Testing and Deployment of a Thermostatic Valve for Use in the Antarctic Rodwell Apparatus for the IceCube Upgrade Project

Koziol, Elliot (School: Madison Country Day School)

The IceCube Neutrino Observatory requires boreholes drilled 2,500 meters into the Antarctic ice sheet using a 5 megawatt hot water drill. During the first 66 minutes of drill startup insufficient water supply reduces drilling efficiency. The Antarctic Rodwell Apparatus (ARA) was adapted to supplement flow but produced 57 liters per minute below target. A thermostatic shuttle valve was proposed to automatically reroute the hot water supply line as a secondary outflow path based on water temperature, doubling the system's output with zero manual intervention. While thermostatic valves are widely used in plumbing and HVAC for temperature mixing, no prior application has used one to repurpose a supply line in a drilling or subsurface system. Three engineering goals were defined: (1) thermal transition time under 1,000 seconds, (2) backflow transition under 1,000 seconds in a field-representative configuration, and (3) pressure tolerance above 2.76 MPa (despite a manufacturer rating of only 1.72 MPa). Four test assemblies were constructed with progressively refined instrumentation including RTD probes and a Linux-based data acquisition system. A lumped parameter thermal model was developed to predict transition behavior. Hot-to-cold and cold-to-hot transitions averaged 25.2 ± 2.5 seconds and 34.9 ± 2.5 seconds (n=5), respectively. Backflow transitions averaged 797.0 ± 3.8 seconds (n=3). The valve sustained a peak pressure of 8.98 MPa (5.2× manufacturer rating) with zero leakage. All three engineering goals were met. The valve was subsequently deployed at the South Pole during the 2025/26 IceCube Upgrade drilling season, successfully operating across three boreholes and adopted as baseline hardware for IceCube-Gen2.

Awards Won:

Third Award of $1,200