Nuclear actuators and automation development

Valves are an important part of every nuclear power plant, they can perform normal operations and ensure the safety integrity of the plant. Valves can be operated manually, electrically, or pneumatically to perform their required functions. Manual valves are being replaced with pneumatic and electric actuators to allow plants to become more automated, reducing the man hours required to operate valves and increasing efficiency. Depending on application valves can be either rotary or linear. Rotary type valves may be ball, plug, or disc designs, and linear types may be globe or gate designs.

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Electric actuators are known as Motor Operated Valves (MOV) and pneumatic actuators are known as air Operated Valves (AOV). Both AOV and MOV actuators come in linear and rotary designs. Linear actuators operate globe or gate valves by raising and lowering the valve stem to control the flow through the valve. Rotary actuators operate the ball, plug, or disc valves stem in a clockwise or counterclockwise rotary motion, in either 90 or 180 degrees of travel to control the flow through the valve. This article will focus on the 90 degree rotary pneumatic type actuators.

Nuclear qualified pneumatic actuators make up the automation portion of the valve package. Actuators are used to operate the main steam lines, ventilation systems, service feed water and reactor isolation valves within a nuclear power plant. Automated actuators can control the valve position from remote safe locations within the control room or move the valve to the required fail safe position on loss of signal.

A linear pneumatic actuator.

Pneumatic rotary actuators

The two basic types of pneumatic rotary actuator functions are spring return and double acting. These can be used to operate the valve open, close, fail open, fail close, or fail in place. Pneumatic Rotary actuators are typically deigned with a diaphragm or piston type cylinder. The cylinder is mounted to a housing and yoke mechanism that transfers the linear motion of the cylinder into a rotary motion. The opposite side of the yoke of the valve can be connected to a spring to provide a static force to drive the actuator in a certain direction.

Double acting actuators have a pneumatic cylinder and housing. They require pneumatic power to operate the actuator in both clockwise and counterclockwise directions. Spring return (or single acting) actuators have a pneumatic cylinder, housing, and spring. They require pneumatic power to operate the actuator in one direction, and on loss of the pneumatic power the spring will rotate the actuator in the opposite direction.

The size of the piston or cylinder and the pneumatic supply pressure will produce a specified amount of force. The force is transferred through a piston rod to the scotch yoke mechanism. This force is then multiplied by the moment arm length of the yoke to calculate the torque output of the actuator. The moment

Redundant stem line pneumatic actuators.

arm length is the distance between the center of the yoke bore and the center of the connecting point of the yoke to the piston rod. This torque is compared to the required valve torque to travel in both directions with the applied differential pressure on the disc, plug, or ball and the applied safety factor. The safety factor will ensure that the actuator has the required torque to operate the valve after any loss of efficiencies to the valve and/or actuator.

The pneumatic rotary actuator scotch yoke torque curve measures the torque output throughout the full 90 degree travel. Due to the scotch yoke design, the maximum torque output is at either end of travel and the minimum torque output is in the center of travel.

Figure 1 shows the typical torque output through the full 90 degree travel.

When sizing actuators for the new specifications, they must meet the EPRI sizing criteria and the plant's sizing requirements. The main reason that the EPRI and plants require that actuators are sized per these stringent specifications is to ensure that the actuators have more then enough torque to operate the valve under the worst case scenarios during and after an event. Many actuator manufactures have their own sizing tools for sizing actuators and the EPRI specifications ensures that the actuators are sized consistently for nuclear facilities. Environmentally Qualified (EQ), seismic, and safety related actuators must go through rigorous testing and qualification programs to validate and document the performance of the product used in the critical containment areas and safety related functions. These actuators are tested to verify they will perform their designed safety function before, during and after an event. The actuators subjected to EQ testing are aged for the service life required by the specifications and are subjected to thermal aging, radiation aging, Loss of Coolant Accident (LOCA) / Main Steam Line Break (MSLB) testing, seismic testing and other functional tests. The EQ actuators are unique in construction and must be purchased as EQ actuators from the factory manufactures.

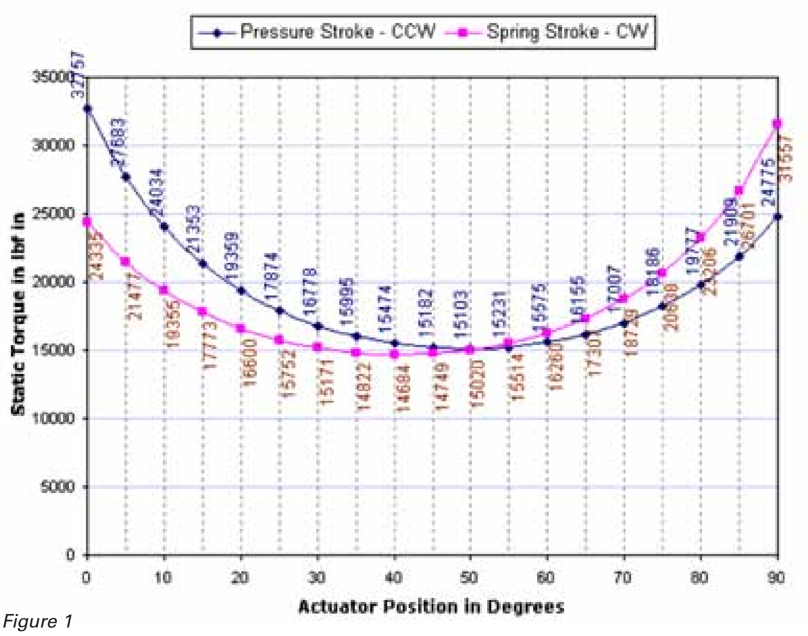


Figure 1

Qualification levels

Actuator manufactures must have a quality assurance program for nuclear service that conforms to the specifications of 10 CFR PART 21 and 10 CFR 50 Appendix B requirements.

Pneumatic quarter turn actuators historically offered to the nuclear power industry were tested and qualified to the following IEEE EQ, Seismic, and Safety Related standards:

- IEEE 323-1974, Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations,
- IEEE 344-1975, Guide for Seismic Qualification of Class 1E Electrical Equipment for Nuclear Power Generating Stations,
- IEEE 382 (ANSI N278.2.1, Draft 3, Rev 0, February 1977) American National Standard for Qualification of Safety Related Valve Actuators.

The development of new nuclear power plant designs and IEEE specifications that have higher levels for EQ and seismic requirements are driving suppliers to re-qualify their products. Re-qualifying can take approximately 12-18 months.

New qualified actuators will be required to meet or exceed the new requirements and the below IEEE standards.

- IEEE STD 382-2006 (Revision of IEEE Std 382-1985 and IEEE Std 382-1996)
- IEEE STD 344-2004 (Revision of IEEE Std 1987)
- IEEE STD 323-2003, a revision of IEEE STD 323-1983

Automation and Controls

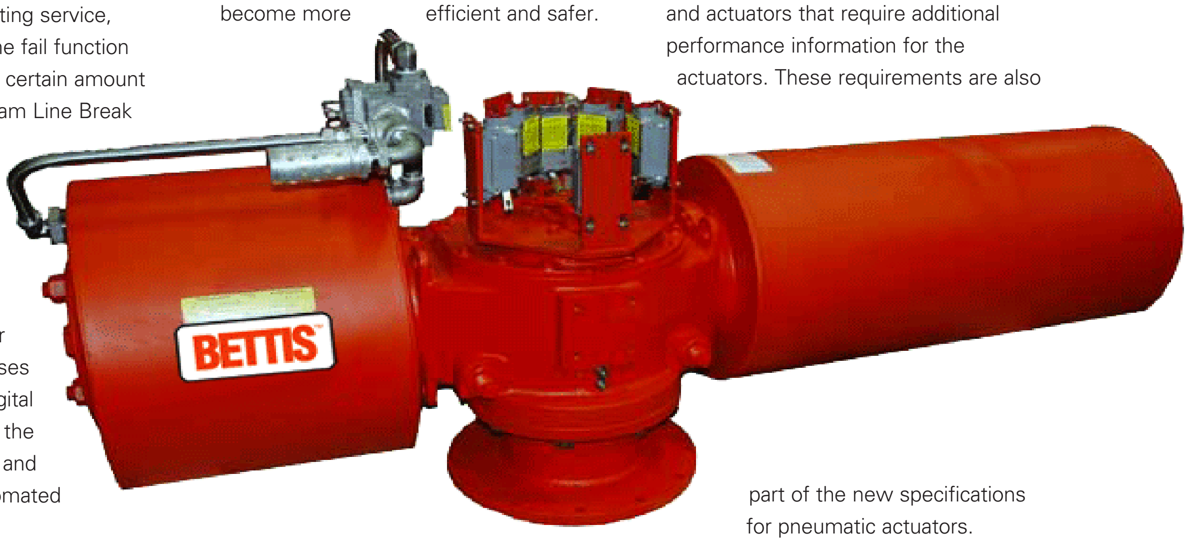
Historically, typical nuclear controls applied to pneumatic actuators consisted of limit switches, solenoid valves, and filter regulators for on/off valves in most applications. Recently the automation trend is changing to more complex control systems that require the automated package to perform different functions. The functions range from fail in place on loss of electrical or pneumatic signal and then close after a certain amount of time, modulating service, fast close, or move to the fail function and then operate after a certain amount of time after a Main Steam Line Break (MSLB) event or Loss Of Coolant Accident (LOCA) event.

Additional automation developments have been the introduction of the digital positioners for diagnosing valve processes in nuclear plants. The digital positioners will increase the response, performance, and repeatability for the automated valve packages.

With the nuclear industry requiring automated solutions to meet these new requirements, manufacturers are required to support the demands with application engineers who can design and offer these solutions.

The nuclear industry requires support for automated packages per 10 CFR PART 21 and 10 CFR 50 Appendix B programs with documentation for qualified controls from the individual control manufacturers. The automated control systems must be designed, tested, and certified to ensure that they meet the required specifications for each application. The test certification becomes part of the final Certificate of Conformance (C of C) for the specific order.

New controls are becoming more readily available to meet the new automation requirements as manufactures are re-qualifying their controls to meet the new specifications. As the new controls and technologies are applied to new and existing nuclear plant designs they will become more efficient and safer.



Emerson's Bettis G Series Scotch yoke actuators have been in used in nuclear power plants for over 40 years.

Product support

Previously, nuclear specifications required 40 year service and support. New specifications have increased the level of service and support to 60 years. Manufacturers must be prepared to support the increasing demand for continuing support for new and existing plants. Complete service kits for soft seal replacement and service intervals must be identified for products offered for new plant designs. The required seals must be proven through the qualification testing process and identified in the operating and maintenance manuals for the qualified actuators.

Older nuclear plants have adapted measurement processes for the valves and actuators that require additional performance information for the actuators. These requirements are also part of the new specifications for pneumatic actuators.

Manufactures must be prepared to support these requirement needs when supplying actuators for the new specifications.

Conclusion

The nuclear industry is growing at a fast and exciting pace for automated actuator and valve applications. The actuator manufacturers that are willing to meet these challenges head on with solutions will be the successful leaders in the nuclear industry.

Pneumatic rotary actuators installed in a nuclear power plant.

General History

Emerson Process Management's Bettis scotch yoke actuators have been one of the leading pneumatic rotary actuators and controls to the nuclear power industries requirements since 1969 and first passed a formal nuclear qualification program in 1980. Emerson Process Management's Bettis facility in Waller, Texas has successfully been audited by the Nuclear Procurement Issues Committee (NUPIC) and Nuclear Industry Assessment Committee (NIAC) as a supplier of products to the nuclear industry.

Emerson Process Management, through its Bettis-branded actuators, has a global presence of 40 years with the largest installed base in the North American (NA) market. The North American installed base includes 56 power plants and approximately 4,000 actuators. There is a significant installed base in Korea, Taiwan, China, and other countries with approximately 20 additional plants that include another 1,500 actuators.