Design Review 1 | Design Problem Statement and Clarification

Embedded Valve & Actuator Sensors
Sponsor: Bray

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Introduction:

Bray is one of the world's premier manufacturers of flow control and automation products and accessories. Bray's excellent reputation includes creating products of superior value and quality compared to competitors. This semester, our team was assigned to work with Bray to develop a method to internally measure valve position independent of an actuator, measure actuator output torque, and detect fluid leakage to increase the valve's service life. Increasing the valve's service life would allow products to be sold at a higher price. Currently, Bray has developed an IOT Torque Bracket in their R&D labs which has proven to accurately measure the valve torque from its reaction forces. The issue with this is that due to hysteresis from the valve and stem, the torque measured from the reaction forces can have a significant error compared to the torque output from the actuator. This IOT Torque Bracket is also an external connection, so it would have to be sold separately with the actuator and valves. Solving these problems would allow Bray to sell the actuator and valve without an external connection and a longer time before product maintenance, creating more value for the products.

Problem Identification:

At Bray, there are a lot of factors that go into selling a successful product. Although each factor has a level of importance, customers of Bray care most about leakage and torque. Customers want their valves and actuators to have minimal product maintenance, and to have no issues with opening and closing valves. After recording responses from customers, Bray decided to provide us with a problem statement that can help improve these important factors.

Current Problem State:

The current solution for the torque and displacement measurements is using the IOT Torque Bracket designed in their R&D labs. This bracket can accurately measure the torque output on the valve, but there is a discrepancy between the torque in the actuator and valve due to hysteresis. The bracket is also an external attachment, meaning that it would have to be purchased in a package or separate from the valve and actuator, creating more work for the customers. Solving the problem statement from Bray would help with these issues having an external attachment. There are currently no new implementations from the company to detect if gas or liquid is leaking from the pipes. The suggested ideas from Bray that have not been pursued are measuring the volumetric flow rate before and after valve connections or measuring with gas detectors outside connection seams.

Background Research:

Ball Valves:

Ball valves, which are essential parts of fluid control systems, stand out for their effective and flexible performance. These valves have a spherical closure, frequently called a "ball," with a bore or hole running through it in the middle. The valve can be opened or closed to control the flow of fluids by rotating this ball 90 degrees. Due to their quarter-turn function, ball valves are

excellent in applications needing quick shutdown or precise control. Their construction minimizes pressure drops across the valve, which lowers energy use and guarantees less leakage when closed. Ball valves are very necessary in sectors including oil and gas, petrochemicals, water treatment, and more where precise fluid control and dependable cutoff are crucial due to their combination of dependability and efficiency.

[1]Figure 1: *Ball Valve with Actuator*

Butterfly Valves:

Butterfly valves, which are noted for their versatile operation, are essential parts of fluid control systems. These valves are composed of a disc that rotates inside a pipe to control the flow of fluids. The disc is commonly made of metal or a durable material. The disc stops the flow while it is closed, and it allows unrestricted fluid flow when it is fully open. Butterfly valves are frequently used because of their quick quarter-turn operation, which makes them perfect for applications requiring rapid shutdown or regulation. They use less energy because of their efficient design, which minimizes pressure loss across the valve. Butterfly valves are a useful tool for fluid control and regulation because they are utilized in many different industries, such as water and wastewater treatment, HVAC systems, chemical processing, and more.

[2]Figure 2: *Butterfly Valve with Actuator*

Pneumatic Actuators:

A crucial part of automation and control systems, pneumatic actuators are renowned for their effectiveness and adaptability. These tools transform pneumatic energy into mechanical motion by using compressed air to generate motion or force. Valves, gates, and robotics are just a few of the industrial uses for pneumatic actuators. They are perfect for applications needing quick responses and accurate placement since their functionality enables speedy and exact control. Operators can create a broad variety of motions, from straightforward on/off movements to complex placement and modulation, by controlling the airflow to the actuator. Pneumatic actuators are used in a variety of fields, including manufacturing, automotive, and aerospace, where their dependability and usability boost automation and productivity.

[3]Figure 3: *Pneumatic Actuator*

Scotch-Yoke Pneumatic Actuators:

Scotch-yoke pneumatic actuators are specialized components that transform compressed air pressure into rotating motion in mechanical systems. Their unusual scotch-yoke mechanism, which consists of a sliding piston attached to a spinning yoke, gives them their name. A linear motion is produced when compressed air is injected into the actuator, pushing the piston along the yoke. This linear motion is changed into rotational motion by the rotating yoke, which can then be employed to move valves, dampers, or other mechanical parts. Pneumatic actuators with a Scotch yoke are prized for their capacity to provide strong torque and fine control in a dependable and small package. They are frequently used in systems and applications like industrial valves and automation that depend on controlled rotational movement for process control.

[4]Figure 4: Scotch-Yoke Pneumatic Actuator

External Torque Bracket Products:

Critical parts of mechanical systems and external torque bracket products are made to transmit torque from one element to another while offering support and stability. These brackets have various crucial purposes and are often positioned externally on rotating machinery. They aid in keeping rotating parts aligned, ensuring that torque is transferred effectively and without vibration or misalignment. Additionally, by appropriately dispersing forces, external torque brackets can stop overloading or damage to shafts and bearings. They are frequently employed in many industrial applications, such as drive systems, conveyors, and gearboxes, to improve the overall performance and dependability of rotating machinery. External torque brackets must withstand high mechanical stresses and environmental conditions to maintain smooth and effective functioning, therefore careful design and material selection are essential to their functionality.

General Valve Leakage:

The unintentional often undesirable spillage of fluid through a valve when it is supposed to be in a closed or sealed condition is referred to as general valve leakage. Inadequate sealing materials, incorrect installation, excessive pressure or temperature conditions, wear and tear on valve components, and valve leakage can all be the result of these factors. External leakage, in which fluid escapes from the valve and enters the environment, and internal leakage, in which fluid permeates the interior of the closed valve, are the two basic categories. Valve leakage is a key issue that needs to be addressed in a variety of industries, including oil and gas, chemical processing, and water treatment. It can have detrimental consequences on system efficiency, safety, and environmental concerns.

Problem:

Solution Neutral Problem Statement (SNPS):

Develop a method to internally measure valve position independent of an actuator, measure actuator output torque, and detect fluid leakage to increase the valve's service life.

Technical Questioning Results:

The problem assigned to our team is all about embedding the position-tracking system and torque monitors into the valve or actuator instead of having an external attachment. The issue with leakage in valves for Bray causes more maintenance and less lifetime of the products. The expectations and desires are to embed the position-tracking system and torque monitors into the products and to prevent potential leakage which would lead to an increased lifetime of products. These desires are appropriate to create an overall better product than what Bray has to offer to their customers. Our team has avenues for creative design in sensor types, sensor placements, the dual function of sensors, leakage prevention methods, and system data processing recordings. The limitations for the project include the valves for the project including ball and butterfly valves. The solution for the system must be embedded in the valve or actuator, instead of having an external monitoring system. The costs of sensors for measuring leakage should be minimal. There are some questions Bray has in terms of the importance of the project because Bray already currently has an IOT Torque Bracket designed in their R&D labs that calculates torque but is an external attachment.

Mission Statement: Embedded Valve & Actuator Sensors

Product Description:

Bray needs an embedded device to monitor and measure the output torque of their actuators in real-time and the true position of the associated valves, as well as a method of determining valve leakage.

Key Business or Humanitarian Goals:

Key business or humanitarian goals include increasing the longevity of valves, monitoring leakage of valves, and increasing the notice time for preventative maintenance.

Primary Market:

The primary market for Bray includes companies wishing to use Bray’s valves and actuators to safely transport a desired fluid or gas.

Secondary Market:

The secondary market includes any parties who consume the products produced in facilities that use Bray's valves. If a valve in the flow process were to have a weakened actuator or become stiff, the reduced flow rate in that pipe could change the composition of the final product.

Assumptions:

Assumptions for the product include little to no leakage, incorporating detection of position into the actuator or status monitor independent of actuator type. The product must be easy to use for customers.

Stakeholders:

Bray, who sells these valves and actuators, their customers who purchase these valves and actuators, and our team that is designing the product.

Avenues for Creative Design:

Our team has avenues for creative design in sensor types, sensor placements, the dual function of sensors, leakage prevention methods, and system data processing recordings.

Scope Limitations:

The valves under consideration for the project include ball and butterfly valves. The solution for the system must be embedded in the valve or actuator, instead of having an external monitoring system. The costs of sensors for measuring leakage should be minimal.

Customer Needs:

#	Need	Importance
1	The final product is embedded into the actuator or valve	1
2	The product is scalable for different-sized valves	3
3	Product records and transmits sensor data	1
4	Works in the desired temperature range (-40^{o}F – 300^{o}F)	4
5	Works in the desired pressure range (100psi – 740psi)	3
6	Works for various fluid mediums	4
7	Measure actuator torque with at most 5% error	1
8	Relatively short lead times for parts (3 – 4 weeks)	2
9	Detects fluid leakage from the valve system	2
10	Determines true valve position independent of the actuator	1
11	Works for both pneumatic and hydraulic actuators	3

1 – Must
2 – Good
3 – OK
4 – Optional

Needs Analysis:

The need analysis was collected after asking a list of questions during our team's in-person visit to Bray's facility. The importance of each need is determined by their input, cost, and the feasibility of adding to the project. To achieve these needs, our team will research and design a solution that can later be sent to Bray's facility to be built and tested. From the results, we can update our solution to make it more efficient and accurate.

Conclusions:

Our team was assigned to work with Bray for our senior capstone project. Our project is about designing a way to accurately measure the true valve position independent of the actuator and determining a way to directly measure the actuator output torque. The issue at the core of this project is that valves and actuators degrade over their working life, so Bray would like a way to measure this degradation in real-time so they can identify errors and the need for preventative maintenance more quickly. As of now, our team has done background research on important topics relating to the project, visited Bray's facilities to meet the team in person, and has started brainstorming ideas for potential solutions.

References/Citations:

[1] "Ball Valves: Trunnion, Multiport, Segmented, Severe Service: Bray." Default, www.bray.com/valves-actuators-controls/ball-valves?page=1. Accessed 11 Sept. 2023.

[2] "Butterfly Valves: Resilient, High Performance, Triple Offset: Bray." Default, www.bray.com/valves-actuators-controls/butterfly-valves?page=1. Accessed 11 Sept. 2023.

[3] "Pneumatic Actuator: Series 92/93 Rack & Pinion Pneumatic: Bray." Default, www.bray.com/valves-actuators-controls/actuators/pneumatic-actuator/series-92-93-pneumatic-actuator. Accessed 11 Sept. 2023.

[4] "Scotch Yoke Pneumatic Valve Actuator: Series 98: Bray." Default, www.bray.com/valves-actuators-controls/actuators/pneumatic-actuator/series-98-scotch-yoke-pneumatic-actuator. Accessed 11 Sept. 2023.