# 1.0 INTRODUCTION

## 1.1 Course Objectives

1. Describe the valve and motor actuator types with emphasis on the most common used in nuclear power plants.
2. Explain the theory of operation of the various valve and actuator designs used in typical motor-operated valve service, including operation at design basis.
3. Explain the application of various motor actuator types, including the principals and techniques used in selecting the appropriate actuator for a given use.
4. Explain the principals of various standard motorized actuator controls.
5. Perform actuator disassembly, assembly, and switch setting, and observe techniques of trouble shooting motor-operated valves, both mechanical and electrical interfaces.
6. Understand the methods for measuring the operational performance of MOVs and discuss the expected results.
7. Understand the regulatory issues associated with MOV sizing and performance, and discuss the history of MOV problems and failures.

## 1.2 Discussion

The piping systems in a typical nuclear plant include hundreds of motor-operated valves. Many of these valves are safety-related valves, a term that denotes that the safety of the plant depends on the ability of these valves to close (or open) when called upon to operate at specific, possibly severe conditions anticipated in the design of the plant. These conditions are commonly called design-basis conditions. The design bases for U.S. nuclear power plants are typically documented in the plant's design and safety documents, for example, the final safety analysis report for the plant.

For some components, the design-basis conditions are the normal operating conditions of the plant, while for other components, especially components in safety-related systems, the design-basis conditions include certain accident conditions. For a motor-operated valve, the design-basis conditions would include the temperature of the fluid, the differential pressure (upstream pressure minus downstream pressure) against which the valve must open or close, the ambient temperature in which the motor is expected to operate, and the voltage supplied to the motor. For some motor-operated valves, the design-basis conditions include very high differential pressure and very high flows.

In the past twenty years, quite a lot of research has been done investigating issues related to the operation of motor-operated valves. When the typical U.S. nuclear power plant was built, design engineers used standard formulas and methods (developed by the valve industry and nuclear industry) to estimate the operating requirements of the valves. These estimated served as the basis for determining how powerful the valve's actuator needed to be and what the control switch settings should be.

The research conducted after the Three-Mile Island-2 (TMI-2) accident showed that some of the standard formulas and methods in use at the time were not precise enough to produce accurate estimates, and some of the assumptions inherent in the calculations were incorrect.

As a result, some motor-operated valves were insufficiently powered. If called upon to operated at design-basis conditions, such valves would fail. Fortunately, few such valves have ever been called upon to operate at conditions that cause them to fail. It is important that such valves are identified and insufficiencies corrected before failures occur.

## 1.3 Historical Overview

In 1980, the Electric Power Research Institute (EPRI), a U.S. association of electric utility companies, conducted simple go/no-go tests of seven motor-operated gate valves of six manufacturers, using standard actuator sizes and control switch settings for the anticipated loads. The tests were part of an effort to resolve an "action item" identified by the post-accident analysis of the TMI event. The valves were 3-inch gate valves similar to the TMI-2 block valve described in the previous chapter.

Three of the seven valves experienced failures to close. Interestingly, these tests were the first laboratory tests ever conducted in which motor-operated gate valves were subjected to the very high differential pressures at which some of them are expected to be able to operate.

In 1985, two auxiliary feedwater isolation valves failed to open on command after a combination of mechanical failures and human errors resulted in an event at the Davis-Besse nuclear plant in Ohio, U.S. Fortunately, quick action by the plant's crew averted serious consequences. For both of these 8-inch wedge-type gate valves, the high pressure (about 1000 psi secondary pressure) on the upstream side created a load too great for the motor actuator to overcome.

Equipment operators were able to get to the valves quickly and open them manually using the handwheel. The follow-on investigation showed that one of the control switches (the torque switch bypass) was incorrectly set. A separate investigation indicated that it is likely that the torque switch was set too low as well. (Control switch settings are discussed in detail later in this course.)

In response, the U.S. Nuclear Regulatory Commission (NRC) issued Inspection and Enforcement (IE) Bulletin 85-03, addressing improper control switch settings in motor-operated valves. The bulletin required U.S. nuclear utilities to reevaluate the control switch settings on certain safety-related valves to make sure the settings were high enough to ensure valve operation at design basis differential pressures. The requirements included in-plant testing of some valves.

Later in 1985, Ontario Hydro tested an 8-inch wedge-type gate valve at its testing facility in Toronto, Canada. The valve was similar to the valves that failed to open on command in the Davis-Besse event. Actual test measurements remained proprietary, but the outcome was published: the valve failed to operate with the control switches set at the settings recommended by the valve and actuator manufacturers.

Also in 1985, the U.S. NRC defined Generic Issue 87, "Failure of HPCI Steam Line Without Isolation," and assigned it a high priority. The concern was the possibility that the isolation valves on the steam supply line that drives the turbines for the pumps in the high-pressure coolant injection (HPCI) system in boiling water reactors (BWRs) might fail to close when required. The same concern applies to the isolation valves in the reactor core isolation cooling (RCIC) system, and a similar concern applies to those in the reactor water clean-up (RWCU) system in BWRs. In the HPCI and RCIC systems, piping connected to the main steam line passes through the containment building wall, with normally open isolation valves on either side of the containment penetration.

If the piping were to break outside the containment building (a low-likelihood event included as one of the design basis accident conditions for the system), the only mitigation available to prevent very serious consequences, including possible common-cause failures involving equipment and controls exposed to the discharge in enclosed areas outside the primary containment, is to close one of the isolation valves. The valve would have to close against the very high flow (blowdown flow) driven by the pressure and volume in the BWR main steam line. Similarly, the RWCU isolation valves would have to close against high-pressure hot water that would flash to steam in the event of a line break outside the containment.

In 1989, the U.S. NRC sponsored full-scale, fully instrumented blowdown testing of two typical 6-inch motor-operated gate valves of two manufacturers. The valves were of the type used in the RWCU application described above. The tests were conducted by the Idaho National

Engineering and Environmental Laboratory (INL). Largely on the basis of the preliminary results, the NRC issued Generic Letter 89-10, "Safety-Related Motor-Operated Valve Testing and Surveillance," expanding on IE Bulletin 85-03 to require testing of a larger number of safety-related valves.

The INL conducted follow-on NRC-sponsored testing in 1990, for reasons related to the significance of the results of the 1989 testing and to the small sample size (only two valves). This test project investigated the performance of six wedge-type motor-operated gate valves of two sizes (6-inch and 10-inch) and four manufacturers at blowdown loads representing the design basis accident loads for RCIC, RWCU, and HPCI isolation valves.

Together, the 1989 and 1990 test projects demonstrated that the standard industry methods for sizing valve actuators and setting the control switches were flawed. Among other findings, the results showed that the standard industry methods failed to specify an adequate value for the valve disc factor, a term that accounts for the friction at the disc/seat interface.

In the early 1990s, the Electric Power Research Institute (EPRI) conducted testing of 28 gate valves of several manufacturers. The results validated the test data produced by the NRC/INL testing and provided supplemental data that could serve as a basis for bounding the disc/seat friction in estimates of valve requirements.

The INL conducted further NRC-sponsored MOV testing in 1991 through 2001. These tests used a test stand that simulates valve loads on the stem, so as to test a valve actuator (consisting of an electric motor, a gearbox, and a valve stem) without the difficulty and expense of subjecting the entire valve assembly to a blowdown flow load.

Among other findings, the results of these tests yielded two methods for evaluating the friction at the interface between the stem nut and the stem. The results also identified flaws in the standard industry methods for estimating electric motor output at high temperature conditions and at reduced voltage conditions. In addition, the results identified a gearbox friction issue related to dc-powered motor operation at low speeds and valve stem/stem nut lubrication issues.

In response to several incidents at various power plants, the U.S. NRC issued Generic Letter 95-07 addressing pressure locking and thermal binding of gate valves. In 1997, the INL conducted laboratory tests examining issues related to pressure locking and thermal binding of flexible-wedge and parallel-disc gate valves. Pressure locking occurs when the high pressure of fluid trapped in the valve bonnet (the area above the gate) causes the valve to be difficult to open. Thermal binding occurs when expansion/ contraction phenomena related to temperature changes cause the disc to be stuck between the two seats.

The previous paragraphs present a condensed history of valve incidents and valve research from 1979 to the present. During the twenty years since the TMI-2 accident, the nuclear industry in the U.S. has responded to the various test results and NRC directives by devising test methods, test schedules, and instrumentation strategies for examining control switch settings and actuator sizing issues. The effort has focused on safety-related gate valves, because issues related to these valves were of greatest concern.

Typically the effort by utilities has included in-plant diagnostic testing of valves, with the valves instrumented to measure or infer stem thrust, actuator torque, or both. (In gate valves, *stem thrust* refers to the force that moves the stem down (or up) to close (or open) the valve; *actuator torque* refers to torque applied by the actuator to the nut that turns on the stem.) In some cases it is possible to test a valve in the plant at its design basis conditions (differential pressure, etc.).

However, in cases where the design basis conditions are too extreme, such testing in the plant might be virtually impossible. For those valves, laboratory tests such as those conducted by EPRI and INL provide data that can be used in analytical evaluations of a motor-operated valve's requirements and capabilities. (In this context, the word *requirements* refers to the amount of stem thrust or actuator torque *needed* to operate a valve; *capabilities* refers to the amount of stem thrust or actuator torque the actuator can *deliver*.)

Most of the serious problems in the industry have been gate valve problems. For this reason, gate valves are a major focus of this course (specifically, rising-stem flexible-wedge gate valves). A less detailed discussion will be provided for parallel disc gate valves, globe valves, rotating stem valves, butterfly valves, plug valves, and ball valves.