ENCLOSURE

MOTOR-OPERATED VALVE PROBLEMS IN THE UNITED STATES and ACTIVITIES OF THE U.S. NUCLEAR REGULATORY COMMISSION TO IMPROVE THE PERFORMANCE OF MOTOR-OPERATED VALVES

Thomas G. Scarbrough
Mechanical Engineering Branch
Division of Engineering
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission

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Abstract

The U.S. Nuclear Regulatory Commission (USNRC) requires by regulations that motor-operated valves (MOVs) important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. Despite these requirements, operating experience and research programs have revealed problems with the performance of MOVs in operating nuclear power plants. Among these problems are inadequate MOV design and incorrect torque, torque bypass, and limit switch settings that have led, or could lead, to failures of MOVs to perform their intended design-basis safety functions. This presentation summarizes MOV problems at U.S. nuclear power plants.

The USNRC staff is conducting inspections of the implementation of programs developed at U.S. nuclear power plants in response to Generic Letter (GL) 89-10, "Safety-Related Motor-Operated Valve Testing and Surveillance," and its supplements. A significant finding of these inspections is that utilities have found that many MOVs require more thrust to operate under design-basis differential pressure and flow conditions than has been predicted by the standard industry equation with typical valve factors assumed in the past. The USNRC staff has found weaknesses in utility procedures for conducting the differential pressure and flow tests, the acceptance criteria for the tests in evaluating the capability of MOVs to perform their safety functions under design-basis conditions, and feedback of the test results into the methodology used by the utility in predicting the thrust requirements for other MOVs. The USNRC staff also has found that utilities have not progressed sufficiently in resolving concerns about the potential for pressure locking and thermal binding of gate valves. This presentation summarizes activities of the USNRC to ensure that MOVs are capable of performing their design-basis safety functions at U.S. nuclear power plants.

This presentation was prepared by an employee of the United States Nuclear Regulatory Commission. It presents information that does not represent a new staff position. USNRC has neither approved nor disapproved its technical content; however, it is consistent with current staff positions.

OVERVIEW OF MOTOR-OPERATED VALVES

Most fluid systems at nuclear power plants depend to a large extent on the successful operation of motor-operated valves (MOVs) in performing their system functions. MOVs are used in various applications to ensure plant safety and to maintain plant availability. For example, MOVs may be required to open to allow cooling water to be provided to the reactor core, steam generators, or containment building. MOVs may be required to open to allow steam flow for turbine-driven pumps in safety systems providing cooling water to the reactor core, steam generators, or containment building. MOVs may be required to close to prevent loss of coolant from the reactor core or to isolate the reactor containment. Other MOVs may be used to control flow in order to maintain the proper balance of fluids for the production of electric power. To ensure plant safety and to maintain plant availability, MOVs must be capable of performing their functions under design-basis conditions, which may include high fluid differential pressure and flow, high ambient temperature, and degraded motor voltage.

There are several types of valves operated by motor-actuators in nuclear power plants. The most common of these valves in the U.S. are gate, globe, and butterfly valves. There are also various designs of gate, globe, and butterfly valves. For example, gate valves may have flexible wedge, solid wedge, or parallel disks. Globe valves may have flow under or over the disk. Butterfly valves may have disks with symmetric or asymmetric shapes, and offset stems.

A motor can be used to drive the gears in an actuator to open or close the valve. The torque output of the actuator is converted to thrust to operate gate and globe valves. Butterfly valves typically require a second set of actuator gearing to provide the proper torque to rotate the valve disk. After receiving a signal to operate, the motor is typically controlled by the torque applied by the actuator or by the number of rotations of gears in the actuator.

The single assembly of the motor, actuator, and valve is referred to as a motor-operated valve (or MOV). Several firms manufacture various sizes and types of motors, actuators, and valves. Therefore, MOVs can be designed and manufactured for a wide range of applications.

The complex nature of the MOV and the varied conditions under which it must operate demand that careful attention be paid to all applicable activities from design to replacement in order to ensure reliable operation. In the design of the MOV, a suitable analysis must be performed using valid engineering equations and parameters to ensure that the MOV will operate, as intended, under normal plant operations and during design-basis events. Manufacture, installation, preoperational testing, operation, inservice testing, maintenance, and replacement of the MOV must be conducted by trained personnel using proper procedures. Surveillance and testing criteria must be applied on a soundly based frequency in a manner that suitably detects questionable operability or degradation of the MOV. Moreover, these activities must be conducted in accordance with a strong quality assurance program.

Operating experience at nuclear power plants has revealed weaknesses in many activities associated with MOV performance. For example, some engineering analyses used in the initial design sizing and setting of MOVs were inadequate in predicting the thrust and torque required to open and close valves under design-basis conditions. Shortcomings in maintenance programs, such as inadequate procedures and training, have also resulted in poor MOV performance. Typical inservice testing consisting of stroke time measurement under zero differential pressure and flow conditions has been shown to be insufficient to detect certain deficiencies that could prevent MOVs from performing their safety functions under design-basis conditions. Given these and other weaknesses, increased attention was needed to resolve concerns with respect to the reliability of MOVs in nuclear power plants.

For many years, the nuclear industry and its regulators were aware of problems with the performance of MOVs. However, it was not until the 1980s that the extent of those problems began to become apparent. For example, a complete loss of main and auxiliary feedwater (AFW) occurred at the Davis-Besse Nuclear Power Station on June 9, 1985, during which time the MOVs in the AFW system could not be reopened electrically after they had been inadvertently closed. At Unit 2 of the Catawba Nuclear Station on March 14, 1988, an MOV in the AFW system failed to close completely against high differential pressure and flow, and subsequent testing revealed that other MOVs in the AFW systems of Catawba Units 1 and 2 were unable to close under those conditions. At the Palisades Nuclear Plant on November 21, 1989, an MOV used to isolate the power-operated relief valve failed to close under high differential pressure and flow conditions during a postmodification test. Many more MOV problems have occurred or have been identified over the last few years.

The potential safety significance of MOV failure, the complex phenomena and other factors affecting MOV performance, the wide variety of MOV problems, and the slow progress in resolving those problems led the nuclear industry and regulatory agencies in several countries to establish comprehensive programs to gain assurance that MOVs would perform well in nuclear power plants. For example, in 1989, the U.S. Nuclear Regulatory Commission (USNRC) issued Generic Letter (GL) 89-10, "Safety-Related Motor-Operated Valve Testing and Surveillance," which requested that U.S. nuclear power utilities establish and implement programs to ensure the capability of MOVs in safety-related systems by reviewing MOV design bases, verifying MOV switch settings initially and periodically, testing MOVs under design-basis conditions where practicable, improving evaluations of MOV failures and necessary corrective action, and determining trends in MOV performance. The USNRC staff requested that nuclear utilities complete the GL 89-10 program within three refueling outages or five years from the issuance of the generic letter, whichever is later.

Nuclear regulatory agencies in a number of countries have placed increased emphasis on ensuring the proper performance of MOVs. The nuclear industry has also recognized the need for increased attention to MOVs and has established programs to improve MOV performance in nuclear power plants. The nuclear industry and regulators throughout the international community have been sharing information on MOV problems and improvements. This NEA/IAEA-sponsored meeting of MOV specialists is an excellent example of the cooperation between the nuclear industry and regulatory agencies from many countries and represents a significant step toward resolving the MOV issue.

MOTOR-OPERATED VALVE PROBLEMS IN THE UNITED STATES

The U.S. Nuclear Regulatory Commission (USNRC) requires by regulations that motor-operated valves (MOVs) important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. For example, Criterion III, "Design Control," of Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to Part 50 of Title 10 of the U.S. Code of Federal Regulations (10 CFR Part 50) requires that utilities operating U.S. nuclear power plants establish control measures to verify the adequacy of design and that vendor requirements are included in the design basis. Criterion V, "Instructions, Procedures, and Drawings," of Appendix B requires the utilities to have procedures and acceptance criteria for the conduct of activities that involve the capability of safety-related equipment to perform its safety function. Criterion XI, "Test Control," of Appendix B requires that procedures for testing components contain provisions for ensuring that adequate test instrumentation is available and that test results be evaluated to assure test requirements are satisfied. Criterion XII, "Control of Measuring and Test Equipment," of Appendix B requires that utilities establish measures to ensure that measuring and test devices used in activities affecting quality are properly calibrated. Criterion XVI, "Corrective Action," of Appendix B requires utilities to establish measures to ensure that conditions adverse to quality, such as deficiencies and defective equipment, are promptly identified and corrected.

Despite the regulatory requirements for MOVs, operating experience and both regulatory and industry research programs have revealed problems with the performance of MOVs in U.S. nuclear power plants. There has been a long history of these problems and regulatory actions for dealing with them. For example, on December 6, 1972, the USNRC issued Bulletin 72-03, which addressed failures of several MOVs to operate. Operating experience and research also identified a wide variety of causes, among which were inadequate design and incorrect torque, torque bypass, and limit switch settings that had led, or could lead, to failures of MOVs to perform their intended functions.

Because of the continuing MOV problems, the USNRC issued Bulletin 85-03, "Motor-Operated Valve Common Mode Failures During Plant Transients Due to Improper Switch Settings," in 1985 requesting U.S. nuclear power plant utilities to develop programs to ensure that MOVs in high-pressure safety-related systems could perform their safety function. In 1988 and 1989, the USNRC staff sponsored tests of MOVs by the Idaho National Engineering Laboratory (INEL) which revealed that certain flexible-wedge gate valves manufactured in the U.S. required more thrust to operate than had been predicted by the valve vendor when sizing and setting the motor actuator. These test results raised concerns that the initial MOV design and qualification, and inservice stroke-time testing required by the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), might be inadequate to ensure the capability of MOVs to perform their design-basis function. On the basis of the implementation of Bulletin 85-03, the staff-sponsored MOV test results, and operating events, the USNRC issued Generic Letter (GL) 89-10, "Safety-Related Motor-Operated Valve Testing and

Surveillance," on June 28, 1989, which requested that U.S. nuclear power plant utilities verify the design-basis capability of safety-related MOVs by dynamic testing in about five years.

Design and Qualification

The most significant MOV problems in the U.S. result from the weakness in the initial design and qualification of MOVs before their installation in nuclear power plants. As described below, the weakness in MOV design and qualification contributed to instances where (1) thrust and torque requirements to operate valves were underestimated as a result of the underprediction of friction, or design-basis differential pressure; (2) motor actuator output was overestimated by failing to determine design-basis minimum voltage, ambient temperature effects on motor output, or load sensitive behavior; (3) structural capability of MOV components was insufficient; and (4) the potential for pressure locking and thermal binding of gate valves was inadequately considered.

(1) Underestimation of Thrust and Torque Requirements

Assumption of Valve Friction for Gate Valves

Gate valve vendors in the U.S. typically have determined the required size and setting of motor actuators for a particular valve based on the operating thrust requirement derived from the sum of (1) the design-basis differential pressure across the valve, multiplied by the area of the valve disk and a valve friction factor, (2) the design-basis system pressure multiplied by the area of the valve stem, and (3) the valve packing load. For the most part, the valve vendors selected a valve friction factor based on an assumption of sliding friction between the valve disk and seat. Tests of MOVs by the Electric Power Research Institute (EPRI), U.S. utilities, and INEL have revealed the typically-used valve friction factors to be inadequate for many gate valves. The resulting underestimation of the thrust required to open or close gate valves has led to some MOVs in safety-related systems in U.S. nuclear power plants being sized or set inadequately and, consequently, failing to operate under differential pressure and flow conditions. U.S. utilities have discovered during analyses or testing in response to GL 89-10 that predicted thrust requirements for numerous safety-related MOVs were inadequate and that modifications to the MOVs were appropriate.

Assumption of Valve Friction and Flow Area for Globe Valves

The typical equation used to predict thrust requirements to operate globe valves is similar to the equation for gate valves except that the orientation of the globe valve stem parallel to fluid flow is incorporated. Although apparently not as extensive a problem as with gate valves, testing of globe valves by EPRI and U.S. utilities has revealed thrust requirements greater than predicted by the vendors for some globe valves. EPRI has indicated that the cause of the higher thrust requirements may be related to the flow area that should be assumed in the thrust equation. Recently, a U.S. globe valve vendor notified the USNRC that, based on testing by EPRI, the thrust predicted for operating its globe valves during design of their motor actuators might be insufficient.

Assumption of Stem Friction Coefficient for Gate and Globe Valves

For a gate or globe valve, the torque required from the motor actuator to open and close the valve is predicted from the thrust requirement multiplied by a stem factor (which is determined from the dimensions of the valve stem and its thread, and an assumed stem friction coefficient). The torque requirement is then used to size the motor actuator. Also, MOVs in U.S. nuclear power plants are not controlled directly by thrust measurement, but by setting torque switches or limit switches. Therefore, an improper assumption for the stem friction coefficient can cause an underestimation of the torque requirement and an inability of the motor actuator to open or close the valve. Stem friction coefficients assumed in the initial design of MOVs appear, for the most part, to have been adequate; however, some U.S. utilities have found limited instances of higher than assumed stem friction coefficients during MOV testing.

Determination of Torque Requirements to Operate Butterfly Valves

Motor actuators for butterfly valves rotate the valve disk to allow fluid flow. A weakness in the design and qualification of butterfly MOVs has led to the underestimation of the torque required to open or close some butterfly valves. From operating events, tests and analyses, U.S. utilities have found some motor actuators to be inadequately sized or set to open or close their butterfly valves.

Assumption of Design-Basis Differential Pressure

As indicated earlier, the differential pressure across the valve is a significant factor in determining the torque and thrust required to operate the valve. Some U.S. utilities have discovered underestimation of torque and thrust requirements as a result of improper assumptions for the differential pressure across the valve under design-basis conditions. The underestimation of torque and thrust requirements might have resulted in some MOVs being sized or set inadequately to perform their safety function.

(2) Overestimation of Motor Actuator Output

Design-Basis Minimum Voltage

The torque delivered by a motor actuator depends on the motor torque-size, motor-actuator gear ratio and efficiency, voltage present at the motor, and other factors. Some U.S. utilities have found the voltage present at particular safety-related MOVs to be less than assumed in the design calculations of the torque and thrust that could be delivered by the MOVs under design-basis conditions. With insufficient voltage, an

MOV could be incapable of performing its safety function under design-basis conditions. Sufficient motor voltage is also important for ensuring the capability of motor-start contactors to start the MOV motor.

Ambient Temperature Effects on Motor Torque Output

The ambient temperature surrounding the MOV must be considered in the design and qualification of the MOV. In 1993, an actuator manufacturer notified the USNRC that, under high ambient temperature conditions, the torque delivered by ac motors used to operate its actuators could be less than assumed during design of the MOV. With reduced torque output as a result of high ambient temperature conditions, a motor actuator might be incapable of opening or closing its valve to perform a safety function.

Load Sensitive Behavior

In the past few years, research and valve testing have revealed that the thrust delivered by the motor actuator at a specific torque output can be lower when the MOV is operated under differential pressure and flow conditions than when operated without fluid pressure or flow. This load-sensitive behavior (sometimes referred to as rate-of-loading) of motor actuators might be caused by an increase in the stem friction coefficient under loaded conditions. Although not completely understood, load-sensitive behavior of motor actuators has been observed in many MOV tests. The reduced thrust output resulting from load-sensitive behavior might cause a motor actuator to deliver insufficient thrust to close its valve when the torque switch stops the motor, or if the torque-capability of the motor actuator is reached.

(3) Structural Capability of MOV Components

The weakness in the design and qualification of MOVs has included inadequate evaluation of the capability of individual components to withstand the thrust and torque exerted upon them. For example, U.S. utilities have discovered cracks in valve yokes that might have prevented motor actuators from operating their valves. In one instance, a manual valve had been converted to a motor-operated valve without appropriate consideration of the additional stress on the valve yoke.

(4) Potential Pressure Locking and Thermal Binding of Gate Valves

U.S. utilities have not always adequately addressed the increased thrust requirements for gate valves that might result from pressure locking or thermal binding of gate valves. Pressure locking can occur in a gate valve with two half-disks when the pressure inside the valve bonnet is greater than the pressure upstream and downstream of the valve. Under this condition, thrust is required to overcome differential pressure across both half-disks instead of the typical design assumption of one disk. Thermal binding between the valve body and disk may occur when differences in material properties cause mechanical interference following temperature changes. Motor actuators might not have sufficient capability to overcome the increased thrust requirements resulting from pressure locking or thermal binding and can lead to the inability of the associated safety train or system to perform its safety function. Some MOVs have failed to operate because of pressure locking or thermal binding in U.S. nuclear power plants.

Maintenance and Training

Operating experience has revealed weaknesses in procedures for MOV maintenance and training of MOV personnel. These weaknesses have resulted in various problems with the performance of MOVs at U.S. nuclear power plants. Particular significant examples include: (1) stem and stem nut failure of MOVs in both trains of the low-pressure coolant-injection system in a U.S. nuclear power plant could have caused this system to be unable to perform its safety function; (2) loose and cracked motor pinion keys in MOVs at several U.S. nuclear power plants because of inadequate staking or stress that exceeded the material strength prevented the motor from driving the actuator; (3) incorrectly set limit switches causing MOVs not to operate properly; (4) disengaged valve disks from butterfly valve actuators prevented proper valve operation; and (5) improper replacement of manual declutch levers resulting in failure of MOVs to operate.

Root Cause and Trending of MOV Problems

Operating experience has revealed weaknesses in the evaluation of the cause of MOV problems, and the trending of MOV problems at U.S. nuclear power plants. In a few cases, U.S. nuclear plants have remained shutdown for extended periods while the root cause of numerous MOV problems was determined. The extent of MOV problems might have been identified earlier at those nuclear plants with an adequate program to trend MOV problems.

Many MOV problems at U.S. nuclear power plants have been revealed as a result of the comprehensive programs of MOV testing and analyses developed by U.S. nuclear utilities in response to GL 89-10. These MOV problems were corrected by the utilities when identified. The USNRC staff believes that the number of MOV problems, and operating events caused by those problems, are being reduced by the response to GL 89-10, and will significantly decrease as U.S. nuclear utilities complete their GL 89-10 programs.

ACTIVITIES OF THE U.S. NUCLEAR REGULATORY COMMISSION TO IMPROVE THE PERFORMANCE OF MOTOR-OPERATED VALVES

The USNRC regulations require that components that are important to the safe operation of a nuclear power plant be treated in a manner that provides assurance of their performance. Appendices A, "General Design Criteria for Nuclear Power Plants," and B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50 provide a broad-based framework of requirements for the design, testing, operation and maintenance of components, including motor-operated valves (MOVs), that are important to the safe operation of the plant. With respect to inservice testing of MOVs, 10 CFR 50.55a(g) requires compliance with Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," of the ASME Code for MOVs within the scope of that code. The recent revision of the USNRC regulations on maintenance activities in 10 CFR 50.65 also provides requirements that address the performance of certain MOVs in nuclear power plants.

In response to continuing MOV problems, the USNRC staff prepared NUREG-1352 (June 1990), "Action Plans for Motor-Operated Valves and Check Valves," describing actions to organize the activities aimed at resolving the concerns about MOV (and check valve) performance. Among those actions are evaluation of the current regulatory requirements and guidance applicable to MOVs, development of guidance for and coordination of USNRC inspections, completion of USNRC MOV research programs, implementation of the research results, and providing MOV information to the nuclear industry.

A significant task of the MOV action plan is the USNRC staff's review of the implementation of Generic Letter (GL) 89-10 (June 28, 1989), "Safety-Related Motor-Operated Valve Testing and Surveillance," and its supplements at U.S. nuclear power plants. In GL 89-10, the USNRC staff asked U.S. utilities to help ensure the capability of MOVs in safety-related systems by reviewing MOV design bases, verifying MOV switch settings initially and periodically, testing MOVs under design-basis conditions where practicable, improving evaluations of MOV failures and necessary corrective action, and looking for trends in MOV problems. The USNRC staff requested that utilities complete the GL 89-10 program within three refueling outages or five years from the issuance of the generic letter, whichever is later.

The USNRC staff issued Supplement 1 to GL 89-10 on June 13, 1990, to give utilities detailed information on the results of public workshops held in 1989 to discuss the generic letter.

On August 3, 1990, the USNRC staff issued Supplement 2 to GL 89-10 to allow utilities additional time to review and to incorporate the information provided in Supplement 1 into their programs in response to the generic letter.

Tests performed by the Idaho National Engineering Laboratory (INEL) as part of a program by the USNRC Office of Nuclear Regulatory Research reinforced concerns regarding the capability of MOVs to perform their design-basis functions. At a public meeting on April 18, 1990, the INEL researchers discussed the results of the USNRC-sponsored MOV tests that revealed that more thrust was required to operate the tested valves under high differential-pressure and flow conditions than had been predicted using standard U.S. industry calculations. These test results were directly applicable to the safety function of MOVs used for containment isolation in the high-pressure coolant-injection (HPCI), reactor core isolation cooling (RCIC), and reactor water cleanup (RWCU) systems of boiling-water reactor (BWR) plants. Following a summary review of the capability of MOVs in those systems and discussions with the BWR Owners Group, the USNRC staff issued Supplement 3 to GL 89-10 on October 25, 1990, which asked utilities of BWR plants to perform a plant-specific safety analysis and to evaluate the capability of MOVs used for containment isolation in the HPCI, RCIC, and RWCU systems (and in isolation condenser lines), as applicable. Also, the USNRC staff asked all utilities to consider the results of the MOV tests in their GL 89-10 programs. BWR utilities have completed their evaluations of the MOVs within the scope of Supplement 3 to GL 89-10, and have modified or adjusted many MOVs to provide assurance of their capability to perform their design-basis function.

On February 12, 1992, the USNRC staff issued Supplement 4 to GL 89-10 and stated that BWR utilities need not address inadvertent MOV operation as part of their GL 89-10 programs based on an USNRC-sponsored study of core-melt probability by the Brookhaven National Laboratory (BNL). Nevertheless, the USNRC staff stated its belief that consideration of inadvertent MOV operation benefited safety.

As an integral part of their GL 89-10 programs, most U.S. utilities are relying on MOV diagnostic equipment to obtain information on the thrust required to open or close the valve as well as the thrust delivered by the motor actuator. The various types of MOV diagnostic equipment estimate stem thrust using different parameters, such as spring pack displacement or strain in the stem, mounting bolts, or yoke. Because some utilities make decisions regarding the operability of safety-related MOVs on the basis of thrust readings of diagnostic equipment, the use of MOV diagnostic equipment can have a significant effect on the safe operation of a nuclear power plant.

During the implementation of GL 89-10, the USNRC staff became aware of information that raised a generic concern regarding the reliability of the data provided by MOV diagnostic equipment. For example, the MOV Users Group (MUG) of nuclear utilities on February 3, 1992, released "Final Report - MUG Validation Testing as Performed at Idaho National Engineering Laboratories" (Volume 1), which indicated that MOV diagnostic equipment relying on spring pack displacement to estimate stem thrust was not as accurate as its vendors believed. In addition, on October 2, 1992, a manufacturer of MOV diagnostic equipment that derives thrust from yoke strain calibrated to stem thrust using measured diametral strain of the valve stem and nominal engineering material properties notified the USNRC that two new factors that could affect the thrust values obtained with its equipment involved (1) the possible use of improper stem material constants and (2) the failure to account for a torque effect when the equipment is calibrated to strain in the threaded portion of a valve stem.

The manufacturers of the MOV diagnostic equipment have evaluated the information revealing the increased inaccuracy of their equipment and have provided guidance to the utilities for their use in correcting the data obtained from their equipment. Further, the manufacturers are developing improved equipment and software to provide more accurate thrust and torque measurements.

On June 28, 1993, the USNRC issued Supplement 5 to GL 89-10 which asked U.S. nuclear utilities to reexamine their MOV programs and to identify measures taken or planned to account for uncertainties in MOV diagnostic equipment. U.S. nuclear utilities were required to notify the USNRC staff of their diagnostic equipment and to report their plans to address the information on the accuracy of MOV diagnostic equipment. The USNRC staff has reviewed the utility responses to Supplement 5 to GL 89-10 and sent replies to the individual utilities. USNRC inspections will address specific aspects of utilities' actions to address MOV diagnostic equipment inaccuracy.

On March 8, 1994, the USNRC issued Supplement 6 to GL 89-10 to transmit information to U.S. nuclear utilities on the schedule of GL 89-10 programs and grouping of MOVs to share test data, and to respond to questions raised at the public workshop held in February 1993 to discuss the generic letter. In Supplement 6 to GL 89-10, the USNRC staff requests that, if a nuclear utility intends to extend its schedule for completing the GL 89-10 program, the utility submit specific information on the capability of those MOVs whose test schedule will be extended. In Supplement 6, the USNRC staff states that U.S. utilities are expected to have their safety-related MOVs set up using the best-available MOV test data by the original completion date accepted by the USNRC, even if their GL 89-10 test schedule is extended.

The USNRC staff contracted with BNL to perform a core-melt probability study to address valve mispositioning in pressurized-water reactor (PWR) nuclear power plants. This study was similar to the BNL study of valve mispositioning in BWR plants. The USNRC staff is preparing proposed Supplement 7 to GL 89-10 to discuss the USNRC staff's position on the need for considering inadvertent MOV operation in PWR nuclear power plants as part of the GL 89-10 program.

In March 1993, the USNRC issued NUREG-1275, Volume 9, "Pressure Locking and Thermal Binding of Gate Valves," which lists the history of pressure-locking and thermal-binding events, describes the phenomena, discusses the consequences of locking or binding on valve functionality, summarizes preventive measures, and assesses the safety significance of the phenomena. Despite several generic industry communications providing guidance for identifying susceptible valves and performing appropriate preventive and corrective measures, pressure-locking and thermal-binding events continue to occur and, also, might occur when an MOV is needed to perform its safety function at a U.S. nuclear power plant. Therefore, the USNRC staff is preparing a proposed generic letter to request that U.S. nuclear utilities identify power-operated gate valves susceptible to pressure locking and thermal binding and implement corrective action for those valves within a specific time schedule.

The USNRC staff issued Temporary Instruction (TI) 2515/109 (January 14, 1991), "Inspection Requirements for Generic Letter 89-10, Safety-Related Motor-

Operated Valve Testing and Surveillance," to provide guidance for its inspectors to evaluate programs developed at U.S. nuclear power plants in response to GL 89-10. Part 1 of the TI contains guidance for performing inspections to review programs developed in response to GL 89-10. Part 2 of the TI contains guidance for performing inspections to determine the adequacy of the implementation of GL 89-10 programs. The inspections under Part 2 of the TI focus on a sample of specific MOVs to determine the adequate implementation of the overall GL 89-10 program at a nuclear power plant. On June 14, 1993, the USNRC staff issued Revision 1 to the TI to update its guidance based on inspections of GL 89-10 programs conducted to date.

In January 1991, the USNRC staff began inspecting the programs developed by U.S. nuclear utilities in response to GL 89-10. The USNRC staff has performed inspections to review the development of MOV programs in response to GL 89-10 at each U.S. nuclear power plant. In Information Notice 92-17 (February 26, 1992), the USNRC staff summarized the findings of the GL 89-10 inspections conducted up to that time. In 1993, the USNRC staff initiated inspections of the implementation of GL 89-10 programs and has conducted more than thirty inspections to date.

The USNRC inspections of GL 89-10 programs show, for the most part, that U.S. utilities are establishing the scope of their GL 89-10 programs consistent with the recommendations of the generic letter.

With respect to the recommendations of GL 89-10 regarding design-basis reviews of MOVs, U.S. utilities have been reviewing plant documentation (such as the final safety analysis report and technical specifications) to determine the design-basis conditions for safety-related MOVs. Some utilities had focused on differential pressure and had not adequately addressed other design-basis parameters (such as flow, fluid temperature, ambient temperature, and seismic/dynamic effects). Although differential pressure is the primary design-basis parameter used to predict thrust requirements in the present industry equations, other design-basis parameters also need to be considered to ensure that the test results demonstrate that the MOV will operate under design-basis conditions. Many utilities found the need to update their degraded voltage studies to ensure that the design-basis voltage is determined at each MOV. A significant concern from the inspections has been the weaknesses in the evaluation of the potential for pressure locking and thermal binding of gate valves.

With respect to the recommendations of GL 89-10 regarding MOV sizing and switch settings, U.S. utilities use various methods to determine the proper size of MOVs and their appropriate switch settings. Some utilities have increased the valve factors assumed in the industry equation (used to predict the thrust required to operate the valves) to reflect industry and plant-specific experience. However, a few utilities continued to use previous guidance provided by valve vendors in estimating thrust requirements which have been or may be determined to be inadequate during design-basis MOV tests. The USNRC inspectors found that the validation of assumptions for the following parameters in the MOV calculations for sizing and switch settings need improvement: valve friction coefficient (or valve factor), stem friction coefficient, and load-sensitive behavior where the output of the actuator may be less under dynamic conditions than under zero differential pressure and flow (static) conditions.

With respect to the recommendations of GL 89-10 regarding MOV testing, U.S. utilities have found during differential-pressure and flow testing of MOVs that many gate valves (and some globe and butterfly valves) require more torque or thrust to operate than was predicted by the valve vendors.

Among the most significant inspection concerns regarding MOV testing have been (1) the lack of progress in completing dynamic testing, (2) weaknesses in procedures and acceptance criteria for the tests to evaluate the capability of the MOV to perform its safety function under design-basis conditions, and (3) feedback of the test results into the methodology used by the utility in predicting the thrust and torque requirements for other MOVs. Among other utility activities found to need improvement with respect to testing are (1) justification for grouping of valves to share test information in order to minimize the number of MOVs tested, (2) verification of methods to extrapolate data from test conditions to design-basis conditions, (3) evaluation of anomalies in MOV diagnostic equipment signature traces, and (4) involvement of quality assurance personnel in verifying the accuracy of test data and analyses.

The USNRC regulations and plant-specific technical specifications establish requirements for actions and reporting by U.S. nuclear utilities when safety-related equipment is determined to be, or has been, unable to perform its safety functions. When a problem is found with one of its safety-related MOVs, the U.S. utility must evaluate the impact of that problem on the capability of the MOV to perform its safety function. GL 91-18, "Information to Licensees Regarding Two NRC Inspection Manual Sections on Resolution of Degraded and Nonconforming Conditions and Operability," contains information on guidance provided to USNRC inspectors in the area of operability of safety-related components. This information is also useful to U.S. utilities in evaluating the operability of an MOV found to have a performance problem.

With respect to the recommendations of GL 89-10 regarding periodic verification of MOV capability, many U.S. utilities have stated that they will attempt to use tests of MOVs with diagnostic equipment under static conditions to demonstrate the adequacy of torque switch settings and the continued capability of MOVs to perform their safety functions under design-basis conditions. No utility, as yet, has provided justification for applying the results of tests conducted under static conditions to demonstrate design-basis capability. With respect to postmaintenance testing, many utilities are improving their methods to demonstrate continued capability of MOVs to perform their safety functions under design-basis conditions following maintenance.

With respect to the recommendations of GL 89-10 regarding MOV failures, corrective action, and trending, the USNRC inspectors found weaknesses in some U.S. utilities' response to MOV failures and deficiencies. Some utilities had not analyzed the root cause of MOV problems thoroughly. Most utilities are attempting to improve the trending of MOV problems, but little progress has been made in implementing those trending programs.

The USNRC staff found that the U.S. utilities have significantly improved their training programs for MOV maintenance and diagnostic testing.

During the GL 89-10 inspections, the USNRC staff found that some U.S. utilities have not made adequate progress toward resolving the MOV issue for their facilities within the recommended schedule of GL 89-10. The USNRC staff has accepted limited extensions of the GL 89-10 schedule for particular utilities where justification has been provided.

The USNRC staff has identified areas requiring further research and analysis to assist the staff in evaluating GL 89-10 programs at U.S. nuclear power plants. For example, NUREG/CR-5720, "Motor-Operated Valve Research Update," provides important information on several areas of MOV behavior under high-load conditions. Additional ongoing research is improving the understanding of MOV performance in support of regulatory activities.

The USNRC staff continues to provide information to the nuclear industry through meetings to assist utilities in resolving MOV issues at their particular facilities. For example, the USNRC staff discusses MOV issues at regulatory information conferences, and presents the status of USNRC activities and current concerns at meetings of the MOV Users Group (MUG) of nuclear utilities. In addition, the USNRC staff and the ASME are sponsoring a symposium to address pumps and valves (including MOVs) to be held in Washington, D.C., in July, 1994.

The USNRC staff issues information notices to alert U.S. nuclear utilities to important aspects of MOV performance. For example, the USNRC issued Information Notice (IN) 92-23, "Results of Validation Testing of Motor-Operated Valve Diagnostic Equipment"; IN 93-74, "High Temperatures Reduce Limitorque AC Motor Operator Torque"; IN 93-88, "Status of Motor-Operated Valve Performance Prediction Program by the Electric Power Research Institute"; IN 93-97, "Failures of Yokes Installed on Walworth Gate and Globe Valves"; IN 93-98, "Motor Brakes on Valve Actuator Motors"; and IN 94-10, "Failure of Motor-Operated Valve Electric Power Train Due to Sheared or Dislodged Motor Pinion Gear Key."

The USNRC staff meets regularly with representatives of the Nuclear Management and Resources Council (NUMARC) and the Electric Power Research Institute (EPRI) to discuss the EPRI MOV Performance Prediction Program. EPRI tested gate, globe, and butterfly valves, and analyzed the results of additional valve tests, as part of its development of a methodology to predict the performance of MOVs. NUMARC has submitted the EPRI MOV Performance Prediction Program as a topical report for USNRC staff review.

The USNRC staff participates on the committees responsible for improving U.S. codes and standards for MOV performance. For example, the USNRC staff participated in the preparation of ASME OM-8, "Startup and Periodic Performance Testing of Electric Motor Operators on Valve Assemblies in Nuclear Power Plants." The USNRC staff is also participating in the revision of ASME Standard QME, "Qualification of Mechanical Equipment Used in Nuclear Power Plants," to improve the functional qualification requirements for valve assemblies.

The USNRC staff recognizes the significant amount of utility resources that has been required to implement MOV programs in response to GL 89-10. However, as discussed earlier in this presentation, the MOV programs established in response to GL 89-10 have led to the identification and resolution of numerous weaknesses in the design, qualification, and maintenance of MOVs, and the corrective action and trending of MOV problems. Through its inspection program, the USNRC staff has found that significant progress has been made by the U.S. nuclear utilities in the design, qualification, and maintenance of MOVs. Therefore, the USNRC staff believes that MOV problems will decrease and that MOV performance will continue to improve in the future.

As the nuclear industry and its regulators work toward resolution of the MOV issue, the USNRC staff plans (1) to continue to inspect MOV programs at U.S. nuclear power plants, (2) to complete the preparation of proposed Supplement 7 to GL 89-10 on the need to consider inadvertent operation of MOVs in PWR nuclear power plants under the GL 89-10 program, (3) to prepare a proposed generic letter on pressure locking and thermal binding of gate valves, (4) to review the EPRI MOV Performance Prediction Program Topical Report, (5) to continue to meet with, and provide information to, U.S. nuclear utilities regarding MOV performance, and (6) to continue international cooperative efforts to improve MOV performance.