Another operational cost requirement is optimising periods between sensor re-calibrations, ideally synchronised with routine maintenance downtimes.

Therefore, sensor manufacturers would offer a competitive advantage if they could demonstrate long-term reliability, with no significant measurement drift, at such temperatures over the 12 to 18 months targeted by the aviation industry.

Solid-state pressure sensors already reached similar levels of measurement accuracy to existing primary standards, as product development outpaced that of calibration methods. Existing calibration methods remained susceptible to variations in ambient conditions so could not offer measurement certainty. Therefore, evolving demands of the aviation sector could not be satisfied by calibration laboratories..

Solution

The EMPIR project *Industrial standards in the intermediate pressure-to-vacuum range* developed new primary standards based on liquid column manometry and force-balanced piston gauges.

The project established the means to provide calibration services using such state-of-the-art pressure measurement instrumentation. Among several metrology institutes, LNE implemented a calibration service using metrology-grade piston gauges and force-balanced piston gauges.

Impact

Druck Ltd, part of the energy technology company Baker Hughes, manufactures Micro-Electro-Mechanical System sensors for flight control and air data measurement applications. By combining silicon-based microelectronics with micro-machining, the technology offers ten times the performance of standard silicon sensors. To suit harsher environments, Baker Hughes repackaged the technology, as Trench Etched Resonant Pressure Sensors (TERPS).

For a future engine platform, GE Aviation commissioned development of a high-temperature TERPS sensor, specified to 150 parts per million (ppm) accuracy over 12 months at 200 °C, a temperate above the operating range of existing Druck sensors.

Baker Hughes developed a test rig at its Leicester, UK facility, to automatically test for long-term reliability, or absence of measurement drift. The rig incorporated a modified version of its PACE 1000 TERPS instrument as a reference pressure indicator for the prototype high-temperature TERPS sensor under test. Demonstrating the target sensor accuracy required long-term 15 ppm accuracy for the reference device, a level of performance that could not be demonstrated by any commercial calibration laboratory.

The company, therefore, contacted LNE, that tested two PACE 1000 devices, before and after Baker Hughes's 18-month test. In July 2019 it certified that pressure readings over this timescale were within the target limits for calibration equipment.

Importantly for Baker Hughes, this established the stability of its reference standard and the reliability of the prototype high-temperature sensor, that was duly delivered to its client at a technology readiness level above its initial expectations.

Many steps lie ahead before production readiness. If, as Baker Hughes hopes, the new TERPS technology is employed in production engines, the new calibration service will have helped enhance the cost-effectiveness of aviation operations and supported EU policies designed to reduce aviation emissions.

New industrial pressure standards

The EMPIR project *Industrial standards in the intermediate pressure-to-vacuum range* developed and characterised primary pressure standards for low pressure: by applying liquid column manometry, force-balanced piston gauges, and refractometry techniques.

A new type of interferometric liquid column micromanometer for the 2 kilopascal range of absolute and gauge pressure was developed. For the 15 kilopascal range, force-balanced piston gauges were characterised as primary pressure standards. For around 100 kilopascal of absolute pressure, a dual Fabry-Perot cavity was designed and investigated to serve as a primary realisation of pressure.

The project also established the means to deliver industrial calibration services with a range covering -100 to 10 kilopascals of gauge pressure and 1 pascal to 10 kilopascals of absolute pressure, using dead-weight pressure balances and force-controlled piston gauges to provide reference pressures.

Fabry-Perot refractometry was also shown to be a promising method suitable as a basis for mercury-free, highly accurate and efficient traceable pressure measurement devices.

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EMPIR EURAMET

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

www.euramet.org/project-14IND06

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11326/0720 - 14IND06