Hermetically Sealed Globe Valve

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Abstract

The goal of this project is to design a hermetically sealed globe valve for Tyco Valves. Hermetically sealed globe valves are made such that there is a permanent seal (i.e. weld) between the hazardous fluid flowing through the valve and the environment. A hermetic seal will be designed and implemented into the Yarway Welbond 5600 Globe Valve, which is currently offered in Tyco’s product line. A metal bellows and a metal diaphragm are the two most common ways of creating a hermetic seal in a valve. With the information gained from research and the requirements set by Tyco it was initially decided to use a multiply metal diaphragm. The idea was that a waveform shape diaphragm would increase stroke length while reducing stress on the diaphragm. After extensive analysis, it was determined that the diaphragm could not withstand the required pressure and displacement. Further research was conducted in order to find an alternative method of sealing the valve. It was decided that a Belleville disc spring assembly could be used and would satisfy the requirements set by Tyco. The flow path has been redesigned so that the stroke length can be minimized while maintaining the required flow characteristics. FEA analysis was performed in order to find the appropriate number and configuration of disc springs that would achieve the desired stroke length. The remaining parts of the valve have been redesigned in order to accommodate the disc spring assembly and have been sent out for manufacturing.
The Need for Project

A hermetically sealed globe valve is needed to prevent leakage of radioactive fluid into the environment. Hermetically sealed globe valves are primarily used in nuclear applications around the world. Their need arises from the fact that harmful fluids such as radioactive water must not leak into the environment. Traditional globe valves do not contain a permanent seal and are not suited for this application. This hermetic seal helps to ensure the safety of power plant employees as well as the environment.

Tyco Valves currently does not offer a hermetically sealed globe valve as part of its product line. Designing one will enable them to compete in a fast growing and profitable market.

The Design Project Objectives and Requirements

To develop an innovative hermetically sealed globe valve that meets requirements set by the ASME Section III Boiler and Pressure Vessel Codes for 2010.

Design Objectives

The main objective of this project was to design a hermetically sealed globe valve for Tyco Valves. This valve had to be designed in accordance to the specifications set by the ASME Section III Boiler and Pressure Vessel Codes for 2010 along with the Westinghouse AP1000 specification for construction of nuclear power plant components. The valve implements an innovative and fully functional hermetic seal into Tyco’s existing Yarway Welbond 5600 valve.

Design Requirements

In order to meet ASME Class 1500 ratings for 1 inch globe valves, the valve must be able to withstand and operate at a temperature of 650°F and a working pressure of 2500 psi. Certain design parameters, such as a minimum valve body wall thickness of 0.241 inches and a service life of 5000 cycles over a 60 year period, must be maintained in order to meet the requirements set by the Boiler and Pressure Vessel Codes. Also, a final design requirement calls for all Stellite material used in the valve to be replaced with a non-cobalt based alloy that has similar wear resistant properties.

Design Concepts Considered

Initial design concepts involved using a flexible metal diaphragm and welded disc springs to hermetically seal the valve.

During the design process several different designs were considered to hermetically seal the globe valve. These can be split up into three categories: flexible metal bellows, flexible metal diaphragm, and welded Belleville disc springs. The flexible metal bellows option is one that is readily used today in the nuclear valve industry and was
discarded early in the process as an innovative and simpler solution was preferred by Tyco.

**Flexible Metal Diaphragm**

Initial designs for a flexible metal diaphragm resulted in two concepts. After extensive analysis the advantages of both concepts were combined into one final diaphragm concept. (Rep 3.3 Concept 3) This design consisted of an upper and lower stem which is separated by the waveform shaped flexible metal diaphragm. The upper stem incorporates a power screw assembly to raise and lower the stem. As the upper stem moves up and down it deflects the diaphragm which in turn moves the lower stem to close the valve. As the upper stem and diaphragm move back to their original position a spring raises the lower stem to allow for flow. (Rep 3.3 Figure 13)

**Welded Belleville Disc Spring Assembly**

The final design consists of a welded Belleville disc spring assembly which will act as the hermetic seal and the spring to open the valve. (Rep 3.5 Figure 15) The disc spring assembly consists of 33 disc springs stacked in series and welded together. Like the diaphragm concept there is an upper and lower stem which moves up and down to open and close the valve. As the upper stem is rotated and lowered, the disc spring assembly will compress and move the lower stem to close the valve. When the upper stem is rotated back to its original position the disc spring assembly will decompress and raise the lower stem and open the valve.

**Recommended Design Concept**

The final design concept is comprised of the Welbond 5600 valve design modified to accept a Belleville disc spring assembly that is welded together to create a hermetic seal. After preliminary FEA analysis and investigation, it was determined that a globe valve featuring a Belleville disc spring assembly would best satisfy the project goal. An expert in FEA software at Tyco was consulted in order to more accurately analyze the welds around the disc springs that hermetically seal the valve.

**Design Description**

The final design of the hermetically sealed globe valve uses a disc spring assembly consisting of 33 individual disc springs welded together on their inner and outer edges. The top disc is welded to the stem and the bottom disc is welded to a bushing, which in turn is welded to the valve body. The hermetic seal has then been created and
fluid cannot leak into the environment. When the hand wheel at the top of the valve is turned, the stem will lower and compress the disc spring assembly, closing the valve. When the hand wheel is turned the opposite way, the spring action of the disc springs will raise the stem to open the valve.

The flow path has been redesigned from the original Welbond 5600 valve in order to accommodate a shorter stroke length. The outlet bore has been designed as a slot as opposed to a circle. This results in the stem and disc having to travel only 0.1875 inches to close the valve while maintaining the appropriate flow characteristics.

The seat and the disc of the Welbond 5600 valve were made of Stellite, which is a cobalt-containing material that absorbs radiation over time. Stellite has been replaced with a material called NOREM, which does not contain cobalt or absorb radiation, while offering very similar physical properties to that of Stellite.

**Analytical Investigations**

An expert at Tyco was consulted for assistance with stress analysis on the Belleville disc spring assembly. The assembly was modeled in ANSYS and stresses determined for both containing the internal pressure and withstanding deflection. Due to the difficulty of simulating welded joints, deflection was limited to less than 10% of the height of the spring assembly. The total height of the spring assembly is 3.432 inches, so it cannot deflect more than 0.3432 inches. With this minimal deflection and the thickness of the discs, the spring was found to be able to contain the internal pressure and deflect up to 10% without yielding.

However, by reducing the deflection to 10% the stroke length of the valve had to be reduced by 70%. In order to accommodate this change and maintain the flow characteristics of the original Welbond 5600, the flow path had to be redesigned. The inlet path was enlarged and the outlet path was compressed to a slot cross section, to increase cross sectional area while reducing height of the path. SolidWorks FlowSim was used to simulate flow through multiple design concepts. The final concept utilized all available space inside the valve body, which will create a simpler exterior shape, while increasing the flow rate over the original Welbond 5600 valve. The original flow path offered a Cv value of 8.582, while the slotted flow path has a Cv...
value of 10.657. This means that the valve has a 24% increase in flow.

After redesigning the flow path and analyzing the disc springs, it was determined that the disc spring assembly only needed to deflect 0.1875 inches, which is below the allowable of 0.3432 inches.

**Key Advantages of Recommended Concept**

One major advantage of this concept is its simple design. This simplified design allows for the reduction in the total number of parts when compared to the previous concepts. By eliminating the yoke assembly, upper glands, and stem de-coupler, the valve now uses only 14 parts compared to over 20 parts used in the previous design concepts.

The metal bellows traditionally used to create a hermetic seal are very expensive and difficult to manufacture. Each diaphragm is only 0.006-0.008 inches thick making them very difficult and expensive to weld, even with very precise welding methods. The Belleville discs are each 0.05 inches thick, making the assembly much easier to weld.

**Financial Issues**

- Hermetically sealed globe valve sales will contribute to over $250,000 in revenue during the first year of production.
- In the first year of production, Tyco expects to make $250,000 in revenue from hermetically sealed globe valve sales.
- Initial manufacturing cost for welding the Belleville washer assembly is $5,000. The price is expected to decrease as more orders are placed and after initial tooling is completed.

**Recommended Improvements**

- Physical testing of the disc spring welds and further analysis of the diaphragm concept could improve the strength of the hermetic seal.
- FEA analysis was performed on the Belleville disc spring assembly in order to determine the maximum allowable pressure and deflection. However, there is no proper way to simulate the welds that hold these discs together. Given more time, actual welded assemblies could be tested and the results could be incorporated into the design.

The original valve concepts using a metal diaphragm were eliminated because the desired pressure and deflection could not be achieved. When analyzing the disc spring assembly, the valve flow path was redesigned to allow for a shorter stroke length. If time permitted, the diaphragm could be analyzed once again using this lower deflection and potentially could have been used to seal the valve.