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ABLE Upgrade Engine Test Bed Hygrometry Systems for Rolls-Royce

With over 12,000 people and an estate of over 400,000 square metres, Derby is home to the largest concentration of Rolls Royce employees in the UK. It's also home to their academy where over 200 apprentices are recruited each year and is the site for their Learning and Development centre.

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While civil aerospace is the main focus for Rolls Royce in Derby, the city plays host to the full breadth of the company. This includes 2,400 people in Raynesway. Its core gas turbine technology has created one of the broadest product ranges of aero engines in the world, with 54,000 engines in service with 500 airlines, 2,400 corporate and utility operators and more than 100 armed forces, powering both fixed and rotary wing aircraft. In 2017, the future of the civil aerospace division was secured for the next 30 years when the company decided that a new £90M test bed would be constructed on the Derby site instead of overseas.

Dew point is a critical measurement in the monitoring of aero engine efficiency. Moisture in the intake air of a gas turbine can affect its operation in two different ways: by possible condensation in the inlet and by changing the gas properties throughout the cycle. Condensation can be controlled by restricting engine operation with limits on relative and absolute humidities.

As air is cooled at constant absolute humidity, its relative humidity increases until it reaches its saturation temperature, also called the dew point. Further cooling will cause the excess water to condense. It is assumed that this process is slow enough to permit the establishment of equilibrium conditions. In engine inlets, depending on the inlet Mach number, depressions in static temperature and pressure can be substantial. If certain conditions are met, the inlet static temperature may fall below the dew point, leading to the possibility of condensation. If the cooling process is very rapid and is followed quickly by a temperature rise, equilibrium conditions will not be reached and an unstable state may exist. This state is called supersaturation, in which relative humidity well beyond 100% can be present for a short time.

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In consideration of the above, a requirement for accurate measurement of absolute humidity, namely dew point, is a prerequisite for any aero engine testing. The chilled mirror (optical condensation) hygrometer is widely considered to be the most precise method for dew point measurement. It is a primary measurement, determining, as its name suggests, the actual condensation point of the sample gas and can easily be made traceable to international calibration standards such as UKAS & NIST. The sensor contains a small metallic mirror, the surface of which is chilled until water condenses out of the sample gas. The mirror is illuminated by a light source and the reflected light is detected by a phototransistor. At the onset of condensation, the reflected light is scattered and consequently reduced at the detector. A control system maintains the mirror temperature at the point where a thin film of condensation or dew is sustained and a PRT embedded in the mirror measures and reports the "dew point" temperature. Accuracies of +/- 0.1°C are achievable with this technology, response times are fast and operation is relatively drift free in comparison with secondary humidity measurement techniques.

When looking to equip their new test bed facility with the latest chilled mirror technology, Rolls Royce turned to ABLE Instruments & Controls. ABLE has a long history of optical hygrometer supply and provision of expertise in good humidity measurement practice to the Derby and Hucknall sites. Part of ABLE's remit has been to advise on the best sensor location for representative measurements, suitable materials of construction for the sampling systems and maintenance regimes for continuous optimum performance.

ABLE supplied several Optica Chilled Mirror Hygrometers and single stage dew point sensors with a typical measurement range of -15°C to +25°C dew/frost point at atmospheric pressure. The sensors were the enhanced accuracy variant (+/- 0.1 °C) with platinum rather than rhodium plated copper mirrors in order to protect against any abrasives or corrosives in the sample stream. Extra-long sensor cables were provided to facilitate the substantial distances (up to 200ft) between the electronics and the sampling points. All Opticas incorporated a patented contaminant compensation system known as PACER (Programmable Automatic Contaminant Error Reduction) which minimises maintenance requirements and permits accurate, long-term operation of the hygrometer without the need for shutdown to clean the mirror.

The hygrometer upgrade has served to assist Rolls Royce's in realising its key objective, to improve the accuracy and precision of analysers deployed on aero engine test beds, both by installation good practice and improved specification, thereby reducing the uncertainty budget involved in calculating engine efficiencies.

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