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Development of a custom on-line ultrasonic vapour analyzer/flowmeter instrument for the ATLAS inner detector, with application to gaseous tracking and Cherenkov Detectors

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Precision sound velocity measurements can simultaneously determine binary gas composition and flow. We have developed an ultrasonic analyzer with custom electronics, currently in expanding use within the ATLAS experiment, with numerous potential applications.

The ATLAS silicon tracker compressor-based C3F8 evaporative cooling system will be replaced with a thermosiphon and may also circulate a blend containing 20-30% C2F6, for enhanced safety against thermal runaway at higher LHC luminosities. Central to these developments is a new speed-of-sound instrument for simultaneous measurement of flow and C3F8/C2F6 mixture. The custom microcontroller-based electronics and the instrument functionality are described.

Summary

Precision sound velocity measurements can simultaneously determine both gas composition and flow. We have developed an ultrasonic analyzer with custom electronics, currently in expanding use within the ATLAS experiment, with numerous potential applications not only in Cherenkov and gaseous trackers, but also in the analysis of hydrocarbon mixtures, vapour mixtures for MOCVD semi-conductor manufacture, and in diving and anaesthetic gas mixtures.

The compressor-based C3F8 evaporative cooling system of the ATLAS silicon tracker will be replaced with a thermosiphon exploiting the hydrostatics of the 92m shaft to the experimental cavern. At 60kW dissipation 1.2kgs-1 of vapour will return to the surface condenser. Following an extensive series of studies, the evaporative coolant may also be changed to a blend containing 20-30%C2F6, giving better protection against thermal runaway under increasing LHC luminosity. Central to these developments a custom acoustic instrument combines flowmetry and vapour mixture analysis, exploiting the phenomenon that sound velocity in a binary gas mixture at known temperature and pressure depends uniquely on the molar concentrations of the components.

Custom electronics, based on Analog Devices ADuC and Microchip dsPIC33F microcontrollers, generates 50kHz ultrasound 'chirps' and synchronously starts a 32MHz transit time clock, which is stopped by an above-threshold sound pulse after amplification in an AD620 instrumentation amplifier. HV transducer bias is provided via TRACO MHV12-0.5K6000P DC-DC converters. Time-stamped bidirectional transit times, vapour temperature and pressure are pipelined from a FIFO memory at up to 100Hz for rolling-average flow and mixture analysis in PVSS-II®, which provides the graphical under interface. Data transfer to the SCADA computer is presently via USB, CAN or RS232.

An ultrasonic gas analyzer has been in continuous use, as part of the ATLAS DCS, since January 2010 to monitor C3F8 coolant leaks into the N2 environmental gas surrounding the pixel detector. Individual leaking circuits have been identified through C3F8 concentration changes of <5.10-4.

In a range of newly-built acoustic vapour mixture analyzer-flowmeters, sound is transmitted from transducers in two opposing directions: parallel/antiparallel to the vapour flow (up to 250lmin-1), or crossing the 137mm thermosiphon vapour return tube at 45°. Comparison of the average sound velocity in the two directions with a look up table of sound velocity vs. mixture ratio (generated from measurements in calibration mixtures or theoretical predictions at the process vapour temperature and pressure) is used to calculate the mixture ratio. The flow rate is computed from sound transit time difference in the opposed directions. Extensive fluid dynamic modelling was used optimize the sound path geometry.

Although ultrasonic binary vapour analysis was first used for the N2/C5F12 radiator of the SLD Cherenkov Ring Imaging Detector and has been subsequently adopted in all major RICH detectors, including DELPHI COMPASS and LHCb, none of these applications exploited simultaneous flowmetry and vapour analysis in the same instrument. We foresee future electronics with Ethernet and wireless connectivity, with flow and mixture analysis in new firmware in system-on-chip implementations.

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