Waters Corporation - Sensor Encasing

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**Abstract**
Waters Corporation currently uses an optical sensor in their liquid chromatography system to detect air bubbles present within a liquid inside a small diameter tube. The sensor frequently breaks during equipment use in which the sensor and tubing are moved around. In the current setup the sensor has a casing, but is affixed to tubing that is not supported in any other way. The purpose of this project is to create a new casing and setup for the sensor to prevent breakage. Constraints include a product cost limit of $50, clearance for maintenance and compatibility with the current software. Focus was placed upon creating a housing in which the sensor could not move freely. The chosen design concept involves milling the current fitting and placing an emitter and receiver inside. A machined plastic casing is bonded to the top of the fitting to fully encase the sensor. The tubing runs through the middle and the sensor leads stick out of the top. The plastic casing includes tabs to help hold the emitter and receiver in place. The assembly can then be inserted into the valve. An electrical connector will be soldered to the sensor leads so that the wiring may be connected afterwards. Once the prototype is complete, Waters must approve it for efficiency and cost effectiveness.

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The Need for Project

The current sensor attachment point often results in the sensor breaking in between tests; a more secure design is desirable. The current setup used by Waters Corporation for their volume detection device (VDD) requires a sensor to be attached to the tubing that delivers the samples to their testing equipment. The location of the sensor exposes it to a lot of interference during handling and in between tests. It is located inside the top of a drawer that slides in and out. When the Sample Manager is used, procedures often require the person using the equipment to come in direct contact with the sensor and casing. Components must be changed between tests and with the current method of attachment, the sensor can easily get knocked around, move or get caught when sliding the drawer back in. The frequent breaking of the sensor increases both cost and maintenance. Each time a sensor breaks, the replacement must also be calibrated because the sensor is not a set distance from the fitting.

The Design Project Objectives and Requirements

The objective of this project is to redesign the sensor casing and how the sensor attaches to the tubing to improve durability. The objective of this project is to create a casing for the sensor used by Waters Corporation to prevent breakage. By creating a casing that firmly attaches to the same location every time, the durability of the sensor improves and calibration is no longer required in between sensor changes. Holding the sensor in place will prevent it from getting hit during maintenance or caught on the drawer.

Design Objectives

Design Requirements

The final product has to cost less than $50 per unit to produce. Most importantly, it must be backwards compatible so that all Waters customers can utilize this device without making adaptations to their current equipment. The design must be made from non-corrosive material. Furthermore, environmental constraints include working within a temperature range of 4° to 40° C and a maximum operating pressure of 250 psi (Rep 3).
Design Concepts considered

Three different prototypes have been created and tested to determine the best design: a housing that encases the fitting, a housing that clips to the end of the fitting and use of the fitting as the sensor housing.

There are three major concepts that we have brought to fruition in order to solve the problem at hand. Our first concept was prototyped. After testing, it indicated areas of improvement for future designs and introduced factors that were not originally considered. These factors included usability of the device, access to the other ports on the valve, and the small size of the minimal clearance for maintenance. This led to the second design concept which was better than the first but still indicated room for improvement.

First Design Concept – Single housing for sensor and fitting

The first design concept achieved many of our design objectives; the casing provided more protection to the sensor and attached it to the measuring device by encompassing one of the fittings. Spacing at the top and bottom allowed the fitting to be turned independently of the casing and not twist the wires. Once the prototype was created and tested, it was evident that the casing was too large to fit in the small amount of clearance (approx. 1 square inch); a technician would not be able to get their fingers around the fitting to tighten it (Rep 4.1).

Second Design Concept – Single housing for sensor

The second design concept is an improvement of the first one. The second concept is a modified sensor casing that can slide down the tubing and clip on to the head of the fitting after it has been inserted into the valve. This allows for maximum clearance when tightening the fitting. Attaching the casing to the fitting keeps the sensor in one secure location and prevents it from getting caught on anything when closing the drawer. The ease of use also increases with this proposed design (Rep 4.1.2).

Third Design Concept – Use fitting to house sensor

The third design concept uses a different approach than the two previous concepts; the goal is to place a LED emitter and receiver inside a milled fitting. A plastic casing bonds to the top to hold everything in place. This design meets the objective to create a single piece out of the sensor and the fitting. The LED emitter and receiver have been tested on an electronic circuit board to verify that they achieve the same voltage reading as the current sensor used by Waters Corporation. The emitter and receiver also cost less than the current sensor.
Recommended Design Concept

The third prototype has proven to be the most efficient solution; the one piece assembly design uses the least amount of material, is cost effective and user-friendly.

Three different designs for a sensor casing were pursued in order to meet as many design objectives as possible and allow Waters Corporation some choice in which design is best suited for their needs. All three design concepts have been prototyped. The first two designs have been tested for compatibility with Waters’ current equipment. The prototype of the third design has been created and testing has been performed on the electrical components of this design. This prototype still must be used with the liquid chromatography equipment at Waters.

Design Description

The third design concept has proven to be the most effective and falls closest to the design objectives. By placing the sensor inside the fitting, it prevents it from getting caught on the drawer. The plastic top bonded to the fitting holds everything in place and prevents unwanted elements from interfering with the sensor. The entire assembly can then be inserted into the valve. A port attached to the sensor leads allow for the wiring to be attached afterwards and prevents the wires from being twisted. This design utilizes the fitting as protection for the sensor and keeps the sensor a fixed distance from the measuring device. This eliminates the need for calibration in between equipment changes. This housing is 0.5 in wide and 0.53 in tall, with a 0.04 in addition to the total height when the clip is considered. This design is made from delrin. Delrin is used because it is easy to work with and an inexpensive plastic.

Analytical Investigations

One of the most important requirements for this design is to improve durability. When inserting the prototype into the fitting it was confirmed that the sensor will stay in place during testing. The drawer could be closed without touching the sensor casing. Stress analysis was completed on the second design concept using COSMOS®. Loads of 5 and 2 lbs. were applied to the top and rear respectively. Nylon was used as the simulated material. Factor of safeties were calculated for the critical points of the design and both exceeded 3. Analysis was also done on the third design concept. Various liquids were drawn through the current sensor and our concept sensor. Voltage values were similar.
Key Advantages of Recommended Concepts

The concept of using the fitting to hold the sensor meets design objectives and satisfies all design constraints. This one-piece design provides a protective covering for the sensor. It easily slides over the tubing used to deliver samples to the VDD. This design is made of a plastic that can be easily bonded to the fitting using epoxy. These are ideal qualities for this application since a durable design is desired yet ease of use is still optimized. Because of the shape of this housing the sensor is stationed at a fixed distance from the measuring device and eliminates a calibration step in between tests. This design also provides a much more secure attachment than the previous setup that was used by Waters Corporation. The sensor is no longer hanging by the tubing alone and will not get caught or hit when an operator closes the tray.

Financial Issues

Main financial concerns include a cost restriction of less than $50 to manufacture this design. Waters Corporation sells approximately 3,000 of these sensor-casing devices per year. The cost to produce each piece can not exceed $50. The first two designs require injection molding for parts to be manufactured. The third design concept requires machining of the currently used fittings and plastic top. Prototypes were produced using the equipment in the Northeastern University machine shop and a 3-D printer. The first and second design concepts use the sensor currently used by Waters (which costs $4.80), while the third design concept uses an LED emitter and receiver purchased from DigiKey® for $0.40 each. This results in a great cost decrease for Waters Corporation. The plastic will be cheap to purchase, but Waters must estimate the costs for machining.

The ease of use for this housing results in little required training for operators and customers. Since the selected design ensures more use out of each sensor, maintenance costs will go down.

Recommended Improvement

Testing must prove that the third design concept is compatible with Waters Corporation’s equipment. Testing verified that the emitter and receiver produce similar readings to the sensor currently used by Waters Corporation. Now, testing with the liquid chromatography system must be performed. Once it is proven that this design concept is compatible with all involved equipment, Waters must approve the final design.