UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555-0001

August 21, 1996

NRC INFORMATION NOTICE 96-48: MOTOR-OPERATED VALVE PERFORMANCE ISSUES

Addressees

All holders of operating licenses or construction permits for nuclear power reactors.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to alert addressees to (1) lessons learned from the Electric Power Research Institute (EPRI) Motor-Operated Valve (MOV) Performance Prediction Program, (2) performance problems with MOV key failures described in a recent NRC Office for Analysis and Evaluation of Operational Data (AEOD) study, and (3) the potential for torque output from MOV actuators to be less than predicted by Limitorque Corporation. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

Background

In the 1980s, continuing problems with the performance of MOVs at nuclear power plants raised concerns regarding MOV design, testing, and maintenance. In response to these problems, both the nuclear industry and NRC initiated efforts to improve the performance of MOVs at nuclear plants. In 1989, the NRC staff issued Generic Letter (GL) 89-10, "Safety-Related Motor-Operated Valve Testing and Surveillance," requesting that nuclear power plant licensees and construction permit holders verify the design-basis capability of their safety-related MOVs. In response to GL 89-10, the nuclear industry has studied the performance of MOVs through testing and analyses. As a result of these activities, some weaknesses in the design and manufacture of MOVs were discovered through evaluation of the performance history of MOVs. In this information notice, the staff discusses three issues involving MOV performance that have been identified.

Description of Circumstances

1. Lessons Learned from EPRI MOV Performance Prediction Program

As part of the industry effort regarding the MOV issue, EPRI initiated an MOV Performance Prediction Program to develop a methodology to be used by licensees in demonstrating the design-basis capability of MOVs when valve-specific design-basis test data are not available. The program included

development of improved methods for prediction or evaluation of system flow parameters; gate, globe, and butterfly valve performance; and motor actuator rate-of-loading effects (load-sensitive behavior). Further, EPRI performed testing to provide information for refining the gate valve model and rate-of-loading methods and conducted numerous MOV tests to provide data for model and method development and validation, including flow loop testing, parametric flow loop testing of butterfly valve disk designs, and in situ MOV testing.

In November 1994, the Nuclear Energy Institute (NEI) submitted the proprietary EPRI Topical Report TR-103237, "EPRI MOV Performance Prediction Program - Topical Report," for review by the NRC staff. EPRI prepared 25 additional reports to support the topical report. On March 15, 1996, the NRC staff issued a Safety Evaluation (SE) documenting the staff review of the topical report. With the conditions and limitations described in the SE, the staff stated that the EPRI program provides an acceptable methodology to predict the thrust or torque required to operate gate, globe, and butterfly valves within the scope of the EPRI program and to bound the effects of load-sensitive behavior on motor actuator thrust output.

In a letter dated September 27, 1995, NEI forwarded a summary of important contributions and findings resulting from the EPRI MOV Performance Prediction Program. As described in an enclosure to the NEI letter, important findings (or confirmatory information) from the EPRI MOV program include the following:

a. The traditional methods for predicting gate valve performance might be nonconservative for many applications because of incomplete equations, design features, manufacturing controls, and wide-ranging friction coefficients.

b. The edge radii on disk seats and guide slots are critical to gate valve performance and predictability.

c. Stellite friction coefficients increase with differential-pressure valve strokes in cold water to a plateau level, stabilize quickly in hot water, and decrease as differential pressure increases.

d. Gate valves with carbon steel guides and disk guide slots with tight clearances might fail to close under blowdown conditions.

e. Many existing gate valve manufacturing and design processes and controls, and plant maintenance practices, might contribute to poor valve performance.

f. Traditional methods for predicting globe valve performance for incompressible flow conditions are nonconservative for globe valves in which differential pressure acts across the plug guide.

g. Globe valve thrust requirements for some designs can be excessive under compressible flow and blowdown conditions because of the potential for plug-side loading.

h. Rate-of-loading effects (load-sensitive behavior) can reduce the static thrust output by up to 30 percent under dynamic conditions.

i. Hydrodynamic torque coefficients used by some butterfly valve manufacturers might be nonconservative for certain applications, with valves located near piping elbows especially vulnerable.

j. Butterfly valve seats should be periodically replaced to avoid hardening or degradation.

In addition to these reported important findings, EPRI confirmed that thrust requirements to unwedge a gate valve can be higher under dynamic conditions than under static conditions.

2. MOV Key Failures

On March 29, 1996, AEOD issued report AEOD/E96-01, entitled, "Engineering Evaluation - Motor-Operated Valve Key Failures," on the continuing occurrence of problems with keys in MOVs at nuclear power plants. A significant number of MOV key failures have been identified that involved (a) anti-rotation keys, (b) valve operator-to-valve stem keys, and (c) motor pinion gear keys. A total of 73 reports were written involving MOV key failures between January 1990 through September 1995. Many of these key failures were not detected during surveillance tests but were detected on demand, during valve operations, or during maintenance activities and had existed for some time before they were discovered. A number of key failures were discovered during maintenance activities even though the valves had been operated satisfactorily and passed all previous surveillance tests.

3. Limitorque Motor Actuator Performance

In 1977, Limitorque Corporation established guidelines (referred to as the SEL documents) for sizing ac-powered motor actuators used in MOVs. Those guidelines predicted the motor actuator output torque as a product of the nominal motor-rated start torque, pullout efficiency, application factor (typically 0.9), overall actuator gear ratio, and a degraded voltage factor. Over the past few years, Limitorque has accepted the use of run efficiency for closing valves powered by ac-powered motor actuators. Limitorque has also stated that licensees may eliminate the application factor when voltage supplied to the motor is less than 90 percent of its rated voltage. (See Limitorque Technical Update 93-03 [Accession 9608120083].) Recent industry

and NRC-sponsored test information has raised questions regarding the accuracy of the Limitorque assumptions for actuator efficiency.

Discussion

1. Lessons Learned from the EPRI MOV Performance Prediction Program

As discussed in the staff SE on the EPRI topical report, the EPRI program provided important information on the design, testing, and maintenance of MOVs in nuclear power plants. Some of the EPRI information is applicable to gate, globe, and butterfly valves regardless of the type of actuator operating the valve. Examples of such information are given below:

Gate Valves

Almost all flow testing by licensees in response to GL 89-10 was conducted under pumped-flow conditions. Several gate valves tested by EPRI under blowdown conditions demonstrated unpredictable performance and internal damage. Extrapolation of test data from pumped-flow conditions to blowdown conditions may not be sufficient to ensure that a gate valve can operate under its design-basis conditions.

Valve aging conditions can influence gate valve performance. The thrust requirements to operate gate valves under normal flow conditions can increase with time and valve stroking.

Thrust requirements to unwedge gate valves under dynamic conditions may be greater than under static conditions.

Globe Valves

Limited testing by EPRI of globe valves under blowdown or high-temperature flow conditions suggested that higher thrust than typically predicted may be required to operate these valves.

Thrust requirements for globe valves are influenced by the area of the valve seat or guide, depending on the valve design.

The EPRI test database is not sufficient to justify modifying the Limitorque guidelines for sizing and setting globe valves to lower the typical valve factor of 1.1 assumed in the guidelines.

Butterfly Valves

Several areas of the EPRI Butterfly Valve Application Guide need improvement or correction. EPRI is currently revising the application guide and plans to include new information on flow and torque coefficients; system analysis techniques; treatment of bearing, packing, and hub-seal torque; upstream elbow modeling; and rated and survivable torque calculations.

2. MOV Key Failures

The MOV key failures may involve a common-cause failure that could render redundant trains of certain safety-related systems inoperable if they had remained undetected. The MOV key failures can be attributed to (a) installation and design deficiencies for anti-rotation keys, (b) loosening or slipping, wear or normal aging, excessive force or overtorque, and discrepancies in material or size for valve operator-to-valve stem keys, and (c) high-impact loads, improper materials, installation deficiency, wear or normal aging, and vibration for motor pinion gear keys.

The anti-rotation key failures involving installation deficiencies were generally associated with inadequate staking and securing of setscrews during installation of the keys. It appeared that the installation instructions provided by the vendors were not always included in licensee maintenance procedures.

Many motor pinion gear key failures involving an installation deficiency were due to failure to stake the keys following replacement of the motors or the pinion gears. Although licensees revised their MOV maintenance procedures to include restaking the pinion key or motor shaft as recommended by Limitorque Maintenance Update 89-1 (Accession 9608120068), many licensees did not investigate the potential problems of maintenance activities that were conducted before their procedure changes.

The motor pinion gear key failures attributable to high-impact loads or improper material appear to involve AISI (American Iron and Steel Institute) type 1018 keys in high-speed and high-inertia configurations. The replacement of 1018 keys with harder 4140 keys in some cases may lead to keyway deformation or damage, depending on impact loads and the shaft material. The situation may present a complex stress problem that is not completely considered in design and could produce a severe and complex stress concentration on the key, as well as the keyway. This situation could lead to cracking and failure of the shaft.

The potential for these key problems to render safety systems inoperable empasizes (a) the importance of plant maintenance programs in assuring that MOV keys are staked and secured as required, (b) the importance of plant MOV surveillance and maintenance activities in the early detection of key

degradation, and (c) the possibility of shaft cracking as a result of replacement of 1018 keys with harder material when the replacement will involve a relatively soft shaft and high impact loads.

3. Limitorque Motor Actuator Performance

The NRC staff conducted an inspection at Limitorque in May 1993 and reviewed the basis for its motor actuator sizing guidelines. As discussed in NRC Inspection Report 99900100/93-01, the staff found that the values for individual parameters assumed in the Limitorque sizing equation were not determined by testing but were founded primarily on engineering judgment. The lack of significant failure history of motor actuators when using the Limitorque sizing equation has been the primary basis for confidence in the equation. Licensee modifications of the parameters in the Limitorque sizing guidelines has the potential to influence performance.

Tests of MOVs under differential pressure and flow conditions performed by licensees in response to GL 89-10 have revealed that significantly more torque and thrust are required to open and close many gate valves than predicted by the valve vendors. This need for more torque than originally believed has led licensees to evaluate the Limitorque motor actuator sizing guidelines to determine whether more torque output is available from the motor actuators than was predicted by the guidelines. The Limitorque sizing guidelines have typically been assumed to underestimate the output torque capability of motor actuators. Therefore, some licensees eliminate the application factor from the output torque equation and use run efficiency for ac-powered MOVs in the closing direction. Further, some licensees have asserted that motor torque greater than the nominal start rating may be assumed in the sizing guidelines because motors typically deliver more torque than their rating before they stall.

In response to the questions surrounding the Limitorque sizing equation, the NRC Office of Nuclear Regulatory Research evaluated the performance of Limitorque motor actuators through testing at the Idaho National Engineering Laboratory (INEL). Preliminary results of the INEL tests suggest that (1) motor output is greater than the nominal rating for many motors, (2) the actual output efficiency may not reach "run" efficiency for some Limitorque actuators and may drop below "pullout" efficiency under high loads, (3) the torque loss under degraded voltage conditions can be more severe for some ac motors than the typically assumed square of the ratio of actual voltage to rated voltage, and (4) the torque loss under degraded voltage conditions can be more severe for some dc motors than the typically assumed linear ratio. Preliminary results of this testing are documented in NUREG/CR-6100, "Gate Valve and Motor-Operator Research Findings" (September 1995). INEL is preparing a report, NUREG/CR-6478, to document its recent findings in this area. This report is scheduled to be issued by the end of 1996.

At meetings of the Motor-Operated Valve Users' Group of nuclear power plant licensees in February and July 1995, Commonwealth Edison (ComEd) presented the results of its motor and actuator output testing program. The testing conducted by ComEd was more extensive than the NRC-sponsored testing and revealed similar results. Previously, in NUREG/CP-0137, "Proceedings of the Third NRC/ASME Symposium on Valve and Pump Testing" (July 1994), motor actuator testing by Texas Utilities raised questions regarding Limitorque motor actuator output. Texas Utilities also found lower output during in situ motor actuator testing compared to torque stand testing.

This information raises concerns regarding the basis for Limitorque acceptance of licensee assumptions that the torque output of its actuators is greater than predicted by the original Limitorque SEL guidelines. The NRC staff has been discussing with Limitorque the discrepancy between guidance relaxing the original motor actuator sizing criteria and the recent motor actuator test results. The manufacturer has stated that updated information for the industry on the sizing of its motor actuators is being developed.

Related Generic Communications

- NRC IN 81-08, "Repetitive Failures of Limitorque Operator SMB-4 Motor-to-Shaft Key," March 20, 1981 (Accession 8011040272).
- NRC IN 88-84, "Defective Motor Shaft Keys in Limitorque Motor Actuators," October 20, 1988 (Accession 8810140018).
- NRC GL 89-10, "Safety-Related Motor-Operated Valve Testing and Surveillance," June 28, 1989 (Accession 8906290082).
- NRC IN 90-37, "Sheared Pinion Gear-to-Shaft Keys in Limitorque Motor Actuators," May 24, 1990 (Accession 9005180095).
- NRC IN 90-40, "Results of NRC-Sponsored Testing of Motor-Operated Valves," June 5, 1990 (Accession 9005290270).
- NRC IN 93-42, "Failure of Anti-Rotation Keys in Motor-Operated Valves Manufactured by Velan," June 9, 1993 (Accession 9306030147).
- NRC IN 93-88, "Status of Motor-Operated Valve Performance Prediction Program by the Electric Power Research Institute," November 30, 1993 (Accession 93111904527).
- NRC IN 94-10, "Failures of Motor-Operated Valve Electric Power Train Due to Sheared or Dislodged Motor Pinion Gear Key," February 4, 1994 (Accession 9402010052).

- NRC IN 94-69, "Potential Inadequacies in the Prediction of Torque Requirements for and Torque Output of Motor-Operated Butterfly Valves," September 28, 1994 (Accession 9409210211).

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact one of the technical contacts listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

for Thomas T. Martin, Director
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

Technical contacts: Thomas G. Scarbrough, NRR
(301) 415-2794
Email: tgs@nrc.gov

Chuck Hsu, AEOD
(301) 415-6356
Email: cch1@nrc.gov

Michael T. Bugg, RIII
(630) 829-9500
Email: mtb@nrc.gov

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96-46	Zinc Plating of Hardened Metal Parts and Removal of Protective Coatings in Refurbished Circuit Breakers	08/12/96	All holders of OLs or CPs for nuclear power reactors
96-45	Potential Common-Mode Post-Accident Failure of Containment Coolers	8/12/96	All holders of OLs or CPs for nuclear power reactors
96-44	Failure of Reactor Trip Breaker from Cracking of Phenolic Material in secondary contact assembly	8/05/96	All holders of OLs or CPs for nuclear power reactors
96-43	Failures of General Electric Magne-Blast Circuit Breakers	08/02/96	All holders of OLs or CPs for nuclear power reactors
96-42	Unexpected Opening of Multiple Safety Relief Valves	08/05/96	All holders of OLs or CPs for nuclear power reactors
96-41	Effects of a Decrease in Feedwater Temperature on Nuclear Instrumentation	07/26/96	All holders of OLs or CPs for pressurized water reactors
96-40	Deficiencies in Material Dedication and Procurement Practices and in Audits of Vendors	07/25/96	All holders of OLs or CPs for nuclear power reactors

OL = Operating License
CP = Construction Permit

- NRC IN 94-69, "Potential Inadequacies in the Prediction of Torque Requirements for and Torque Output of Motor-Operated Butterfly Valves," September 28, 1994 (Accession 9409210211).

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Original signed by Brian K. Grimes

for Thomas T. Martin, Director
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

Technical contacts: Thomas G. Scarbrough, NRR
(301) 415-2794
Email: tgs@nrc.gov

Chuck Hsu, AEOD
(301) 415-6356
Email: cch1@nrc.gov

Michael T. Bugg, RIII
(630) 829-9500
Email: mtb@nrc.gov

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Brian K. Grimes, Acting Director
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

Technical contacts: Thomas G. Scarbrough, NRR
(301) 415-2794
Internet:tgs@nrc.gov

Chuck Hsu, AEOD
(301) 415-6356
Internet:cch1@nrc.gov

Michael T. Bugg, NRR
(630) 829-9500
Internet:mtb@nrc.gov

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- NRC IN 94-69, "Potential Inadequacies in the Prediction of Torque Requirements for and Torque Output of Motor-Operated Butterfly Valves," September 28, 1994.

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Brian K. Grimes, Acting Director
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

Technical contacts: Thomas G. Scarbrough, NRR
(301) 415-2794
Internet:tgs@nrc.gov

Michael T. Bugg, NRR
(301) 415-3303
Internet:mxb5@nrc.gov

Chuck Hsu, AEOD
(301) 415-6356
Internet:cchl@nrc.gov

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Chuck Hsu, AEOD

(301) 415-6356

Internet:cchl@nrc.gov

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