IN SITU TESTING OF MOTOR-OPERATED VALVES IN NUCLEAR POWER PLANTS

ASME/NRC Symposium on
Inservice Testing of Pumps and Valves
Washington, D.C.
August 1-3, 1989

Owen O. Rothberg, Senior Task Manager
Engineering Issues Branch
Division of Safety Issue Resolution
Office of Nuclear Regulatory Research
U. S. Nuclear Regulatory Commission
Washington, DC 20555

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ABSTRACT

This paper presents a perspective of the status of in situ testing of motor operated valves in nuclear power plants. The objectives of in situ testing are discussed. A short history of in situ testing of motor-operated valves in nuclear plant applications is offered. Recent developments regarding in situ testing are discussed followed by a perspective on needed research and development.

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Owen O. Rothberg[1]

Motor-operated valve (MOV) failures and the subsequent consequences have been concerns of the Nuclear Regulatory Commission and its staff for some time. Reports, Bulletins, Circulars, and Notices dating at least as far back as 1972 document failures and resulting NRC recommendations to the nuclear industry. The critical problem is that MOVs have been experiencing high failure rates when called upon to operate against pressure or flow. The major root-causes include:

1. Defective parts or sub-components.
2. Mis-adjustment of switches or components.
3. Poor coordination, on a life cycle basis, of design, installation, maintenance, and testing.
4. Vague maintenance, test, and failure analysis procedures.
5. Ignorance of the design basis parameters that control MOV size and adjustment.

Motor-operated valves are to be found in most fluid systems of every commercial nuclear power plant. The vast majority of MOV operators in the United States are made by Limitorque Corporation of Lynchberg, Virginia. Most of the

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1 Senior Task Manager, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission.

remainder are made by Rotork Controls Incorporated of Rochester, New York. In most cases, identical MOVs are installed in the parallel trains of safety systems. Where two MOVs are installed in a train of a particular safety system to act as two valves in series they are usually identical. MOVs in parallel trains are usually served by identical power and control systems and have similar operating environments. These MOVs are serviced by the same personnel and procedures for each particular plant. Therefore, MOVs are especially subject to generic and common mode problems. Since the reliable positioning of valves in a nuclear power plant is critical to the safe and economical operation of the plant, generic MOV problems are a serious concern.

The MOV operators in nuclear plants are close adaptations of a commercial design originally developed in the late 1930s. The design has evolved, but the basic concept of a torque-limited motorized gear box remains. The equipment design has not changed radically over the years. Several problems arose in the application of the operator design to nuclear power plants, some of which were not recognized for some time thereafter. Problems that are inconvenient in the commercial field are intolerable in nuclear power plants. For example, spring pack relaxation has only recently been recognized as a significant problem in the industry. Improperly loaded spring packs can disable an operator or cause damage to a valve.

MOVs are subject to loads and stresses from the control systems and power systems that serve them, as well as from the fluid systems in which they serve. MOVs are subject to partial damage or degradation that will leave them operable for normal or no-load situations, but may cause failure at design basis demands.

MOVs are somewhat unique as a class of components, because they exist at a junction of several systems and other components that must all work in order for the MOVs to function properly and without damage. There are a number of effects that can operate either individually or synergistically and that can prevent an MOV from functioning, either partially or fully.

In situ testing is only one aspect of a comprehensive program to assure the operability of MOVs under all required conditions. The role of in situ testing of MOVs is burdened by several factors. First, the testing that can be done in a nuclear plant is limited by safety and plant operational considerations. Second, there is an implicit assumption, justified or not, that a particular component that is in place has been properly designed, fabricated, and installed.

In situ testing may indicate that a MOV is deteriorated or inoperable, but may not be able to provide all of the information needed to verify design basis operability. If the assumption of design basis operability is to be validated by in situ testing, then appropriate methods must be available. The methods may be somewhat different than those used for the detection of degradations or other anomalies. Thus, the in situ test methods should provide plant operators with techniques that will verify that each MOV has the ability to meet design basis requirements and allow diagnosis of anomalies as well. Such in situ testing may not be possible, depending on a number of considerations, some of which are discussed below.

In spite of these limitations, the NRC staff has focused attention on in situ testing primarily because virtually all of the components are in place and operational. Initially, the focus on in situ testing developed when it was recognized that the then existing MOV operability test was inadequate and would have to be modified.

The assumption was made, and still remains to be completely proven, that in situ testing can be used as the primary tool to maintain assurance of design basis operability. This assumption was bolstered by the emerging signature analysis techniques that made it possible to diagnose misadjustments, internal damage, or wear without extensive disassembly. The assumption was weakened, however, by results of recent full scale blowdown tests that were recently conducted under NRC sponsorship. The blowdown test results indicate that some of the extrapolation techniques that were used to predict MOV operability under design basis conditions may be unconservative. This may be due to the limitations of the existing diagnostic equipment as well as the variables associated with converting torque to thrust in the MOV operator. The design basis conditions modeled in the NRC blowdown tests were extremely severe. Signature analysis diagnostic techniques, as they evolve, may provide reliable extrapolations for less severe conditions. Certainly, signature analysis techniques are valuable to maintain normal service operability of MOVs.

A proper in situ test of an MOV should provide objective assurance of future operability under the required conditions. The ASME Code (Section XI) stroke-timing test, that is the test mandated by 10CFR50.55a(g), does not provide such assurance. That test indicates that a MOV may be capable of moving for a particular stroke, but provides little information about future operability. The Section XI stroke-timing test is almost always conducted under no-load (no flow or no differential pressure) conditions. Very little information about wear, misadjustment, excessive loadings, broken parts, deteriorated parts, etc., can be gathered from the stroke-timing test. In several instances MOVs have been left inoperable after a stroke-timing test and only found to be inoperable when called upon to function later. Such a situation is obviously unsatisfactory but, until the recent development of signature analysis techniques, there were few in situ testing options available. Disassembly is not a particularly attractive option because the degraded condition might not be detected and the MOV could be reassembled incorrectly.

The advent of a system to record and allow subsequent detailed analysis of pertinent MOV electrical and load parameters was truly innovative. The recognition that such data could provide insights into the misadjustments and deteriorated conditions that might occur in the working mechanisms of an MOV was a significant milestone.

Signature analysis diagnostic techniques provide unique insights into the on-line performance characteristics of an MOV and allow detection of wear, deterioration, or misadjustment without major disassembly of the equipment. The technology is developing rapidly. For example, on-line monitoring of MOV operating parameters is expected to become available in the near future.

The first signature analysis diagnostic system for MOVs became available just about the time of the Davis-Besse incident that prompted the development of Bulletin 85-03 by the NRC. That signature analysis system was originally intended to serve as a diagnostic tool for misadjustments or degraded conditions. The system was adapted by the vendor to accommodate the need to verify design basis operability by means of an in situ test that would allow extrapolation from the conditions that were encountered at the time of a particular test to design basis conditions. The basic assumption was that a linear relationship exists between thrust, torque, and motor load. A direct, if not perfectly linear, relationship has been verified to exist between motor load and operator torque. However, the relationship of torque and thrust, as applied to motor-operated gate valves, is not well understood. The usual practice in the industry has been to provide sufficient torque to envelope the losses that occur in the operator when it converts thrust to torque. It was discovered that the losses may not have been conservatively estimated in the usual engineering methodology. The various diagnostic system vendors are now developing strategies and hardware to measure thrust directly. There appear to be other factors such as the number of strokes and time between strokes that affect the thrust developed by a MOV. Again, it still remains to be shown that required thrust can be reliably extrapolated from a test conducted at less than design basis conditions (either in situ or prototype) because of the variability of the thrust developed by the operator. Factors such as valve stem design, valve trim material, number of strokes, time between strokes, temperature, wiring size, voltage, stem lubrication, and spring pack adjustment, among others are all pertinent. Load duration and intensity may be a major consideration. The individual and combined effects of such conditions are not completely understood.

A number of safety-related MOVs are ball, plug, or butterfly types and, as such, do not require the development of thrust in the valve stem in order to operate. These types of MOVs do not depend on the adjustment of a torque switch in order to achieve proper closure position of the valve. The majority of MOVs covered by Bulletin 85-03 are gate or globe valves. These MOVs usually develop thrust in the valve stem during operation. The extension of design basis operability verification to all safety-related MOVs is expected with the forthcoming publication of a NRC generic letter. This will place several additional MOV types under closer examination and it is expected that problems other than those that have been previously identified will be brought to our attention. These new problems may require additional or modified testing and evaluation schemes.

Alternatives and supplements to in situ testing include bench testing and prototype testing. Environmental qualification tests provide a data base of prototype test information. The environmental qualification tests do not seem to provide much information about testing of the complete MOV as an operational unit under design basis conditions or, for that matter, any conditions where the MOV is subject to pressure or flow loads. Other prototype tests include those performed by valve manufacturers under various ANSI standards, the EPRI/Marshall PORV block valve tests, a number of proprietary tests performed in the U.S. and other countries, and the tests conducted by the NRC as part of the resolution of Generic Issue 87, "Failure of HPCI Steam Line Without Isolation." All of these tests may provide some needed information, however the detailed information needed to predict design basis behavior of a particular MOV will probably not be conveniently available.

Bench tests refer to tests performed on an MOV that is removed from its installed location, or perhaps prior to installation. Such tests may be conducted by a valve vendor prior to shipment, or by a licensee prior to installation, or as part of a maintenance program. One recent innovation is the use of a device to simulate force and/or torque on a valve stem in order to adjust and load test the operator. Several such devices are now being used in the industry. Even if the loads do not duplicate design basis load conditions, the use of such tests provide some insights about the behavior of the operator under load. Use of such testing, in parallel with use of suitable diagnostic equipment, is far superior to the Section XI stroke-timing test.

The action statements in Bulletin 85-03 were focused primarily on switch setting adjustment. The implication was that switch adjustment was all that was necessary in order to assure design basis operability. The NRC generic letter that extends the scope of Bulletin 85-03 to all safety-related MOVs contains virtually the same emphasis in the first few action statements. However, it is now known (due in part to industry actions taken in response to Bulletin 85-03) that design basis operability is influenced by a number of other factors besides switch settings. Three of these items are of particular concern. First, MOVs may not be sized properly to meet design basis requirements. It became apparent to NRC that many licensees did not have complete design basis information on all safety-related MOVs. Second, the steps taken in an effort to assure design basis operability might compromise the operability of the MOV at conditions other than those considered for the design basis. For example, torque switch settings made to assure MOV closure against design basis flow could, under certain conditions, cause damage to the valve or operator at no-load conditions that may be encountered, for example, during a stroke test. Third, a number of misadjustments, degraded conditions, material problems and design deficiencies not related to switch settings have been identified.

All of these items are at least mentioned in the new NRC generic letter; however, the guidance provided for resolution is necessarily vague. The problem of determining what capability is needed in order to meet design basis force requirements should be fairly straightforward. It may be somewhat complicated and expensive to make the needed hardware changes in the plants. The competing demands of design basis operability and normal or no-load operational requirements may also not be easily resolved without hardware changes and could be difficult to resolve at all. The problems associated with misadjustments, material deficiencies and degraded conditions will require excellent coordination within the industry, as well as education of all concerned. Finally, it will probably be expensive for the industry to research design basis operability parameters, particularly at older plants, but there is no alternative to this effort.

The NRC staff will soon produce a Temporary Instruction to assist inspectors in making uniform judgements about licensee compliance with the recommendations of the generic letter on MOVs. In addition, the staff plans to sponsor workshops on the NRC generic letter. NRC staff members may attend industry sponsored meetings and workshops if invited. The efforts by NUMARC, EPRI/NMAC, INPO, licensees, and various vendors have produced a large amount of information in a very short time concerning the particular problems of motor-operated valves. All of these efforts represent an educational process for the industry that must continue if the problems described above are to be solved. A coordinated effort involving the use of shared information might prove to be cost-effective for the industry as a whole. The problems associated with the production and use of proprietary information could be difficult to overcome, however. The industry would also profit greatly by an increased awareness by utility managers of the technical issues associated with in situ testing and maintenance in general, as well as some awareness of MOV operation and associated problems in particular.

The results of the recent research on MOVs, as well as the increase in meaningful testing, can be expected to suggest generic hardware improvements in not only the test equipment but in the operators and valves as well. The NRC efforts under the Aging Research Program and toward the resolution of Generic Issue 87 have provided some useful data. Improvements in lubrication technology, valve trim materials, operator mechanical operation, and motor design might be reasonably expected from future industry efforts. Further, it has already been observed that the industry efforts on maintenance programs have resulted in increased coordination of MOV in situ testing and maintenance. The competing demands of design basis operability and normal or no-load operability remain to be resolved. Testing methods that will demonstrate design basis operability of installed equipment need to be developed and improved.

This paper was written from the point of view of one who is somewhat familiar with the particular problems and history of motor-operated valves. For those who may be interested in a description of the equipment and some of the various problems associated with MOVs, a short bibliography is provided.

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