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Abstract:

The inner concrete containment structures of pressurised water reactors must be able to contain steam at the pressures and temperatures associated with a leak in the primary circuit (~160°C and 5 bar). The behaviour of high-temperature steam within the cracks in concrete is therefore a concern for the organisations that operate these reactors. The aim of this project is to measure the temperature profile over time within model cracks as steam/nitrogen mixtures flow through them to high-accuracy.

Results and Discussion:

Experiments were conducted on three model cracks in concrete, planar, 2cm wide and 22 cm long with initial separations of around 80µm, 120µm and 240µm. The experiments produced complex datasets with fluctuations in the surface temperature of the cracks and pressure caused by interplay of heat transfer, condensation, absorption and evaporation within the cracks (top). The crack separations were found to reduce over the course of the experiments as mineral deposits were formed on their inner surfaces in response to the cycles of heating and rehydration.

For the smaller crack separation with steam/nitrogen mixtures at low flow rates, the limiting pressure differentials follow simple trends with both total flow rate (middle top) and the proportion of steam (middle bottom). The fluid is effectively cooled to room temperature, condensing all of the water from the steam, and gives almost the same pressure differentials as for the cold nitrogen flows.

With larger crack separations and higher flow rates, a whole spectrum of thermal behaviours occurs up to crack separations and flow rates in which the concrete is heated to the boiling point of water and simple mixed flow ensues. Correlations of thermal fluctuations between thermocouples (bottom) reveal changing response of the heated concrete.