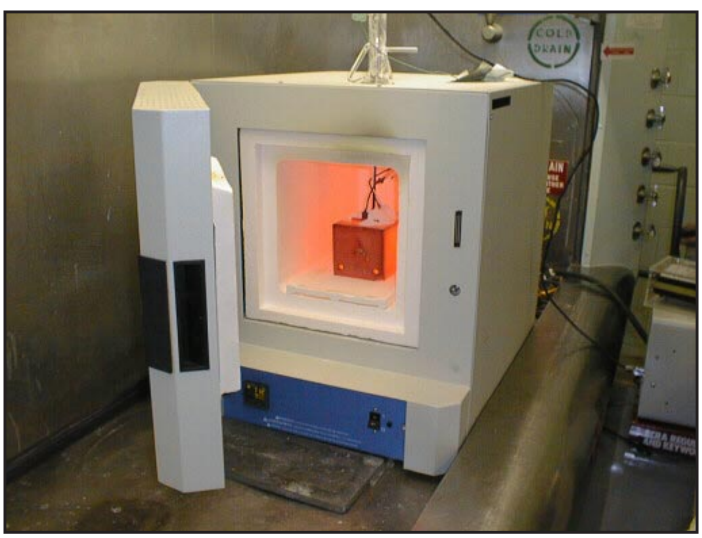
TEMPERATURE SENSING AND FUZZY LOGIC CONTROL OF GLASS MELTING

The Idaho National Engineering and environmental Laboratory (INEEL), in collaboration with AccuTru International Corporation (AIC), is developing a self-verifying temperature sensing and fuzzy logic control technique. The sensor is designed to monitor temperature in aggressive, high temperature environments such as glass melters. Using both optical and resistive methods to measure temperature gives it an accuracy of ±0.4%. Using two physically different methods of temperature measurement also gives makes the sensor immune to common mode failure. The expert knowledge of a human operator, captured in a rule-based control strategy called a fuzzy observer, arbitrates the two temperature measurements and confidence values. The fuzzy observer uses linguistic rules to emulate the rule-of-thumb thought process used by humans to "control" process parameters. For example, one rule set would state the trust an operator places in a new temperature sensor versus the trust the operator places in a temperature sensor that has been used for several months.



INEEL produces glass from radioactive waste to reduce the waste volume and create a stable waste form that is suitable for transport and long-term storage. Accurate monitoring of the molten glass temperature is necessary to ensure a homogeneous, consistent waste form that can be characterized to determine its long-term storage properties. However, accurate temperature measurement has been problematic for the aggressive chemistry of borosilicate glass. INEEL and AIC are collaborating in an effort to improve the reliability of temperature sensing and control in production of glass waste forms. Surrogate waste, contained in a refractory brick crucible, is heated to 1150^{o}C. The self-verifying sensor monitors the temperature from 18 to 1150^{o}C. During the experiments, temperature was monitored using three temperature devices - the self verifying sensor placed in the center of the feedstock, a conventional R thermocouple housed in an alumina thermowell at the edge of the melt, and the oven thermocouple located in the upper quarter of the oven. The self-verifying temperature sensor performed well, providing a true glass temperature with excellent sheath corrosion resistance.

A pilot-scale glass melter is being used to prepare glass waste forms with the desired composition. INEEL and AIC are collaborating on instrumenting this melter with a self-verifying sensor. We are also working with glass researchers to develop the linguistic rules for the fuzzy observer control strategy. The optical enhancement of the sensor is of great interest for glass manufacturing because the sensing element is completely and electrically isolated from the sensor head, which is crucial during joule heating. The INEEL and AIC have filed a joint U.S. patent

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on this novel technology.

Sensor Head Concept

The sensor head that contains the resistive and optical temperature sensing elements is designed to be immersed in a process stream, such as glass. The optical temperature sensor houses a simulated black body source with a minimum 5:1 (length to diameter) ratio cavity for temperature determination using the infrared intensity emitted by the cavity surface. The novel approach of housing a black body source in the sensor overcomes the variable emissivity problems experienced when optical readings are obtained directly from molten glass. Appropriate materials must be used to maintain optical opacity (the cavity needs diffuse reflectivity and low transmission) and mechanical integrity at the desired operating temperature; INEEL has identified materials for operating temperatures up to 1200 and 1600^{o}C. The radiation from the black body cavity is focused onto an optical fiber. The fiber and focusing optics are located at the exterior end of the sensor, away from the molten glass region. Although only a fraction of the radiated light can be collected into the fiber, sufficient light can be focussed onto the fiber and amplified to achieve repeatable detection. In addition to temperature information, the two-color approach being used provides a confidence factor that the temperature detected is accurate.

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