Solutions for Application Obsolescence in Nuclear Power Plants

Since the mid 1860’s through the end of the 19th century, names very familiar to the valve industry, such as Lunkenheimer, Grinnell, Powell, Jenkins and Crane have been granted patents for the globe valve. The earliest of which is attributed to Frederick Lunkenheimer on March 7, 1865. Since then its inherent design has gone generally unchanged. Enhancement through the years in materials and hard faced along with designs such as Y-pattern to reduce turbulence and increase flow have allowed to globe valve to find its way into isolation applications. Designed for throttling, globe valves are largely used in vent drain and isolation applications in power generation.

This is especially true in the nuclear industry. Widely accepted because the Generation I plants were built with them. It is one of most misapplied valve technologies in operating nuclear plants. Its time has come and gone, but old habits are hard to break.

The nuclear industry thrives on obsolescence. Everything about it is basically obsolete, from the technology of the domestic operating fleet to the aging workforce, where according to the Nuclear Energy Institute (NEI) the average age is beyond 50 years old and close to 40% is eligible for retirement in the next few years. It is no wonder that the ability to adapt to new technologies due to regulatory constraints and the cost associated with changing is the utilities ability to implement upgrades that would safely and economically increase plant efficiencies and operations.

In most cases where valves are concerned, the cost of the engineering design package far exceeds the cost of the equipment being upgraded, including installation. Even where the plant can justify the associated cost, the regulatory issues imposed due to the operating license is but another barrier toward plant improvement. Despite their ubiquitous presence in nuclear plants, the globe valve designs of three inch NPS and smaller, defined as high energy or severe service used in the aforementioned applications are obsolete.

The Generation I nuclear plants were essentially a design/build on the fly. In the heyday of the first wave of construction, valve manufacturers were scrambling to provide what was needed as the specifications changed and engineers played catch up. Conversely the Generation III and III+ plants currently under construction worldwide and in Georgia and South Carolina are built to design. Meaning all components are preselected and many of the systems are constructed as modules and assembled at the construction sites.

It is important to reiterate that the operating domestic fleet is Generation I design from the 1960’s. The industry deserves plenty of credit for operating safe and reliable base load power while overcoming the daily struggles of obsolescence. The Nuclear Utility Obsolescence Group (NUOG) is an industry users group devoted to dealing with the day-to-day obsolescence problems of operating nuclear plants, all within the regulatory restrictions imposed. NUOG’s mission is to share information and solutions to the daily issues surrounding the safe, successful and profitable operation a nuclear power plant.

The use of quarter turn severe service metal seated ball valves (MSBV), largely perfected in the mid 1980’s is a new technology to the mature nuclear industry. Because of the costs associated with upgrades and improvements previously described, there is an inert reluctance to change. The path of least resistance is generally taken unless the threshold of pain is so great that the particular the responsible System Engineer says enough. He or she then implements a plan that includes a cost benefit analysis, including O&M costs; proof of improved safety of personnel, piping and equipment along with efficiency upgrades and a rapid return on investment, are but some of the elements presented to the Plant Health Committee. No easy task.

Globe Valves vs. Metal Seated Ball Valves

Globe valves are linear operated valves and are commonly found in every conceivable high energy vent, drain and isolation application in a power plant operating nuclear or fossil fueled. The most common sizes and pressure classes utilized in nuclear plant applications can range from .375 inch through three inch with pressure classes ASME 600# though 2500#. Materials are typically A105, F22 and 316SS. There are two valve types are “Teed” (Figure 1) and Y-pattern (Figure 2).

Globe valves are normally supplied in compliance with FC70-2 Class IV or V leakage standard. It is important to realize that these leakage standards allow for leakage during the cold hydrostatic testing during manufacture. Once installed in high energy applications it is not unusual to notice leakage at a very early stage of startup.

In short the combination of a tortuous flow path, high turbulence and the susceptibility of impingement as the media passes through the seat during an opening all contribute to the rapid deterioration of globe valves in vent, drain and isolations services.

Typical seating surfaces in high energy isolation globe and gate valves are hard faced with Alloy 6. Alloy 6 has excellent wear and corrosion resistance, but it is very prone to cracking with rapid temperature swings. It also is susceptible to scratching and galling at elevated temperatures as it softens with temperature which is noticeable at 500°F. The cobalt content is also a deterrent to use, but the industry has yet to identify a satisfactory weld overlay substitute for Alloy.

Metal Seated Ball Valves

Conversely metal seated ball valves are a quarter turn operation. They are a posi...
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station seated, or sometimes called a float-
ing ball design (Figure 3). They match all
sizes and pressure classes in the nuclear
industry and are flexible enough to be
considered for gate valve replacement
in a bi-directional configuration as well.
They are typically lever or handwheel
operated, are extremely quick opening
manually and are easily actuated when
required. These valves are the best avail-
able isolation technology.

Due to their design and the require-
ment to mate-lap the ball and seat(s),
creating a matched trim set, these
valves are expected to have seat leak-
age performance that exceeds FCI 70-2
Class VI. Class VI is typically expected in
soft seated ball valves. It is also known
as bubble tight. Again, even a Class VI
leakage standard still allows for some
leakage during manufacture. For intent
and purpose metal seat ball valves can
have their own classification of seat
tightness one could call Class VII which
is zero visible leakage, hydro for a peri-
od of three minutes and Class VIII which
is zero visible leakage for a period of
three minutes on high pressure gas.
This is a reality in 21st century valve
technology and design.

Because metal seated ball valves es-
sentially have pressure assisted seat-
ing, there are no axial unseating forces
as with globe style valves. The seats are
also entirely protected in the fully open
position eliminating the impingement
expected causing damage in globe and
gate valves. Additionally metal seated
ball valves are typically free from any
elastomer seals and are therefore in-
herently environmentally qualified for
harsh nuclear service.

Metal seated ball valves of a position
seated or floating design depend on a
load applied from a combination Bel-
leville spring with an upstream seat
guide. Once the valve endcap is torqued
to a specified value the ball defaults to
an axial and radial alignment which is
fixed. The load is applied to the ball and
downstream seat. This load provides a
wiping action through the stroke of the
valve and therefore system particulate
such as pipe scale and magnetite cannot
dislodge the seating surface contact.

Other features inherent with ball valve
designs are the quarter turn operation
which minimizes packing wear and tear
for extended packing life. The straight-
through flow path eliminates turbu-
lence and high velocity seat erosion.
The sealing surfaces are fully protected
in both the open and closed position
and the Cv’s are much higher than
globe valves and can match or exceed
those of gate valves.

Finally, absolute zero leakage can be
achieved when properly engineered
and manufactured internally and exter-
nally. This is especially important to the
safety conscience nuclear industry.

The hard coating used is the heart and
sole of the product once properly de-
signed and applied. The manufacture of
high energy MSBV applications in the nu-
clear industry incorporates a chrome car-
bide or tungsten carbide combinations.

The process is known as High Velocity
Oxygen Fuel (HVOF) (Figures 4 and 5).
This is not a hardfacing process; rather
it is a relatively low temperature ap-
plication. The substrate rarely exceeds
300°F (149°C), thus stress reliving
in not needed. The mechanical bond
strength can be greater than 25,000 psi
and it withstands thermal cycling with-
out cracking. The friction coefficient is
low .2 – .28, which is appealing to the
nuclear industry.

The most impressive aspect of the hard-
coating is its hardness which in the case
of nuclear power applications with rare
exception will never drop below 68-70 Rc.
At this value the carbide particles are
harder than most, if not all particles in a
pipeline including ferrites and magnetite.
It resists any wear, scratching, galling and
corrosion. This is illustrated in the com-
parison with Alloy 6 (Figure 6).

Comparison

When placing a globe valve side by side
against a metal seated ball valve the
benefits are eye-opening:

1. Globe valves are exposed to high
pipeline unseating forces versus a met-
al seated ball valve where pipeline pres-
sure equates to higher seating forces.

2. Globe valves are throttling valves

Figure 3

Figure 4

Figure 5
used in isolation applications. Ball valves are designed for isolation.
3. Globe valves have exposed seating surfaces when open. Ball valves seating surfaces are always protected.
4. Globe valves have a torturous flow path for increased turbulence and reduced Cv. Ball valves have an undistorted flow path for the highest possible flow capacity.
5. Globe valves are multi-turn linear operated with a deep stuffing box with maximum potential for scoring and leakage. The ball valve is quarter turn with a hardened and polished stem with a minimum four bolt live loaded packing system, standard for drastically reduced packing wear and tear for long term leak free reliability.
6. Additionally, due to the expected allowable leakage, continuous seat degradation when in operation at pressure and temperature globe valves has a much higher cost of ownership.

Real Success

The article would not be complete without examples of where upgrading a technology from the incumbent globe and gate style small bore isolation valves to metal seated ball valves. A Utility with a Pressurized Water Reactor (PWR) had a Main Steam System (MSS) with monitored losses from a steam trap isolation and startup vents drains were replaced with metal seated ball valves. This installation commenced in 1995. According to the Component Engineer at the time the globe valves ran an annual cost of up to $125,000 in repair and replacement.

Furthermore, due to their degradation over the course of a fuel cycle the plant personnel were unable to perform the required maintenance while the plant was on line for extended periods. To date the valves are in operation for 20 years at a cumulative savings in excess of $2,500,000 dollars.

As with the first example this plant component engineer was forward thinking and well ahead of his time. The technology was less than 10 years old when he made the decision to make the changes. A decision with no regrets.

Conclusion

One should ask a simple question... Why put a throttle valve in an isolation application? Looking forward, using metal seated ball valves in isolation applications requires a paradigm shift. An understanding of why the use of globe valves in isolation applications is not necessarily the best choice, and because it is the incumbent technology it is not the long term solution for plants expecting to operate 20 years beyond their original license to operate.

Unfortunately, the “Nuclear Renaissance” has hit a few bumps in the road and hadn’t panned out as most expected and who believed it was real in the early 2000’s. As a manufacturer, huge investment is required to provide the latest technology and product innovation to the nuclear industry. Programmatic costs are real and unavoidable for those who chose to stay in it rather than bailout once the plant construction in the US all but dried up. The pursuit of application obsolescence is an arduous task; one that requires patience and understanding that the forward thinking engineer everyone seeks is out there and is willing to put forth the effort with management support for the overall good of the safe operation of the plant.

What to Look for...

There are several features a specifying engineer encountering an application obsolescence issue should look for when sizing and selecting a metal seated ball valve for isolation service in power generation:
1. Body end cap should be integral. As with globe valve inbody seat weld inlays integral seats eliminates a potential for behind seat leakage.
2. The valve stem must be one piece blowout proof, inserted through the body. Stems which are collared and pinned should be considered a weak link and a safety hazard.
3. The stuffing box should be shallow and inserted with flexible graphite packing with proper anti-extruding features and a minimum four bolt live loaded packing system
4. Gland should be 316SS to protect against corrosion.
5. The body seal (gasket) should be inconel and self-aligning.
6. The ball and seats should be hard coated with tungsten or chrome carbide hard coating with a minimum hardness of 70 – 72 Rc.
7. Shutoff shall be absolute zero leakage, exceeding the requirements of FCI 70-2 Class VI and ASME/ANSI B16.34
8. Every valve is serialized assembled tested and documented with QA signoff.

ABOUT THE AUTHOR

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