Pitot Tube Flow Sensor for use in Black Smoker Chimneys

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FINAL REPORT:

We have constructed a bench top model of a pitot tube flow sensor for measuring fluid velocities within black smoker chimneys. The design is such that it can be inserted well into the mouth of an active chimney to obtain a good flow rate value.

Black smoker chimneys form at seafloor hydrothermal systems, and vent hot (~350ºC), metal-rich, Mg- and SO4-poor fluids into the ocean at velocities of ~1 to 5 m/s. These seafloor hydrothermal systems support a complex ecosystem on and beneath the seafloor, and it has been suggested that these ecosystems may represent a model for the origin of life on Earth, and for exploration of life on other planets. Accurate measurement of the velocities within chimneys are needed 1) to quantify fluxes of heat and mass from the ocean crust and lithosphere to the oceans, 2) to examine how flow rates vary over time, and 3) to calculate the pressure within chimney structures. The latter can then be used to calculate the rates at which fluid flows across chimney walls and within the porous areas of vent structures where a diversity of microorganisms are known to reside. Over the past twenty years there have been numerous attempts at measuring the velocity within and at the exit of black smoker chimneys, but there is still no tried and true method for doing so.

To address this, using funds from the DOEI, we have built a bench-top prototype of a pitot tube flow sensor that can be inserted well into the mouth of a chimney to obtain measurements of velocity within the conduit. A pitot tube consists of an inner tube open at the end, and an outer tube that is sealed at the end but contains several small holes. The velocity of flow within a pipe or conduit is determined by inserting the pitot tube and measuring the difference in pressure at the tip of the small tube from that within the outer tube. The pitot tube gives a direct measure of flow by measuring the difference between the stagnation pressure of the flow and the ambient pressure of still water. This is a simple measurement but requires a very sensitive differential pressure sensor. A 1-cm/sec flow would produce a signal of only about 0.00001 psi.

Our sensor uses a thin metal diaphragm that flexes slightly when the pressure on one side is greater than the pressure on the other side. A circuit measures the electrical capacity between a fixed plate held next to the diaphragm and the flexing diaphragm itself. The change in capacity as the diaphragm flexes changes the frequency of an oscillator, and we record the signal from this oscillator. Our electronic components have been chosen to be completely pressure tolerant (to pressures up to 5000 psi, or depths of the ocean to x meters). The components operate in an oil bath, which protects them yet is kept accurately at ambient pressure by a thin rubber diaphragm that separates the components from ambient seawater. The sensing diaphragm is stainless steel and can tolerate the hot, corrosive vent fluid on the other side for short periods of time.

A major advantage of this type of sensor is that its working range can easily be changed by substituting stainless diaphragms of different thickness. We have tested the sensor on the bench and are currently evaluating and calibrating it. If it continues to pass its tests, we are in an excellent position to write a proposal to NSF to make a complete deep ocean flow sensor system for use with *Alvin*, *Jason* or any other ROV.