

Retrofitting feedwater valves at North Anna reduces vibration and improves control

Tortuous path feedwater regulating valve trim permits staged pressure reduction and precise flow control

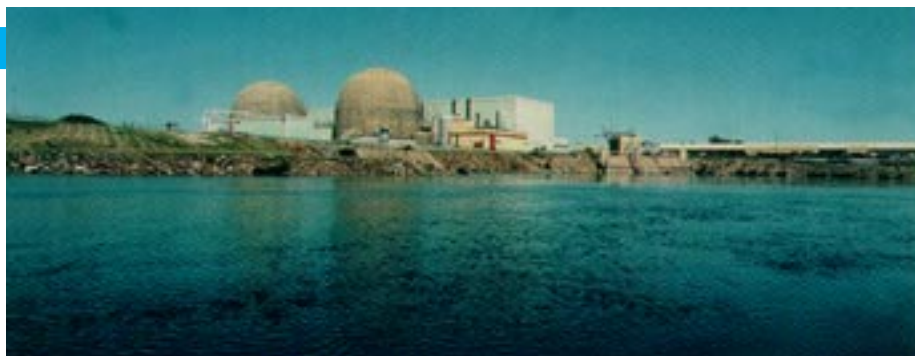
By Quinten Parker and Kevin J. Avery, Virginia Power Co., and Herbert L. Miller and Curtis G. Sterud., Control Components Inc.

Since the 1978 startup of Unit I at Virginia Power's 954-MW, pressurized water reactor (PWR), North Anna Nuclear Generating Station, in Mineral, Va., plant operators have experienced feedwater flow regulation problems with that unit's single-stage, main feedwater regulating valves. Similar problems have also plagued the regulating valves on Unit 2 since its startup in late 1980.

Upon actuation, the valves would cause wide control pressure swings as high as 135 pounds per square inch at the 800 pounds per square inch gauge control point (Figure 1). These events would sometimes cause a total loss of control and trip the reactor.

To help manage this problem, manual feedwater control valve operation became a cumbersome and unsatisfactory necessity. Furthermore, excessive vibration, as high as 1.9-g acceleration and 1/6-mil displacement peak-to-peak, occurred at flows above 50 percent of full load, and flow-versus-time oscillations were passed on to the steam generator because small valve stroke changes produced large flow changes.

In some cases, the stresses associated with this kind of valve actuation would break the



Virginia Power Co.'s North Anna Nuclear Generating Station.

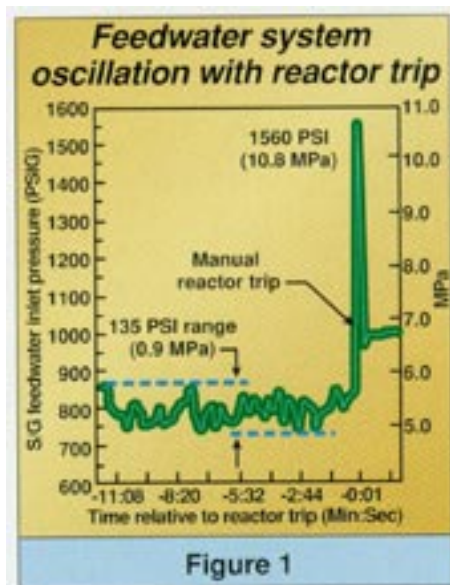


Figure 1. Typical original feedwater regulating valve pressure oscillation producing a reactor trip.

valve's stem. The original feed-water regulating valves were a 12-inch by 12-inch single-stage pressure-breakdown design, characterized by a window cage, double-seated valve trim (Figure 2), and a single-acting diaphragm spring-to-close, air-to-open actuator.

Root causes

Several factors may have contributed to the possible root causes of these problems. For example, the vibration could have been related to possible coincident pipe and valve frequencies where the frequency of the standing wave in the piping is coincident with the natural frequency of the valve plug and actuator spring.

Poor velocity control with a single pressure-drop cage, or unstable forces from high seat-ring fluid velocity—especially at

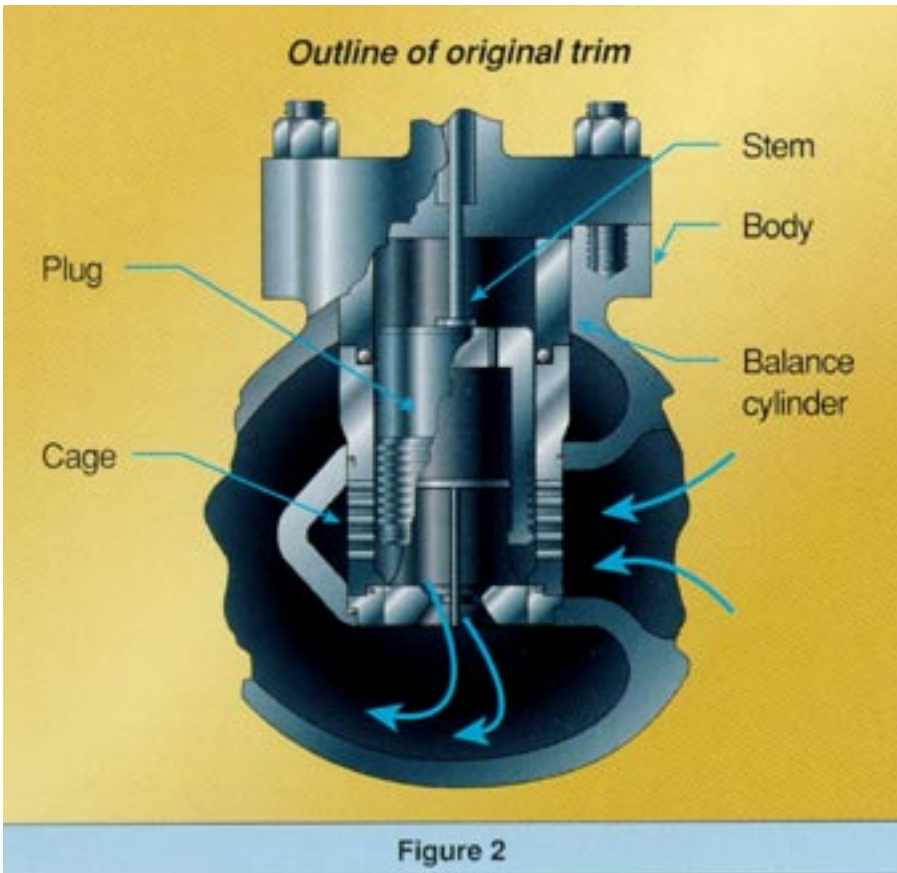


Figure 2

Fig. 2. Outline of original valve trim

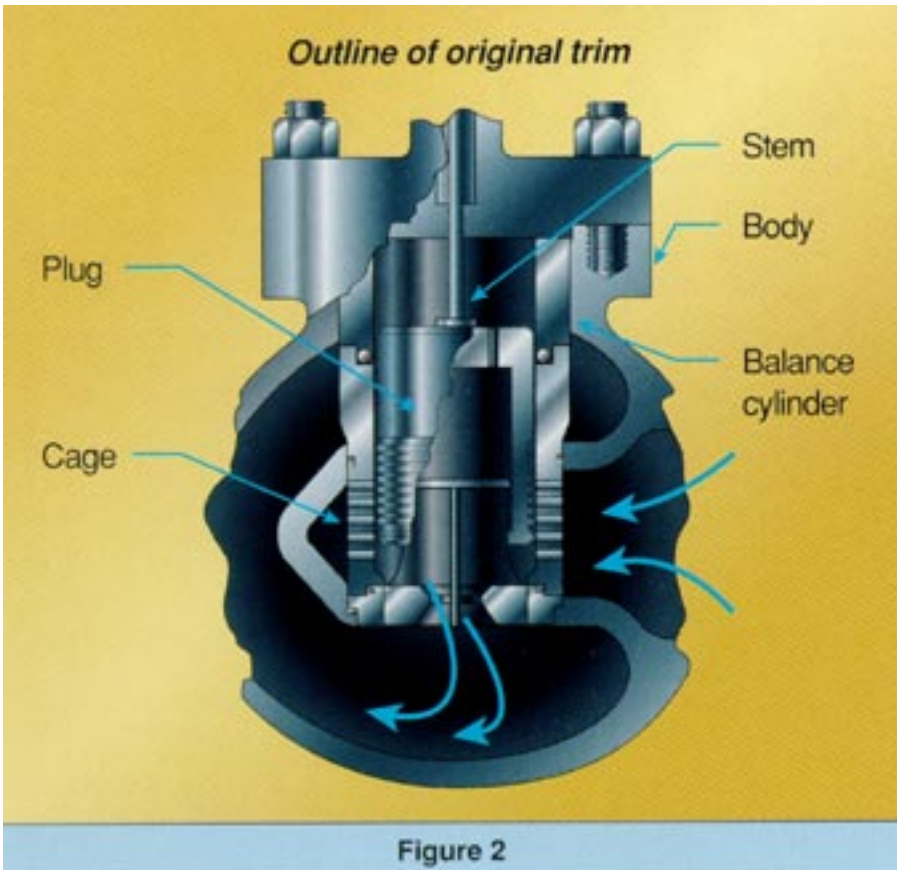


Figure 2

Fig. 3. Retrofit valve trim

low flows—were also identified as possible causes.

Initial problem-solving steps

To alleviate these problems, operators resorted to limiting the velocity across the feedwater regulating valves by opening the bypass valves around them, recirculating flow around the valves and carefully adding pumps as needed in order to minimize pressure perturbations.

Virginia Power tried a variety of corrective valve modifications with limited success. These modifications included adding a balance cylinder, as seen in Figure 2, and installing a quadrant-flow baffle assembly attached to the valve seat ring. This modification changed the valves from a double-seated configuration to a single-seat design. Furthermore, in an attempt to correct the flow-oscillation problem, the natural frequency of the valves was changed by modifying plug geometry and weight and installing new actuator springs. A larger 1 1/4-inch diameter valve stem was also installed to better handle operating stresses and prevent it from breaking.

Although some of these modifications significantly improved the valve's operating characteristics, operators still had to manually operate the regulating valve on numerous occasions. Because operating procedures and valve modifications failed to solve control and excessive vibration problems, Virginia Power decided to retrofit new valve internals in an attempt to completely eliminate the system's chronic problems.

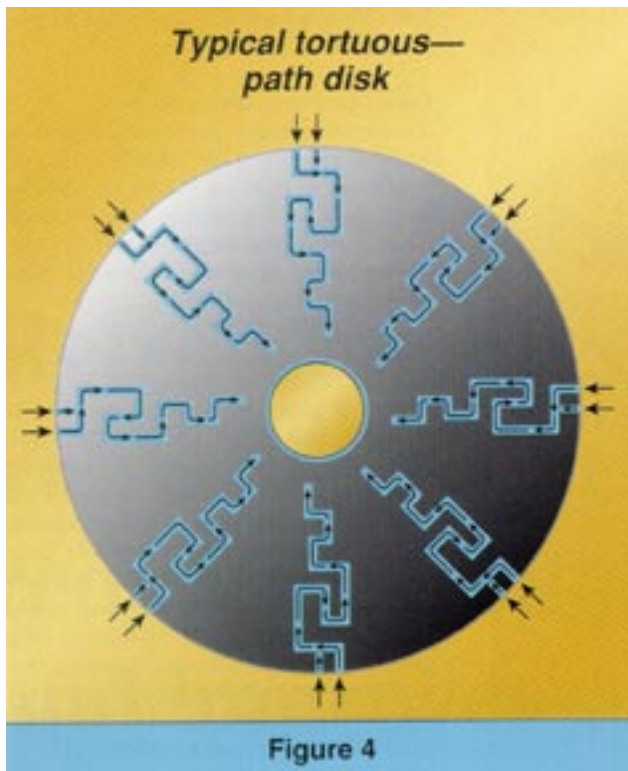
No removal required

Retrofitting the feedwater regulating valves involved two primary elements: completely new, multistage, pressure-breakdown valve trim (internals), as shown in Figure 3, and new, stiffer, double-acting piston actuators.

The new multi-stage valve trim required absolutely no modifications (field machine or welding) to the existing valve bodies and was accomplished without having to remove the valves from the piping system.

The replacement trim's design incorporates a stack of tortuous-path disks that permit multi-stage pressure reduction over the entire stroke of the valve. The stack of disks, each involving up to ten pressure-drop stages, replaced the original single-stage pressure-reducing cage design and reduced internal flow velocities in excess of 85 percent. Feedwater pressure is continually dissipated at a controlled velocity by being forced through a number of channels with right-angle bends etched into the disks (Figure 4).

To preclude cavitation, the channels control the fluid velocity so that it exits all disks at a maximum velocity of 100 feet/second. In addition, each disk incorpo-



rates a pressure-equalizing ring on its inside diameter to ensure that equal pressure acts radially around the circumference of the plug at any position in its stroke. This design keeps the larger diameter plug centered at all loads thus preventing plug vibration. These features hold noise levels at full load (4.4X106 lb/br) to 78 dBA at three feet, which is background level.

Characterization

Discrete groups of tortuous-path disks within the stack were “characterized” for inherent linearity, which requires valve stroke directly proportional to the valve flow requirement.

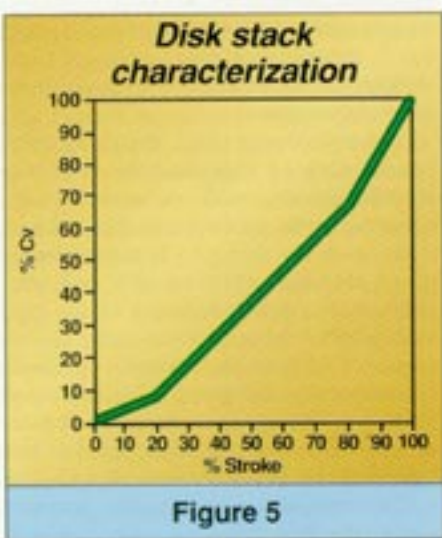


Figure 5. Disk stack characterization.

Characterization permits precise velocity control over the total valve stem stroke range and permits good control over the entire load range.

Five groups of characterized disks were provided in the retrofit to produce this inherent linearity. Figure 5 shows the characterization curve which meets nuclear steam supply specifications. This provided appropriate fluid velocity at all valve stroke positions.

In addition, valve plug diameter was increased to 9 1/2 inches from 7 inches.

This reduced velocities through the seat ring by as much as 84 per-cent. Plug stroke was increased to 6 3/4 inches from the original 2 3/4 inch-stroke for improved flow control. Full-

load, valve-stem stroke was increased to 70 percent of wide open as opposed to the original full-load stroke of 50 percent open. Even larger 1 1/2-inch diameter valve stems were fitted to replace the 1 1/4-inch diameter stems installed during the first round of modifications.

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Replacement actuators

Although the replacement actuators retained the existing positioner, solenoid and limit switches, a variety of changes were incorporated, including double-acting pneumatic pistons to replace the original air-to-open, spring-to-close diaphragm design. Larger, 200 square inch area pistons were also used to replaced the original 160 square inch pistons.

Twenty-gallon receivers were provided for fail-closed operation and exhaust and lock-up valves were installed to operate the air receivers. Boosters were used for increased operating speed (trip-to-close in 2.5 seconds).

By contrast, the original design’s speed was just meeting the five-second requirement. The plug size increase, the tortuous-path pressure letdown and the actuator changes have eliminated the fluid oscillations.

Retrofit results

As a result of the valve retrofit program, Virginia Power’s North Anna Nuclear Generating Station, now has fully-automatic feed water control during startup and at all loads. Vibration displacement has been reduced from nine mils (originally 16 mils) to two mils and vibration velocity has been reduced by three times. Moreover, vibration acceleration has been reduced by a factor of 10 to 16, and valve-stem breakage has been eliminated alto-gether. Finally, the time required to install the trim and actuators did not exceed the time required for a normal valve internal inspection—less than three days per valve.

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AUTHORS

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