MEEN 401-900

Design Review 1 Report

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Bray Engineering

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INTRODUCTION

Ball and butterfly valves are critical components in various industrial applications and processes that involve transporting nearly any fluid medium. When these parts fail or reduce their performance unexpectedly, they can lead to lengthy system downtimes and potentially expose workers to toxic gasses. In order to avoid these risks of lost productivity and downtime, a demand for a product that can measure the relative health of a valve over time.

Bray International is a world-leading manufacturer of flow control and automation products including ball and butterfly valves. Their motivation to reduce system downtime due to valve errors and increase service life led them to sponsor our Team, six senior mechanical engineering students at Texas A&M, to create an embedded sensor system.

The main components found in both butterfly and ball valves are illustrated in Appendix A [1] [2]. In order to identify the exact problems that need to be addressed to improve valve life, Bray used customer data and in-house testing of their products to determine the most common modes of failure in pneumatically powered actuated valves [3]. After long periods of usage, the pneumatic actuator itself loses its ability to output its maximum torque due to friction losses and electrical wear. On the other hand, the mechanical valve system itself would become more stiff as gaskets degraded and lubricants between essential components dried up. These two factors would continue to diminish the performance until they reached a point where the actuator could no longer toggle the position of the valve shaft.

While there are currently sensors that can detect the actuator torque and track its performance over time, these systems are only external to the valve and only measure the reaction forces between the actuator and valve shaft. An External Torque Bracket, for example, attaches to the bracket of a valve between the shaft and actuator, and a strain gauge records the change in torque applied to the system. These external sensors are inadequate systems because they rely on the performance of the valve itself in order to accurately measure the actuator torque, so it is not clear which part of the system is actually failing. Separate from this, it is difficult to also know the exact position of the valve itself independent from the actuator. This is important to know due to any hysteresis that may occur between rotating the valve shaft and moving the bearing ball itself.

The problem proposed by Bray to our Team aims to overcome these challenges and accurately generate a report on the health of a pneumatically powered actuator-valve system by creating an embedded sensor product that can determine the actuator output torque, valve position, and detect any leakages.

BACKGROUND

To understand the need for the embedded monitoring system proposed by Bray, alternative market solutions for external torque brackets should be considered as well as their effectiveness in accomplishing the Team's mission. As a method of diagnosing the performance of an actuated valve, hand-held and attachable torque sensors do currently exist on the market. An ABQ hand-held torque meter [4] is a device that can be placed over almost any rotating cap or wheel. As the vices that grip onto the cap are rotated, the resistance torque applied by the sensor rod is read by the computer, and translates this signal into a torque measurement that can be read and recorded. While this product can be accurate and diagnose valve health, it is only an intermittent solution. This product cannot measure the torque when an actuator is placed on the valve, and must be tediously used continuously over time to track the general performance trends. Additionally, this product does nothing to monitor the output from an actuator.

Other solutions, such as a Futek Valve Torque Sensor [5], offer a more continuous monitoring solution. This sensor is used in place of a valve bracket that normally separates the actuator casing and valve housing. When the actuator is toggled and rotates the valve shaft to open or close the fluid system, it creates a reaction moment against the fasteners that hold it in place. The sensor then uses strain gauges placed along its casings to determine the reaction torque that acts on the valve. This system is a commonly used solution in monitoring the performance of actuated valves. The problem with this, however, is these types of sensors only measure the *reaction* forces of the actuator, meaning it must be acting on an object in order to be measured. This distinction makes it impossible to know the performance of the valve or actuator independently from each other, so while this product may monitor the health trends over time, it is impossible to know what part of the valve system is failing when it comes due for maintenance.

The deliverables from Bray aim to overcome this issue by tasking our Team to create a product that is capable of measuring the torque output of an actuator *independently* from the actuator or valve itself. Achieving a solution that meets this requirement results in the ability to fully diagnose all components of a valve system.

PROBLEM

The mission of the Project Team is to work with Bray to design, build, and validate a product that meets the project's deliverables while remaining cost effective and convenient for the customer to use. The methodology and tools employed to complete the project will depend upon the scope and constraints of each deliverable provided by Bray. The Solution Neutral Problem Statement for our product is as follows:

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.

In order to consider the project successful, all deliverables of the problem statement should be met with the Team's product solution; as well as satisfy all of the clients' or stakeholders' requirements. To better understand the deliverables and goals of the Team, a thorough analysis of the mission statement and its involved parties is performed.

Mission Statement: Bray Embedded Valve Sensors

Product Description	An embedded device to measure actuator output torque, true valve position, and determine leakage in butterfly and ball valves.
Key Business Goals	• Increase valve service life • Monitor valve leakage • Increase notice time for preventative maintenance
Primary Market	• Clients or companies using Bray actuated valves
Secondary Market	• Any party that consumes products made in facilities that use Bray actuated valves
Assumptions	• No fluid leakage from valve • Fully embedded sensor system • Actuator torque is measured independent of the actuator • Position is measured independent of the actuator • Intuitive design & ease of use for customers
Stakeholders	• Bray Engineering • Clients who buy Bray actuated valves • Parties who consume products made using Bray actuated valves • The design team (us)
Avenues for Creative Design	• Sensor types, placement in valve • Dual functionality of sensors • Leakage detection method • Data processing method
Scope Limitations	• Ball or Butterfly valve • Fully embedded solution • Cost effectiveness of system • Size constraints to fit in valve

At its core, the problem proposed by Bray is about improving the service life of production systems with their ball and butterfly valves. By accurately measuring the increasing valve stiffness and actuator precision over time, preventative maintenance can be scheduled long before the part causes the entire system to fail. Not only will this prevent downtime for vendors that utilize Bray valves, but the customer will also decrease their operation and maintenance costs. The desires expressed by Bray to the Team in accomplishing this goal is to develop a product that is capable of measuring and recording data about a valve's reaction torque, precision of the actuator motor, and to develop a system to detect leaks from the entire valve system.

As an interpretation of the deliverables required by Bray, the customer needs were noted and described in Appendix B. These demands limit the scope of our product to be adapted to an already existing valve, as changing the design of a product being produced at a large scale will prove far too costly to reap the benefits of a monitoring system. Additionally, the product must be fully embedded into Bray's existing valve product, so it could not be sold as an external monitoring device.

Given these constraints, there are still plenty of avenues to explore regarding the design of our product. The types of sensors, for example, can be optimized to cost, functionality, and ease of use to determine what exact quantity should be measured, what vendor the sensor will be sourced from, and determining how it will collect and share diagnostic data with process engineers. Moreover, the system to detect valve leaks was given very little constraints by the customer, presumably being embedded in the final product.

The characteristics of the product are based on the constraints and creative design avenues available to our Team. The final product must be independent of any other part of the valve assembly (e.g. the sensor that measures valve torque must do so independently of the valve actuator, and sensors for the actuator must operate independently of the valve). The justification given for this characteristic decision is so the Team's final product will have the ability to be added to existing Bray actuated valves as an aftermarket part and not just a production-line installation. The sensor data collection method and software must also be independent of the valve system itself so it can not only be easily adapted for both butterfly and ball valves, but be adapted for future types of valve monitoring systems as well.

At the early stages in the design process of the development project, some aspects of the final design can begin to be quantified, such as the relative size of the valve our final product will fit in to, the types of actuators used in Brays valves, and the type and number of sensors that should be incorporated into the final product. Intrinsically, these quantifications include bias between what Bray provides as deliverables for the product and what the customer actually needs from an actuated valve. A customer or vendor that incorporates actuated valves into their system may not have a want or need for the diagnostic data that provides notice that a part may be failing or needs maintenance, but Bray wants a system developed that is capable of recording this data and determining the state of the valve from a remote location.

The technical and technological challenges the Team expects to face throughout the design process of this project is that most group members have relatively little experience in dealing with sensor technology and design of sensor placement in order to measure position or applied torque. There is also a collective lack of knowledge of the operating principles in how valves are optimized or selected for a task. These challenges, however, can be addressed early in the project by researching existing works on valve products and associated sensor technologies.

CUSTOMER NEEDS

Alongside the deliverables of the final product, Bray also had various additional requirements for the characteristics and operating ranges. After touring their facilities and speaking with the lead engineers working on valve design in Houston, Texas, our Team determined the needs of the customer and their importance illustrated in the table below. The ratings are on a scale of 1 to 4, 1 being a ‘must’ for the product, 4 being ‘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℉-300℉)	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

Each need for the product was determined during the Team’s interview with Bray and the tour of their facility, notes from this interview are listed in Appendix B. As Bray explained the current operation of their valves and the life cycle challenges their clients faced when using them, the desired characteristics of the sensor system became clear. These qualities were then discussed with the Bray engineers to quantify how important each need was to both themselves and the clients. The temperature operation range of the system, for example, was listed as an optional quality for the product. Although Bray's valve systems are typically capable of operating within the range of -40℉-300℉, the our design Team might find this challenging to implement while meeting the deliverables; and most clients operate their valves under a much smaller temperature range.

On the other hand, some needs were considered critical to the final product. Current solutions proposed by Bray consider a set of external sensors that determine actuator torque using an external power source and an IOT connection. This setup exposes equipment to the ambient environment, requires constant upkeep to replace the batteries, and is not convenient for the customer to install. Because of this challenge, the Team's final product must use the actuator's power supply and fit into its casing, as well as transmit any recorded data over an ethernet connection. Additionally, the product having a small torque measurement error and determining true valve position were considered equally important. When the valve operates under normal conditions, Bray explained that the actuator may rotate the shaft a small amount before the valve ball itself moves and introduces hysteresis into the measurement system. Therefore, using a highly accurate sensor to measure position and torque is critical in diagnosing the health of the valve.

Based on the customer needs and their relative importance, our final product should be a system capable of measuring the components of a pneumatically powered actuator-valve system and determining its performance over time. The product must fit into the actuator casing, transmit data over an ethernet connection, and measure torque and position to a very small tolerance. The product components should be able to be sourced in under four weeks and be able to determine if fluid is leaking from the valve. If the previous constraints are met, the product may be adapted to work on various sized valves under different fluid pressures, and be applicable to both pneumatically and hydraulic actuators. Optionally, the product could be adapted to operate under a wide range of temperatures and be agnostic to the fluid medium in the valve. The Team also assumes that this system would be pre-installed by Bray, so the client would need no training on installation past supplying power and an ethernet connection.

CONCLUSIONS

A common problem that exists with actuated butterfly and ball valves is their diminishing performance over time. The increasing stiffness of the valve combined with the decreasing strength of the actuator leads to a point where a valve could fail to toggle its position at unpredictable times. The desire to track a valve's health and perform preventative maintenance before it fails drove the need for a system that can measure an actuator's output torque, determine valve position, and detect fluid leaks.

While there are some devices that are capable of measuring a valve's torque, actuator torque monitoring devices are less common and require many inconvenient support systems such as external power, wireless communication, and climate protection.
These factors have led Bray International, a valve manufacturer, to task our design Team to design, build, and validate an embedded monitoring system that can accurately measure the health of a valve and send alerts for preventative maintenance. These deliverables, along with the customer's needed characteristics, will guide our design of the final product.

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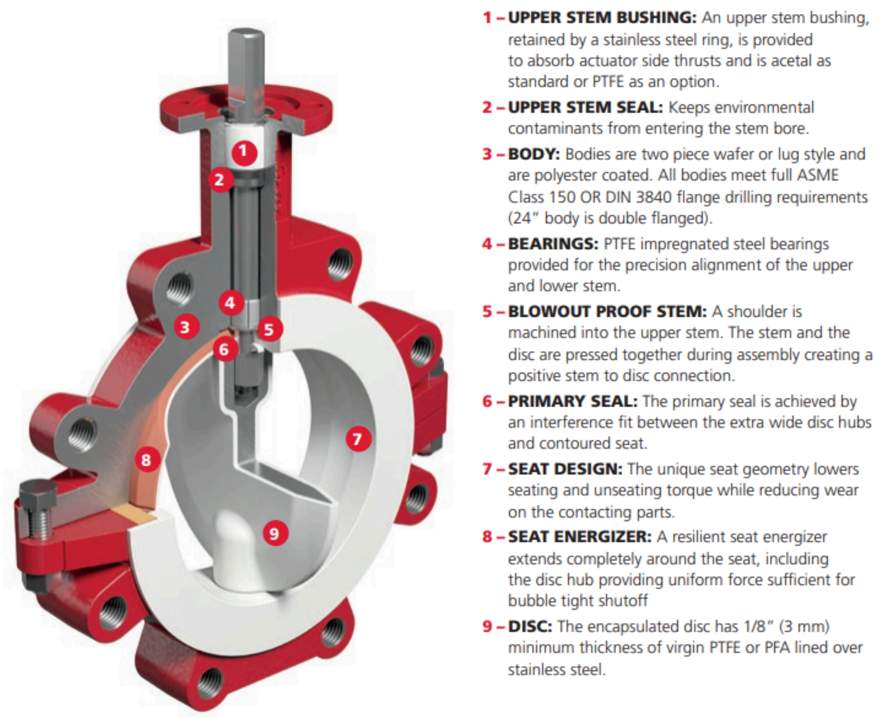
APPENDIX A

Critical components of both butterfly and ball valves. For both valves, the upper stem bushing is connected to the actuator system and is used to toggle the state of the valve.



Components of a butterfly valve, Bray International.

1 **Ball |** Balls are precision machined and mirror finished for bubble-tight shut off and less operating torque. As an added safety feature, a hole in the stem slot of each ball equalizes pressure between the body cavity and the line media flow.

2 **Body/Endcap |** ½"-4" (DN15-DN100) valve bodies are investment cast and solution annealed/normalized for the highest quality and added strength. All body castings are marked with a foundry heat number for full traceability. Carbon steel bodies are phosphate coated for increased corrosion resistance.

3 **Seat |** The seat design ensures bi-directional, bubble-tight sealing with low operating torque. All resilient seats feature relief slots or seat O.D. clearance to relieve pressure past the upstream seat. The seats are preloaded between the ball and body during assembly to ensure sealing against low-pressure and vacuum service.

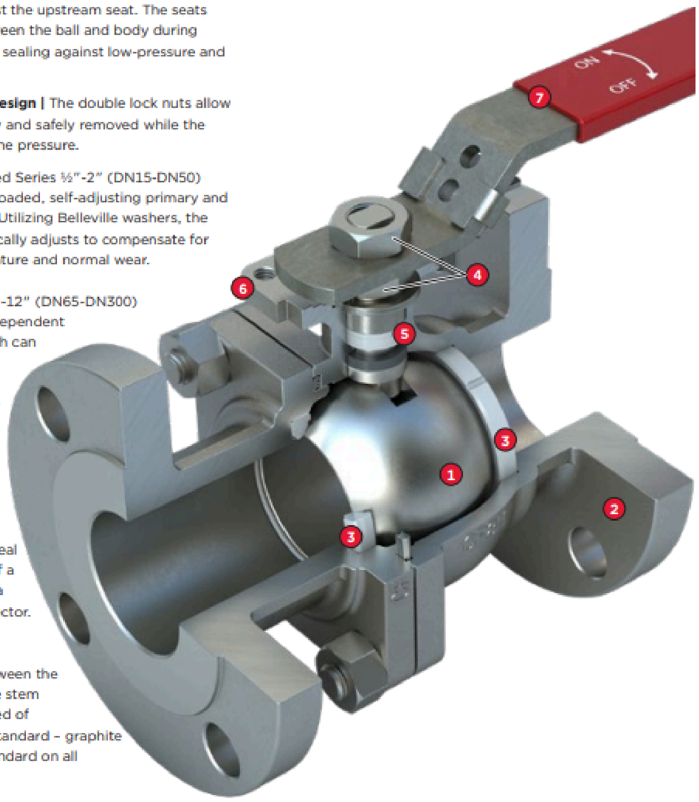
4 **Double Lock Nut Design |** The double lock nuts allow handles to be easily and safely removed while the valve is under full line pressure.

5 **Stem Seals |** Flanged Series ½"-2" (DN15-DN50) valves feature live-loaded, self-adjusting primary and secondary sealing. Utilizing Belleville washers, the stem seal automatically adjusts to compensate for changes in temperature and normal wear.

Flanged Series 2½"-12" (DN65-DN300) valves utilize an independent packing gland which can be easily adjusted without removing mounting hardware or operator. The packing gland is contoured to more uniformly distribute the load across the packing. The primary stem seal is a combina-tion of a thrust-washer and a thrust washer protector. An adjustable stem packing creates a secondary seal between the stem and body. The stem packing is composed of RPTFE V-rings as standard – graphite stem packing is standard on all fire safe valves.

6 **Secure Mount |** Flanged Series valves offer ease of automation due to an integrally cast actuator mounting pad which complies with ISO 5211 through 2" (DN50) sizes.

7 **Handle |** The handles feature a standard Safety Trigger to prevent accidental movement of ball position. Operation is easily made with one hand. The trigger locks the handle in the open or closed position. The handle lock can be bypassed, if needed, with a small bolt through the handle in the bypass position. An Anti-Tamper Padlock can be used to secure the handle in position, preventing unwanted access. Travel stops limit the movement of handle to set 90º intervals, preventing over travel of the ball.



Components of a ball valve, Bray International.

APPENDIX B

Notes taken during the Team's visit to Bray International facilities in Houston, Texas on September 8, 2023 to discuss the deliverables of the project.

- make applicable for ball valve, probs also applicable for butterfly valve
- narrow scope as needed

		Embedded	1
	2" to star	Scalable	3
		Data Collections	2
	-40°F - 300°F	Temp. operations	4
	max 740psi	Various pressures	3
no tolerances → Beats current hysteresis better than ± 2°		Fluid medium variation	3
	<5% error	Torque Measurement	1.1
		lead times	2
hvac industries		usable data	2

Customer Needs notes for Bray International, Haynes.

Rack & Pinion torquer } actuators
↳ Straight arm

[types, sizes
↳ email 4 info

IoT Sdns:
- measure torque on valve
- external bracket added to actuator
- Battery powered
- agnostic to actuators & valves
- Bracket measures Reaction to valve
- we want to embed this & read actuator torque

maybe
-320 F - 400 F

same for pneumatic & hydraulic actuators

Existing Torque Bracket characteristics from Bray International, Haynes.