How Valve Companies and Integrators are Ensuring Quality in an Era of Off-shoring and Increasing Scrutiny

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INTRODUCTION

Over the last decade and a half, valves sold in Europe and the United States have been increasingly manufactured in developing countries with lower labor costs. Even established valve manufacturers in the developed world have outsourced at least some of their manufacturing overseas in order to compete by controlling prices for their customers. The challenge for manufacturers is to maintain quality when valves are partially or entirely manufactured overseas. Although most valves perform very simple operations, such as controlling the flow through a single pipe branch, failure can be extremely costly. Even when valves are manufactured domestically, concerns over quality are leading to increased scrutiny.

Occasionally valve failures make the headlines, such as with the Deepwater Horizon leak in April of 2010 when a bent pipe kept the valves in the blowout preventer from closing. Six months later, the Tennessee Valley authority found that a flow control valve failed to open while attempting to establish shutdown cooling during a refueling outage at the Browns Ferry Nuclear Plant. An investigation determined that the valve failure was due to a manufacturing defect resulting in undersized disc skirt threads. The valve stem to disc separation had occurred prior to November 2008, so the unit had operated for at least two years without discovery of the faulty valve.

When designing, manufacturing or purchasing a valve, it is important to ensure that it meets real-world application requirements, not just that possibly outdated sizing charts indicate the design will work. A true performance evaluation of the entire valve package can only be achieved through a physical test.

Demonstrating Safety

For routine, low-cost, low-value applications, valve testing may not be needed. It is common practice for manufacturers to offer full replacement for any valve that fails. Sometimes, low-cost valves can be oversized to provide some margin of safety. Of course, these warranties do not cover the cost of lost production nor lost customers as a result of unscheduled downtime.

Offshoring offers valve manufacturers a way to lower costs, but it also makes it harder to verify that their valves or parts made by contract manufacturers are up to the company standards. Even if the manufacturing is done correctly, it can be difficult to obtain documentation proving that the metallurgy is just right or that hydrotesting was done in a way that matches real world conditions. Having an independent facility test the valves provides both the manufacturer and its customers peace of mind in knowing that the valves will perform as expected.

Valve customers or systems integrators may also want to conduct their own testing before installing a valve. In terms of valve sizing, it is straightforward to specify a valve with enough margin to ensure performance on the job. That margin comes at a cost, however, in terms of a larger, more expensive valve and also a larger, more expensive actuator. An additional consideration is that the extra margin does not necessarily guarantee reliability.

With safety applications, in particular, it is important to document that a valve will perform. There is increasing awareness among nuclear plant operators about performance of old valves as they seek to extend the life of their plants beyond the original forty year license. The rough calculations that were done decades ago, if they still exist, are not enough to satisfy a regulator. Even if the original data could be located, we now have much better tools to evaluate the valves and performance than engineers had 25 years ago, as well as a much better understanding of materials science and the long-term effect of heat and radiation on equipment. As part of their relicensing applications, nuclear operators need up-to-date validation that the valves will continue to perform flawlessly through an additional twenty years.

Testing Criteria

Computer modeling has become popular in the valve industry over the last two decades, and its virtues are significant, particularly in the design phase. Modeling alone, however, is not sufficient for determining fitness for service. A Computational Fluid Dynamics (CFD) analysis should be done as an initial step and can help guide the parameters for physical testing. It cannot, however, accurately determine whether a valve will meet expectations in the field.

The testing should match the in service operating conditions, including flow rates, pressure, viscosity, temperature and contaminants or abrasives entrained by the fluid. At a minimum, particularly when dealing with isolation valves, the pressure differential across the valve needs to be known for a proper test design.

Finally, the tests should be run through enough cycles to verify that the valve will continue to operate successfully throughout its expected lifespan.

Following these guidelines and executing a properly designed physical test of a valve can build confidence that the valves will meet the expectations of customers in actual application. It is far better to show them that all of the upfront computational analysis is not just colorful but has resulted in real-world performance.

Another key element to consider for testing and for service is that the valves and the actuators be closely matched. This applies whether the actuator is automatic or manual. An oversized actuator can power its way through a sticky valve, but it may mask a valve problem and eventually shear the valve stem. An undersized actuator will not be able to operate the valve if the performance declines over time, which is likely to occur. The resistance of the valve when first installed will not remain the same after 10,000 cycles, so the actuator must be adequate to accommodate changing resistance without covering up problems that need urgent attention.

Two case studies below illustrate typical challenges and associated test programs to address them.

Case Study: Fire Protection System Valve Testing

Three years ago, Valve Automation and Control (VAC), a business unit of W&O, which is a wholly owned subsidiary of PON Holdings B.V. of the Netherlands, took on the job of changing out 60-year-old firefighting systems on some of the U.S. Navy's T-AKE (Auxiliary Cargo and Ammunition) ships. The ships are designed to carry fuel, ordnance and other supplies in support of naval fleets, so a robust fire suppression system is essential. The work was being performed by VAC under a contract General Dynamics Nasco had with the U.S. Navy. The plans called for using four 8" ball valves from Montreal Bronze with actuators from Emerson's EIM unit in Houston. The design criteria for the valves showed they were adequate if there was a fire in a single hold, but there were concerns about a hypothetical catastrophic event with fires in multiple holds for which all the fire pumps started simultaneously, a realistic scenario for a ship filled with ordnance and fuel under enemy attack. There was no data to verify that the valve could perform in that situation, so testing was needed.

Conservative analysis conducted prior to testing showed that hydrodynamic torque could be a significant component of the overall required valve torque. Testing was employed to put the valve in a realistic operating scenario and measure the required torque. While the exact relationship between pressure and flow experienced by the valve on ship is difficult to calculate, two operating points can be easily identified. The first is the pressure of the system against which the valve is seated and then has to open. The second is the terminal flow rate through the valve under fully open conditions. Two operating conditions are important to the T-AKE valve installation on the sprinkler system. The first is the test condition for which sprinkler associated hardware is periodically tested for performance and timely response. The flow rate for these conditions is expected to be less than 1,000 gallons per minute (gpm). The second condition is the operating condition in which flow is supplied to the sprinkler headers during an emergency requiring sprinkler actuation. The flow rate for this condition was identified to be 4,570 gpm. While many test cycles are expected for the valve, very few operating condition cycles are expected. The testing consisted of 500 operating condition cycles and 1,500 test condition cycles.

Testing was conducted over a one week period in April, 2011 using an open test loop design (Figure 1). A 200 HP centrifugal pump was used to drive the primary loop. A second boost pump was installed in parallel with the primary pump. A swing check valve installed downstream of the primary pump allowed the second pump to work in series with the first when the test valve was closed. Loop operation was fully automated with the valve controller dictating the pace of cycling. Downstream of the pump, different restrictor plates were installed to provide varying levels of system resistance depending on whether the cycles were conducted for valve operating or valve test conditions.

Three measurements formed the core data related to the test: flow rate, valve inlet pressure and valve actuator torque. The latter was measured by monitoring the current supplied to the actuator. The actuator had a known relationship between current and torque. A limited number of cycles were also conducted using a manual over-ride hand wheel. Torque measurements for hand-operated cycles were also obtained using a slip-ring / strain-gauge based torque sensor. Flow was measured using a venturi flow meter and valve inlet pressure was monitored using a piezo-resistive electronic sensor. Data collection was continuous throughout all cycles, recording one second data averages throughout the test.

Valve performance was maintained throughout all cycles with no detectable increase in required actuator torque during the testing. The current profiles (proportional to torque) obtained during opening and closing for high flow show a distinct hydrodynamic contribution. The unseating and reseating torque is generally expected to constitute the torque peak in a valve cycle. However, the torque added to the ball and stem due to the redirection of flow through the ball at partially open positions can cause even greater resistance. Note that hydrodynamic torque is only a contributor during the opening cycle whereas during closing, hydrodynamic torque works with the actuator. The peak in torque on the closing cycle is observed at the reseating of the valve. Testing was able to show that while hydrodynamic torque can play a significant role in the peak actuator torque requirements, the valve and actuator package were properly designed to power through the added load and no adverse performance was observed even after extended valve cycles (see sidebar).

Computed versus actual torque: VAC needed to validate the valves before installing them on the T-AKE's. They first went to a nuclear engineering company in Houston that had software to convert the data on flows and pressure into the torque values required to open and close the valves. When the valves and actuators were run through tests at Alden Laboratory, however, the actual torque values were about 40% lower than the theoretical torque values predicted by the engineering software, which can make a huge difference in costs. There can be many reasons for such differences, including non-fluid mechanical forces not taken into account, as well as unsteady flow characteristics often ignored.

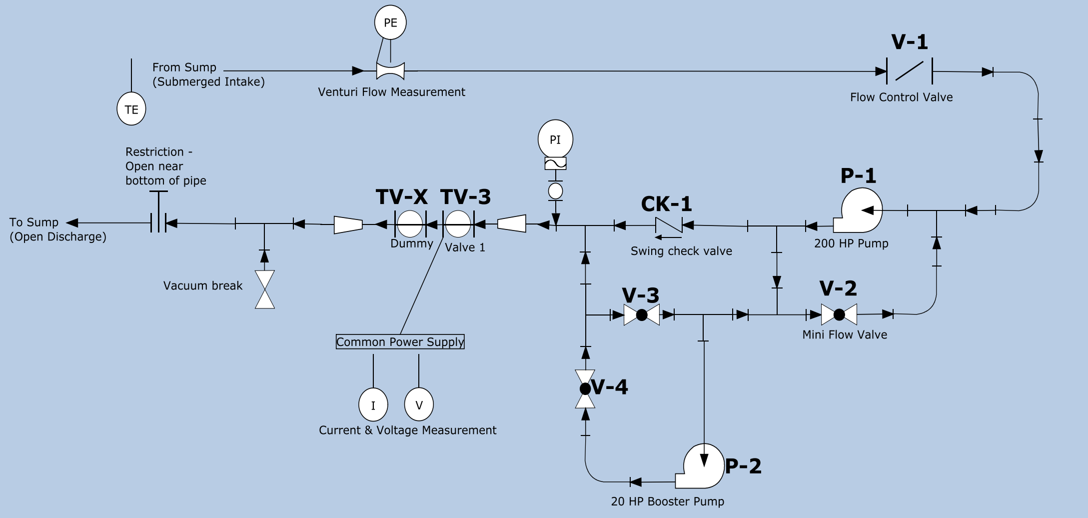

Figure 1. Test setup schematic.

Figure 2. Test Valve

Case Study II: Naval Ship Chiller Valve Testing

The United States Navy is one of Metrex Valve's key customers for valves used in the HVAC systems in its vessels. In the past, only shock and vibration testing were required for condenser water control valves. Recently, however, sourcing company changes resulted in more stringent requirements for valve testing. After winning the bid, Metrex had to follow the testing protocol developed according to the valve specification and approved by the customer. During the developmental phase, one sample valve had to undergo endurance, noise, and contamination testing protocols outlined in the valve specification for these valves. Any testing failure would result in a necessity either to justify the failure based on some installation aberration, or to make design and manufacturing changes, which could seriously hamper profitability on the valve, particularly now that testing has become a noticeable fraction of the overall cost of delivery. Metrex contracted with Alden for the testing, as described below.

Endurance Testing

Endurance Testing consisted of actuating the valve for a total of 20,000 cycles with 3,200 gpm (+/- 5%) continuously flowing through the valve to determine the wear on the valve seats, transmission and otherwise loaded components, fatigue, actuator life, and general ruggedness and longevity of valve. A seat leakage test was then performed on each inlet port after each 1,000 cycles for the first 5,000 cycles, and every 5,000 cycles thereafter for a total of 8 tests, in accordance with internally developed test procedures. Flow leaking past the seat was quantified by collecting and measuring the water volume (gallons) over a known time (minutes) for approximately two minutes (1-minute minimum).The torque required to manually actuate the valve fully open and fully closed under a no-flow condition with the actuator removed was measured with the use of a calibrated torque wrench after 10,000 and 20,000 cycles.

The test setup for the endurance testing included a 10"/12" PVC pipe loop with a 50 hp centrifugal pump drawing water from a supply sump, to deliver the required maximum flow of approximately 3,360 gpm (7.5 cfs) to the valve. The flow was set and measured using a 12" x 8" Alden-calibrated flow meter and control valve. A 12" x 10" reducer allowed the meter to be installed in the 10" loop. Custom 10" spool sections were fabricated and installed to allow the piping to be connected to the military valve flanges at all three ports. A 12" x 10" reducer was installed at the outlet port and 12" piping returned the flow back to the supply sump. A drawing of the flow loop is shown in (Figure 3) and a photograph of the test loop is shown in (Figure 4).

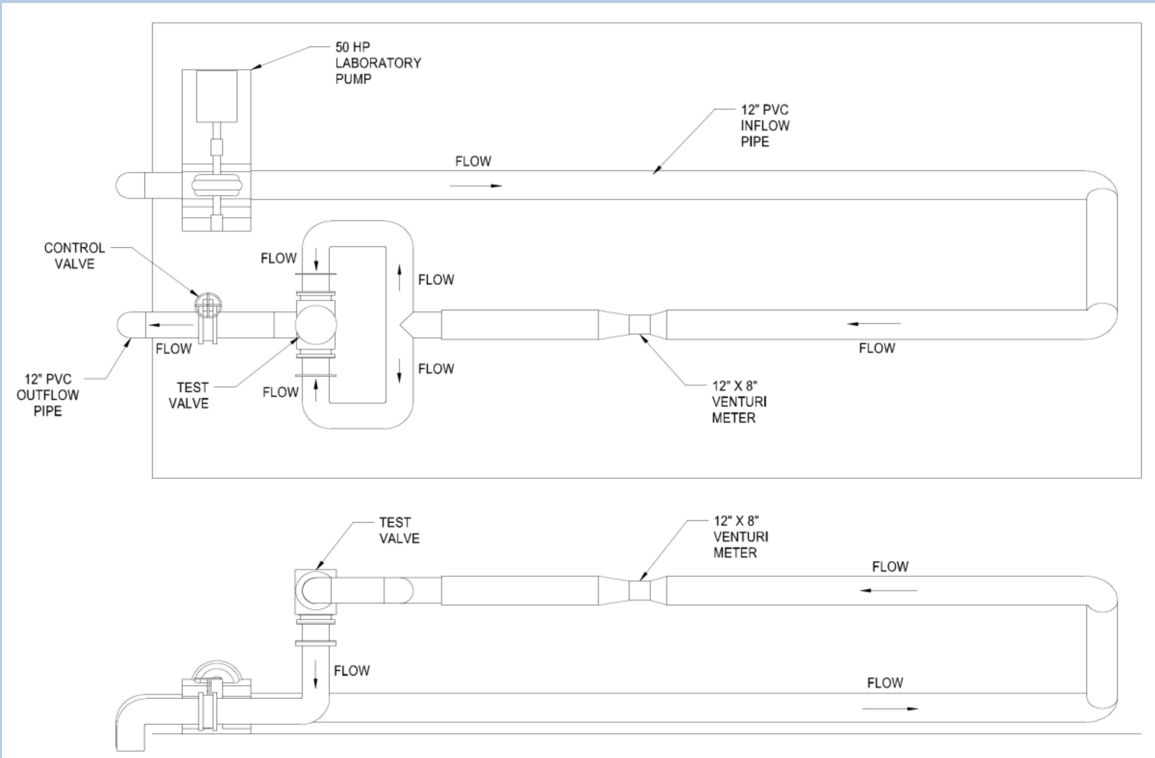

Figure 3: Endurance testing flow loop for 10" Metrex 3-way valve

Figure 4- Metrex 3-way valve in the endurance test loop

Sound Pressure Level (SPL) Tests

The valve was installed in the test loop described above, and tested in accordance with both Metrex developed protocol and MIL-STD-1474D, now required for these valves used in naval ship HVAC systems. Testing consisted of recording the Sound Pressure Levels (SPL) at 3 locations as shown in (Figure 5).

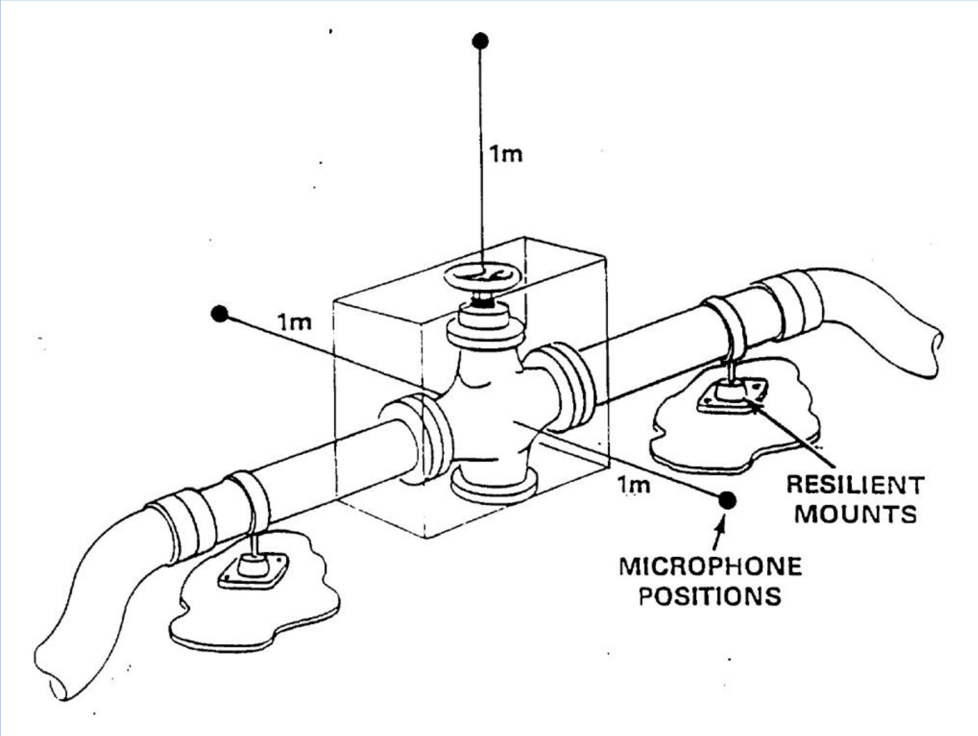

Figure 5- Microphone Data Acquisition Positions (MIL-STD-1474D)

A-Weighted and C-Weighted background sound pressure levels (SPL) were recorded at the specified locations prior to the initiation of the valve testing. A-Weighted and C-Weighted SPLs (dB re 20 µPa) were recorded with the valve positioned in the “shut” position (rest mode), as well as during cycle actuation, while supplying a continuous flow of 3,200 gpm to the valve. The octave band SPL (dB re 20 µPa) was recorded at the location and for the mode that produced the highest A-Weighted and C-Weighted readings.

In order to reduce background noise and isolate valve noise, all influent PVC fittings (elbows, and tee) were located a minimum of 9 to 12 ft from the valve. All influent and effluent fittings (elbows, tee and valve) were wrapped in 3” polyester acoustic foam, with a noise reduction coefficient (NRC) of 0.94. The pump noise was reduced by encasing it in an enclosure lined with the same acoustic foam. The flow loop was modified for the background test by disconnecting the influent piping from the test valve and returning the flow directly back to the sump. All pipe fittings to be used in the valve test were included in the background test to account for any turbulence noise generated from the fittings.

Contamination Testing

Testing consisted of continuously flowing "simulated contaminated seawater" through the valve at 35-45 gpm, with an operating pressure of 50-60 psi, for a duration of 200 hours, in accordance with internally developed test procedures. The torque required to fully open and fully close the valve was recorded before and after the test. Testing was conducted under a Quality-Control Program, with all test setups and calibrated instruments reviewed and approved by a government agency representative.

The simulated seawater was produced by adding Crystal Sea Marine Mix® sea salt to the fresh water supply to produce a salinity of 35 parts per thousand (ppt). The specified sediment particle sizes ranged from 0.1 to 1,000 microns, and the required sediment concentrations were produced by adding a blend of commercially available silica sands. The specified organic detritus concentration of 10 ppm was produced by adding commercially available organic peat, which was sieved to meet the 50-250 micron requirement.

All three phases of testing met the naval sourcing requirements for the Metrex valve, enabling final development and on-time, profitable delivery without the need for modifications or follow-up testing.

SUMMARY

With the increasing globalization of valve manufacturing, even domestically manufactured valves are receiving increasing scrutiny, particularly those used in safety applications. Flow testing under conditions that will be experienced in the field has become an essential tool for proving quality and performance. Careful development of a testing plan that is appropriate to the expected service and that will meet customer requirements is a key to success. The use of a well respected independent laboratory for testing will also go a long way in lending credibility to the results. This white paper has outlined two case studies in which valve flow testing proved performance and allowed final development and installation.

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