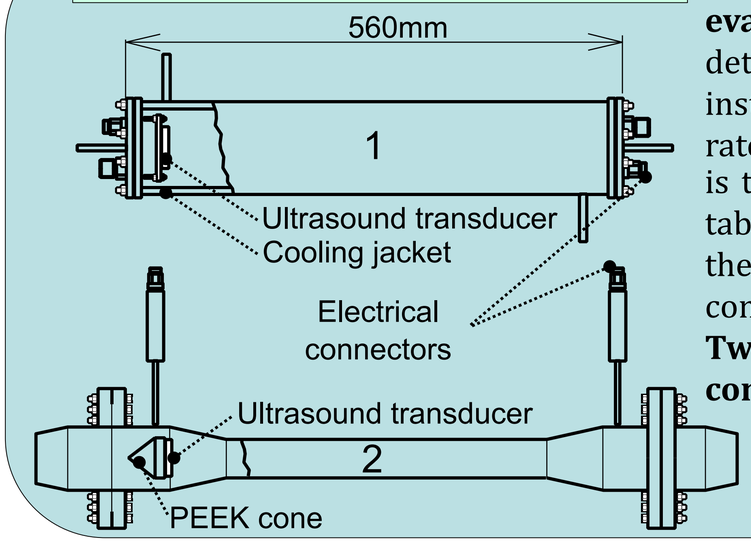
European Organization for Nuclear Research

ATLAS EXPERIMENT

CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF MECHANICAL ENGINEERING

SIMULTANEOUS ON-LINE ULTRASONIC FLOWMETERY AND BINARY GAS MIXTURE ANALYSIS FOR THE ATLAS SILICON TRACKER COOLING CONTROL SYSTEM

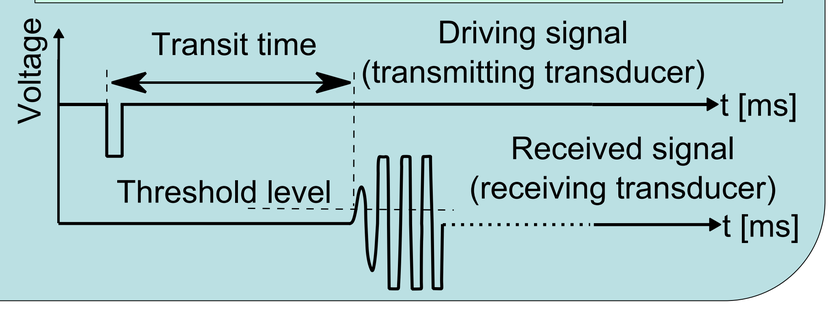
Axial binary gas analyzers/flowmeters.



Several versions of a novel on-line ultrasonic instrument have been developed for use in the fluorocarbon evaporative cooling system of the ATLAS silicon tracker. These allow operation ranging from low-flow leak detection to intermediate and high volume flowmetry with simultaneous binary gas mixture analysis. In these instruments the difference in transit time of ultrasound pulses sent in opposite directions is proportional to gas flow rate while their average can be used with the sound path length to calculate the sound velocity. Mixture composition is then calculated by comparison with velocity-composition tables, since at known, measured temperature and pressure the sound velocity is a unique function of the relative concentrations of the two components.

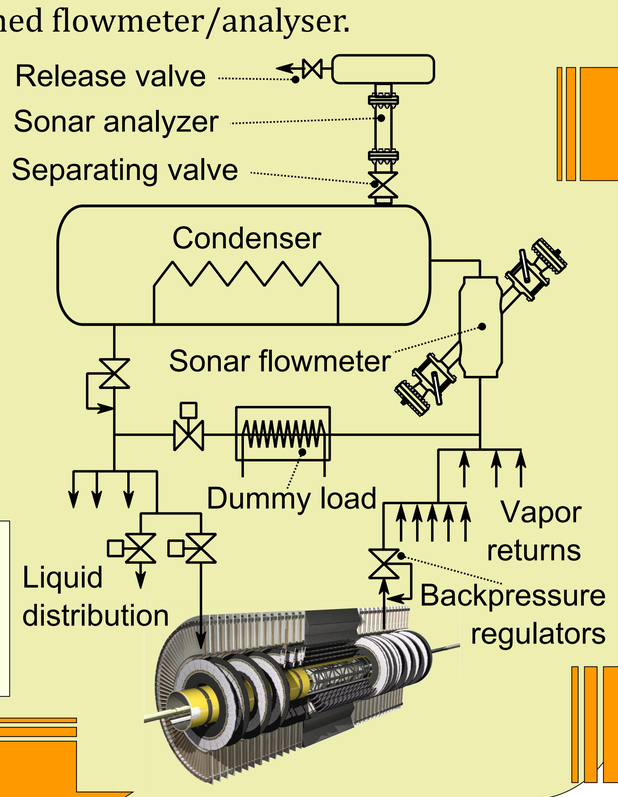
Two axial sonar instruments analyze gas aspirated at constant low from the nitrogen envelopes of the ATLAS silicon pixel and SCT detectors with a sensitivity of ~5.10^{-5} to trace C_3F_8 concentrations.

Signal detection and transit time measurement.



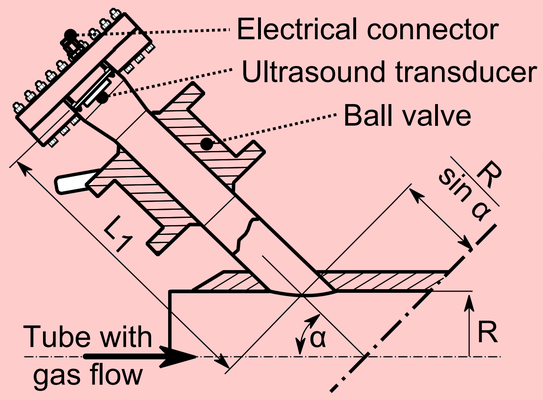
Two ultrasonic ("sonar") instruments are implemented in the Thermosiphon, which is being built as a new evaporative coolant recirculator for ATLAS silicon tracker. This will begin operation with C_3F_8 in 2013 with possible future operation with C_3F_8/C_2F_6 blends. The required liquid pressure is provided by the hydrostatic column in a 92 metre liquid pipe. The first operates as a flowmeter in the vapour return lines with possible future operation as a combined flowmeter/analyser.

Since the condenser of the new thermosiphon system will operate below atmospheric pressure, any air ingress will be monitored using ultrasonic binary gas mixture analysis in an instrument located above the condenser. This instrument will trigger the evacuation of excess air, depending on the air ingress rate.

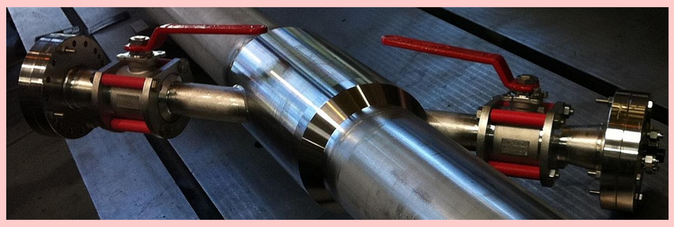


The thermosiphon recirculator with sonar installations in the vapour return to the condenser, and in its degassing system.

We have developed a flowmeter/analyser with a sound path crossing the gas flow at 45° for operation in fluorocarbon vapour flows up to 20000 $l.min^{-1}$ through a tube of 133.7 mm ID. The positioning of the ultrasonic transducers to minimize pressure drop and turbulence in the sound path was the subject of an extensive CFD simulation. The final instrument, constructed in stainless steel with a total sound path around 800 mm, has been recently calibrated in air in flows up to 10 ms^{-1}, demonstrating linearity with *rms* precision of ± 2.3 % of full scale. This instrument will be used as a high-flow flowmeter in the new ATLAS thermosiphon recirculator.

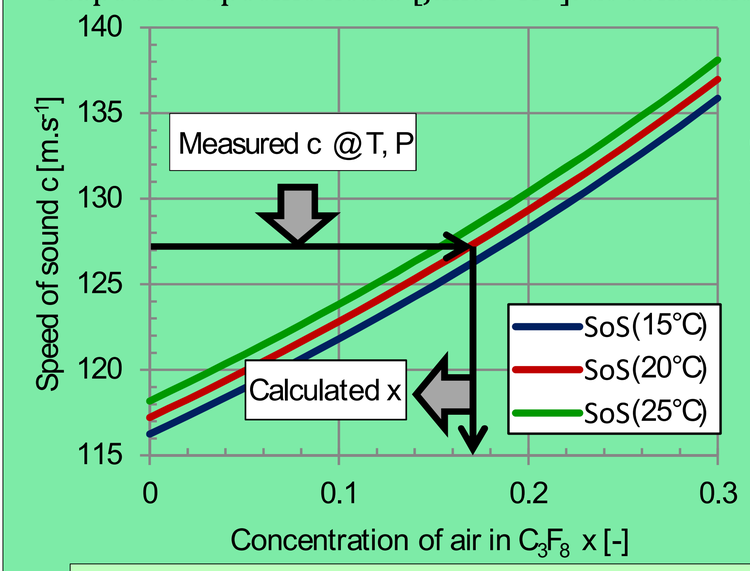


Total sound path: $2(\frac{R}{\sin\alpha}+L_1)$



The high volume 45° angled flowmeter.

The supervisory computer will continuously compare measured sound velocity to a velocity/composition look-up table for air/C_3F_8 mixtures. The look-up table has been prepared using the C_p/C_v ratio in the mixture, γ_m, computed for a variety of mixture compositions: $x_{i=1,2}$ are the molar concentrations of air and C_3F_8 while $C_{P\ i=1,2}$ and $C_{V\ i=1,2}$ are their respective specific heats [$J.mol^{-1}K^{-1}$]. at constant pressure and temperature.



$$\gamma_m = \frac{\sum_i x_i C_{pi}}{\sum_i x_i C_{vi}} \qquad c = \sqrt{\frac{\gamma_m RT}{\sum_i x_i M_i}}$$

The sound velocity, ***c***, in the lookup table is given by:

R, universal gas constant [$J.mol^{-1}K^{-1}$],

T, temperature[K],

$M_{i=1,2}$, molar masses [kg] of air and C_3F_8

± 0.5ms^{-1} sound velocity measurement precision ➔ ± 0.1 % air concentration measurement precision

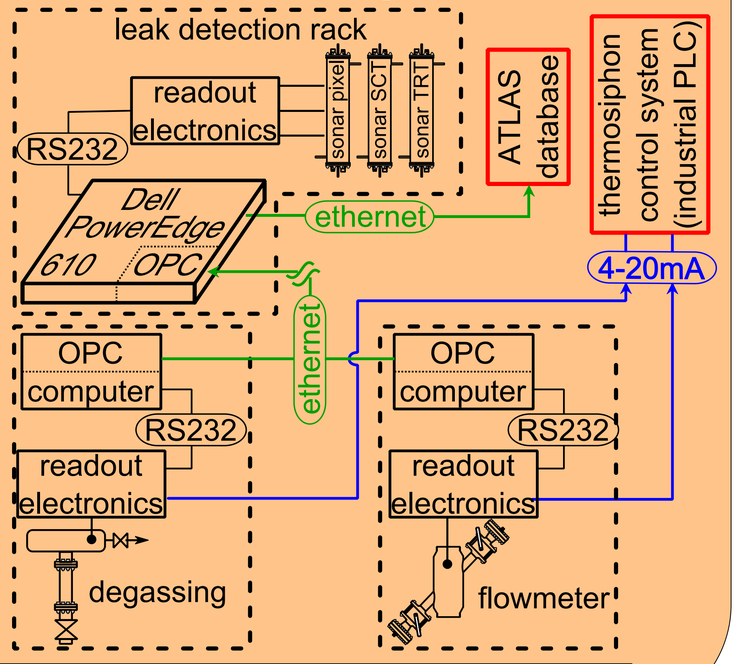
Sound velocity *vs.* air/C_3F_8 composition at 3 temperatures and a pressure of 300 $mbar_a$.

The on-line ultrasonic instruments for coolant leak detection, thermosiphon condenser degassing and flowmetry will be implemented in the ATLAS detector control system (DCS).

The µ- controller based local electronics of each instrument will pass sound transit time, temperature and pressure data to a PowerEdge 610 server running PVSS-II under Linux, where complex tasks such as composition analysis or flow calculations will be performed. The computer is located in an underground technical cavern in a rack with the local electronics of the ultrasonic leak detection system. All the electronics will operate on UPS.

The custom PVSS II project -

- gathers data from all the instruments;
- communicates with remote instruments via Ethernet using OPC clients, or via short serial links;
- calculates flow & mixture composition using on-line transit time, temperature and pressure data;
- archives data, including calculated flow and mixture composition to the ATLAS DCS database and other DBs.



Interconnection of sonar instruments in ATLAS.

*Communicating author:
martin.doubek@cern.ch
Faculty of Mechanical Engineering,
Czech Technical University in Prague

R. Bates, A. Bitadze, School of Physics & Astronomy, Univ. Glasgow, UK; M. Battistin, S. Berry, J. Berthoud, P. Bonneau, J. Botelho-Direito, G. Bozza, O. Crespo-Lopez, E. Da Riva, B. DiGirolamo, G. Favre, J. Godlewski, D. Lombard, L. Zwalinski, CERN, Geneva, Switzerland; N. Bousson, G. Hallewell, M. Mathieu, N. Langevin, A. Rozanov, CPPM, 13288 Marseille, France; G. Boyd, Dept. Physics & Astronomy, Univ. Oklahoma, Norman, OK, USA C. Degeorge, Dept. Physics, Indiana Univ. Bloomington, USA; C. Deterre, Deutsches Elektronen-Synchrotron Hamburg, Germany; M. Doubek*, V. Vacek, M. Vitek, Faculty of Mechanical Engineering Czech Technical University in Prague, Czech Republic; S. Katunin, Petersburg Nuclear Physics Institute, Russia; S. McMahon, Rutherford Appeleon Laboratory, Didcot , UK; K. Nagai, Dept. Physics, Univ. Innsbruck, Austria; D. Robinson, Dept. Physics & Astronomy, Univ. Cambridge, UK; C. Rossi, Dept. Mechanical Engineering - Thermal Energy & Air Conditioning , Università degli Studi di Genova, Italy.