Bray Team:
Embedded Valve & Actuator Sensors

Design Review 1

Sponsor: Bray

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I. Introduction

Bray International is one of the premier flow device manufacturers in the world with products in over forty countries [1]. Their products are used in almost any fluid control field including oil and gas, HVAC, mining, chemical, and many more. Bray's commitment to excellence, safety, and innovation allows them to boast a revenue of $22.0 billion in 2022 alone [2]. Their desire to "become the most respected and successful valve, actuator, and controls company in the world" drives Bray to discover creative ways to expand their product line. Bray's innovative mindset has led them to partner with us. We are a team of six senior mechanical engineers from Texas A&M University who will create a new product to help Bray's customers better maintain their equipment. The overarching problem is that Bray's customers struggle to accurately monitor the valves' and actuators' true rotational position and perform preventative maintenance. This customer need was conveyed to Bray directly from their customers. Currently, the problem is being addressed by placing strain gauges on the bracket connecting the actuator to the valve, reading the reactive forces on the bracket by the actuator, and calculating the resultant position. The issue with this strategy is: rather than measuring the true position of the valve and actuator, the strain gauges are only measuring forces, and the positions are being calculated based on those forces. Furthermore, there is a slight hysteresis between the torque output by the actuator and the torque received by the valve due to slight deformation in the valve stem. We wish to fill this information gap by redesigning Bray's current valves and actuators such that they can house embedded sensors which accurately record the position of each component independent of the other.

II. Background Research

This project calls for extensive research into components of flow devices like valves and actuators. Understanding ball and butterfly valves is critical to the project scope because they are the main types of valves that Bray manufactures. Bray requested that we as a team familiarize ourselves with the functionality of ball valves (along with various other products), so I became the subject matter expert.

A ball valve uses a pivoting ball with a center bore to control the fluid flow by turning it anywhere from 0° to 90° to control flow. It is one of the most common valves used due to its simple design, ease of operation, and reliability. When the valve is closed, the ball is rotated so that the bore is perpendicular to the flow direction. This means that the bore blocks the flow of fluid while the seats on either side form a seal against the ball, preventing any leakage. When the valve is open, the valve stem is turned 90 degrees, which causes the ball to pivot within the body and align the bore with the flow direction [4] (see **Figure 3** in the Appendix for illustration).

Ball valves are predominately used in onshore and offshore oil and gas production facilities but can be utilized in any hydraulic system due to their versatility. Advantages of using a ball valve include their leak-proof service, quick response time, long service life, low maintenance needs, and low cost. The largest concern when using a ball valve is the possible buildup of solid particles in the ball's casing, restricting it from rotating [3].

Bray manufactures various ball valves ranging from two inches in diameter to twenty-four inches in diameter. For example, one of the ball valves that will be focused on is the *Flow-Tek Series F15 | F30* (shown below in **Figure 1**). This valve is a two-piece, flanged, floating ball valve designed for low torque and increased cycle life specialized for industrial applications [1].

SPECIFICATIONS

Body	2-Piece, Full Port
Size Range	NPS ½ to 12 | DN 15 to 300
Pressure Ratings	F15: ASME Class 150 | PN 10 & 16 F30: ASME Class 300 | PN 25 & 40
Materials	Stainless Steel Carbon Steel Special Alloys
Design	ASME B16.34* API 608 (Available upon request)
Flange Design	ASME B16.5 | DIN EN 1092-1
Face-to-Face	ASME B16.10
Testing	API 598 MSS SP-72 Special testing available upon request
Shutoff Rating	Zero leakage, Bi-Directional
Approvals & Certifications	API 607 ISO 15848-1/2 API 641 NSF/ANSI/CAN 61 & 372 CRN PED 2014/68/EU PE(S)R UKCA S.I. 2016:1105 SIL ATEX

* Pressure-temperature rating, wall thickness, blowout-proof stem

Figure 1: Flow-Tek Series F15 | F30 Specifications

Bray has developed their *IOT Torque Bracket* to address the issue, but it is in the R&D stage and is not embedded in the system. While this is a solution, Bray wants us to create a way to determine actuator torque, valve position, and leakage without depending on another component in the system. As stated before, the *IOT Torque Bracket* only measures a force applied on the bracket by the actuator and uses it to estimate the valve position.

III. Problem

Our mission is stated in the solution neutral problem statement:

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

The basis of our project is to improve the service of Bray's valve-actuator systems by accurately determining the position of each component individually. A central problem with the current technology is that Bray uses *an IOT Torque Bracket* which connects to the valve stem, not the ball/plate within the valve. The current sensors are reading the reaction forces felt by the stem from the actuator which is inaccurate in determining the valve's position due to hysteresis in the stem. Simply put, the actuator is exerting a torque that should close/open the valve, but it fails to do so due to the deformation of the stem. A valve stem deforms over time due to torsion, therefore not delivering 100% of the torque to the ball/plate. This produces an issue for the customer because the system could be slightly open when it should be closed and vice versa. Understanding this and being able to relay it to operators will allow customers to prevent leakage and service their valves and actuators sooner.

Additionally, a valve will require more and more torque to close due to solid build-up in the body and deterioration. At the same time, an actuator outputs less and less torque over time due to its repetitive motion. So, in the system's lifetime, there will be a point where the valve requires a higher torque to be closed than the actuator can produce. Through accurately measuring the valve's increasing torque needs and the actuators declining condition, customers can be notified when preventative maintenance needs to be performed.

Lastly, we will develop a method to detect leakage through the valve in operation. Bray valves are used in highly dangerous applications like natural gas transportation, high pressure systems, and chemical processing, so their system needs to be tightly sealed to prevent damage. Fluid leaks affect the integrity of the system as a whole and must be avoided at all costs. Placing sensory devices near these leakage areas could allow customers to service their equipment promptly.

Overall, being able to measure valve position, measure actuator output torque, and detect fluid leakage will lower customer costs, lower equipment downtime, decrease safety hazards.

Mission Statement

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:

- Increase the lifetime of valves.
- Monitor leakage of the valve.
- Increase notice time for preventative maintenance.

Primary Market: Companies wishing to use Bray's valves and actuators to safely transport a desired fluid.

Secondary Market: 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: Little/no leakage desired, incorporate position directly into actuator or status monitor, independent of actuator type. The method/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 the team (us) who are designing the product.

Avenues for Creative Design: Sensor types, sensor placement, dual function of sensors, leakage prevention method, system data processing recording.

Scope Limitations:

- Valves: Ball valve and Butterfly valve.
- Solution System must be embedded in the valve (not an external monitoring system).
- Cost of sensors for measuring leakage.

Technical Questioning Results

What is this problem really about?

Design a way to accurately measure the true valve position independent of the actuator and determine 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.

What implicit expectations and desires are involved?

Design a valve that degrades less over time by monitoring torque and using the data to use preventative maintenance. If the valve position can also be monitored, then more insights about preventative maintenance and degradation can be made. A "stretch goal" is determining a method for identifying valve leakages in real-time, but it is expected that other goals will take priority.

Are the stated customer needs, functional requirements, and constraints truly appropriate?

The main constraint is that the sensors should be embedded into the valve and actuator. This constraint is appropriate, but it will be a difficult task given the limited free space inside Bray's actuators and valves.

What avenues are open for creative design and inventive problem-solving?

The method for measuring valve position and valve leakage is not specified, so there will be creative freedom on how to best measure the true valve position. Bray has not specified which sensors should be used, therefore there is liberty in choosing sensor type.

What avenues are limited or not open for creative design? Limitations on scope?

Bray R&D has developed their valves and already has a method to measure torque so the project will be confined to meet what they have already designed. The sensor will have to fit onto the already designed valve and not impede the purpose of the valve.

What characteristics/properties must the product have?

The product must be independent of the other parts of the assembly. For example, a sensor for the valve must be independent of the actuator, and a sensor for the actuator must be independent of the valve. This is so the parts can be packaged easily and sold separately to Bray's customers.

What characteristics/properties must the product not have?

The valve sensing system must be independent of the actuator so that the data collection method/product is not dependent on the actuator type. In other words, the product for the valve must not be dependent on the actuator and vice versa, so that the parts can be sold separately and can work independently.

What aspects of the design task can and should be quantified now?

It would be useful to quantify what specific type of valves will be used, what size they are, and what kinds of actuators are being used so that the design of the proper sensor products is appropriate.

Do any biases exist with the chosen task statement or terminology? Has the design task been posed at the appropriate level of abstraction?

The main bias for this project is the deliverables Bray identified versus what the customer wants. Bray identified true valve position, actuator torque, and leakage as the three main values to measure. Bray's research into the wants of their customers revealed leakage and torque to be the main concerns. Bray wants these specific sensors on the valve when the customer may not know how it affects the performance of preventative maintenance and monitoring the conditions of the valve.

What are the technical and technological conflicts inherent in the design task?

As a group, there is little experience with sensor technology and the design of sensor placement to report valve position. There is also limited understanding of how valves work and operate. The team has researched how butterfly and ball valves work in detail but now needs to understand have valve sensory technology operates.

IV. Customer Needs

This project has specific needs that must be included in the final product design. From discussion with the Bray engineers, the needs are stated in **Figure 2** and ranked by severity from 1 to 4. A score of "1" denotes the need as a must, and a score of "4" denotes the need as optional.

#	Need	Importance
1	Final product is embedded into the actuator casing	1
2	Product is scalable for different sized valves	3
3	Product records and transmits sensor data	1
4	Works in a wide temperature range (-40°F-300°F)	4
5	Works under various pressures (100 psi - 740 psi)	3
6	Works for various fluid mediums	4
7	Measures actuator torque to < 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 actuator	1
11	Works for both pneumatic and hydraulic actuators	3

Figure 2: Customer Needs Analysis Chart

Being able to embed the sensors into the actuator is paramount because Bray would like to be able to analyze their products in real-time through sensor data and run diagnostics to determine the actuator's condition. Minimizing the amount of allowable error is important to any measurement device because the inaccuracy of the data being recorded could lead to negligence of issues within the system. For example, if the sensor misreads the output torque of the actuator, it may not alert the customer that the actuator needs a replacement, leading to systematic failure. Being able to "determine the valve position independent of the actuator" received a score of "1" because Bray already has the technology to determine valve position based on actuator torque. That being said, the true valve position may differ due to hysteresis in the valve stem.

Detecting fluid leakage from the valve system was a deliverable that Bray added to our project but was deemed as not as important as the original deliverables. Determining leakage is very important to the overall fluid system because it can cause system failure and is a safety hazard depending on the medium. Since the project entails working with high-grade sensors and other technology, Bray requested that the product have components with short lead times. This will allow the team to have ample time to prototype and test the system.

Scalability of the product is a desired outcome but is not paramount to the completion of the project. Being able to scale the design from a 2-inch system to a 24-inch system is desired but is not needed. The typical operation pressure for Bray valve and actuator systems is 100 psi – 740 psi and the product should be able to operate at any pressure in that range. Lastly, the torque sensors should be able to operate in pneumatic and hydraulic actuators.

The ability to work in a wide temperature range (-40°F to 300°F) is optional because the product can be "specialized" for certain climates. For the same reason, the product would be more applicable if it can be utilized with various fluids, but this is not a requirement.

V. Conclusion

Bray has tasked our team with developing a method to precisely determine the position of a valve in service independent of the actuator, determine the actual output torque, and detect valve leakage. Ball and butterfly valves will be the main focus of this project due to their versatility and longevity in various fluid systems. The main issue with current valve-actuator technology is their dependence on the reactive forces produced by the actuator output torque. Bray needs accurate sensors embedded in the valve and actuator to transmit real-time data through low-frequency software so that customers can perform preventative maintenance on their products. So far, our team has met with Bray at their office in Houston to clarify needs and design specifications. These needs include a solution that is cost-effective, retroactive, and scalable. Through these needs and the creative freedom given to our team, we will develop a product that satisfies Bray and their customers' desires.

VI. References

[1] “Bray International, Inc. Your Global Flow Control Partner - Butterfly Valves, Ball Valves, Check Valves, Actuators and Accessories.” *Bray.com*, Bray, 2017, www.bray.com/. Accessed 10 Nov. 2019.

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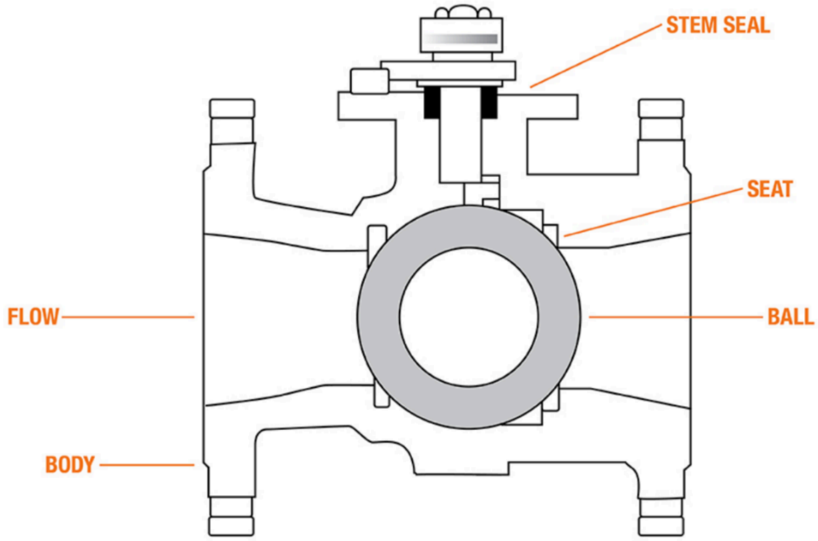
[3] Joy, Anju Thangam. “Ball Valve Applications.” *Tameson.com*, tameson.com/pages/ball-valve-application#_eb8zgvc3omya. Accessed 12 Sept. 2023.

[4] “Ball Valves vs. Gate Valves.” *The Home Depot*, www.homedepot.com/c/ab/ball-valves-vs-gate-valves/9ba683603be9fa5395fab901367d3983. Accessed 12 Sept. 2023.

VII. Appendix

Figure 3: Basic Ball Valve diagram



Stem Seal: This connects the ball to the external control mechanism (handwheel, lever, actuator, etc.)

Rotary Ball: The ball is designed with a center bore which the medium flows through and rotates 90 degrees to block/allow the medium flow.

Body: The casing that contains all the other valve components and fits between the two pipes. There are four types of ball valve bodies: single body, split body, top entry, and welded.

Seat: Ring of either metal or rubber that secures the disc in place and prevents leakage.

Flow: Direction of medium movement