Development of an On-Line Alkalinity Sensor Cluster for Water Treatment

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Introduction

Water treatment is an essential process in providing drinking water to residents and businesses of a city. As technology becomes more sophisticated, new treatment approaches are being developed to increase the efficiency and quality of water treatment plants. For instance, Minneapolis Water Works (MWW) installed a 265,000 m^3/day ultrafiltration membrane plant in 2005 at a cost of $70 million. However, these membranes may foul if there is insufficient water pretreatment.

Alkalinity and pH are important water quality parameters in monitoring the effectiveness of water pretreatment. Currently, the alkalinity measurements are conducted by titrating a known volume of water with sulfuric acid to an endpoint pH of 4.5. This technique is labor intensive and costly because it requires a trained technician. Therefore, it is essential to develop an on-line alkalinity sensor for water treatment that can be used simultaneously with pH, TDS, calcium ion concentration, and temperature sensors.

The objective of the research is to develop a Total Inorganic Carbon Alkalinity sensor which is inexpensive, has a fast response time on the order of seconds, and an alkalinity accuracy of +- 0.3 mg/L as calcium carbonate for water treatment.

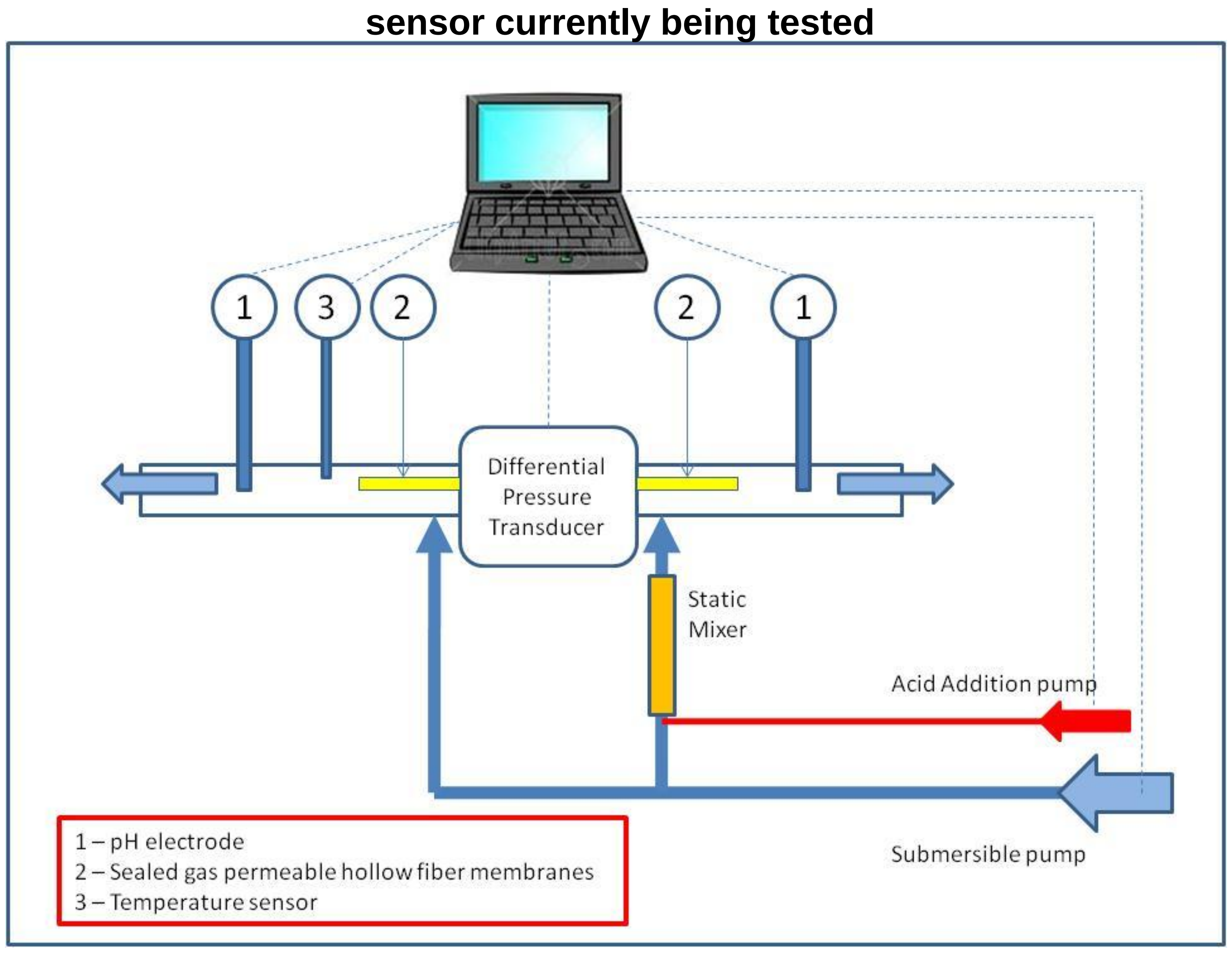
Methods

The design of the alkalinity sensor incorporates two gas permeable membrane modules, which are encased inside PVC housings, that are connected to a wet/wet differential pressure transducer (2.5psi) with positive and negative ports. The water enters both housings, but the water in one housing is adjusted to have a pH of less than 4. The differential pressure transducer measures the pressure difference that is created by the release of carbon dioxide from acidification. The transducer records the pressure difference as a voltage reading, which can be converted into a change in pressure knowing that two Volts equals one psi.

The membrane modules encased inside of the housings are constructed using about 112 membrane fibers per module. The membranes are rolled into a cylindrical shape and are potted in a nylon shoulder washer using epoxy. Once the epoxy has dried, the membranes are cut flush with the head of the shoulder washer leaving the fibers open to be connected to the pressure transducer. The membrane modules measure about 2 inches in length and 0.25 inches in diameter.

Two computer programs are needed to calculate the Total Inorganic Carbon Alkalinity. The Omega differential pressure transducer program and the Elit 9705c 5-Channel Aqualyser program from Nico2000 were combined into one program using National Instruments LabView software that allow for a complete user-friendly interface. The LabView program displays various numeric quantities such as bicarbonate and total alkalinity, pH, temperature, TDS, and the Langelier Saturation Index.

Schematic representation of the dual membrane alkalinity sensor currently being tested



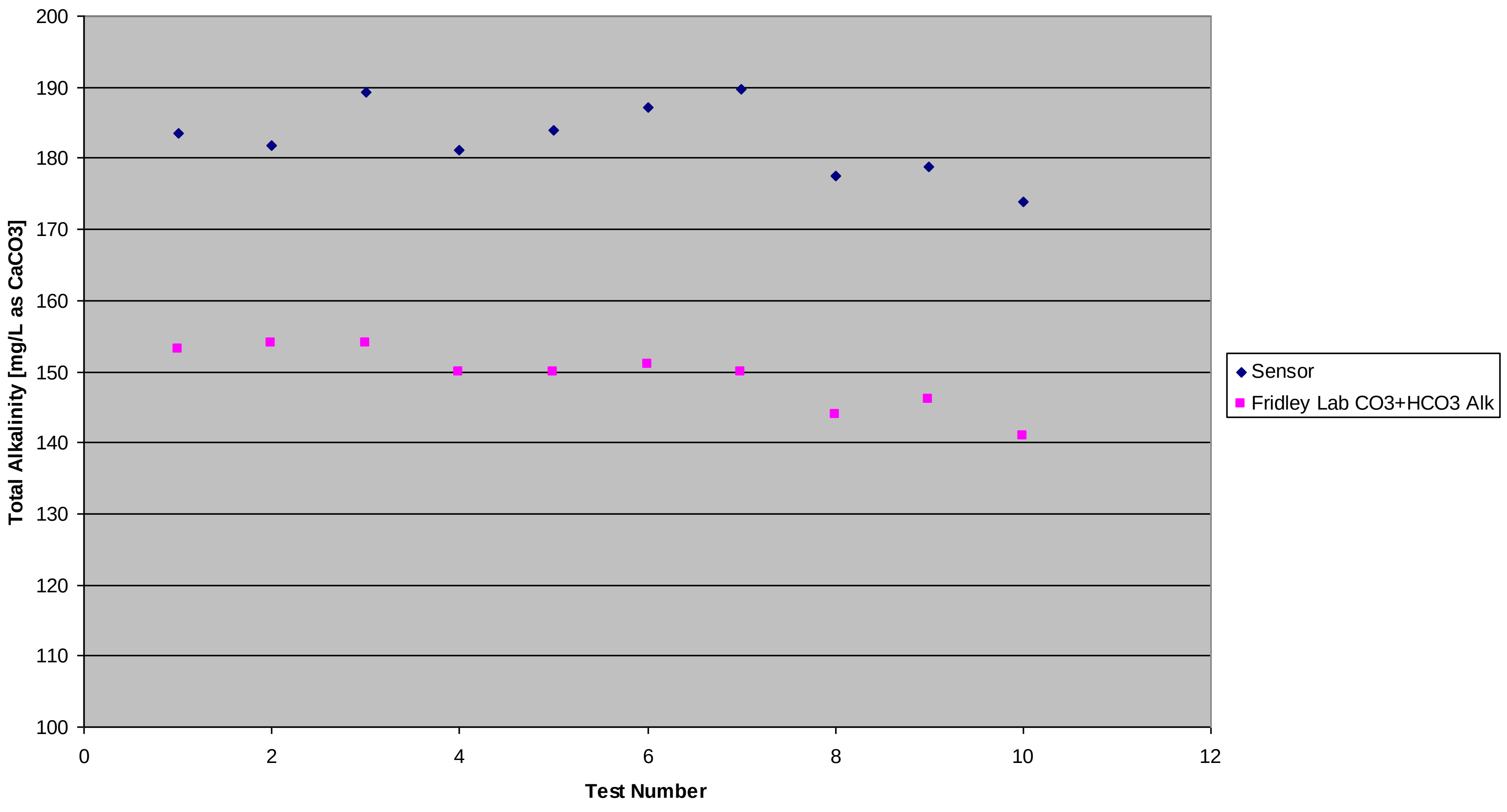
Results

The sensor was taken to the MWW Water Quality Lab in Fridley, Minnesota. The system was set up in the MWW lab and side by side measurements were completed from various locations throughout the plant. The MWW lab uses titration methods, i.e. indicators, as described in Standard Methods to determine alkalinity. Alkalinities at MWW varied from about 150 mg/L as $CaCO_3$ for raw water samples to about 35 mg/L as $CaCO_3$ for distribution main samples.

Results for total alkalinity from the raw water, softening plant effluent, and distribution main samples were consistently higher for the sensor than for the Fridley lab. For example, sensor raw water alkalinities were about 30-36 mg/L as $CaCO_3$ higher. Also, distribution main samples were 4-10 mg/L as $CaCO_3$ higher than Fridley lab results. However, force main total alkalinities were very similar for both the sensor and the Fridley lab.

Response times averaged between 4.5 and 7.5 minutes. Testing indicated that response times were optimized by increasing membrane surface area exposed to the water samples, decreasing the diffusion length between the membrane module and the sensor, and increasing the flow rate. A flow rate of about 25 mL/min resulted in fastest responses.

Sensor and Fridley, MN Lab Raw Water Total Alkalinity showing consistent trend.



Conclusions

Sensor results are significantly higher than Fridley lab results. Contributing to the higher sensor alkalinities is that Fridley uses color indicators, instead of a pH probe, to determine the endpoint pH of 4.5. The actual endpoint, as determined by the technician using indicators, averaged about 5. In the case of raw water samples, adjusting to a pH of 4.5 would increase the Fridley total alkalinity results by about 4.9 mg/L as $CaCO_3$.

Moreover, testing indicated that the sensor must reach an equilibrium state before acidification. It takes about 30-60 minutes to reach equilibrium.

Decreasing the dead volume inside of the PVC housings and increasing membrane surface area would likely decrease the response times significantly.

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