Proceedings of the ASME/NRC 2014 12th Valves, Pumps, and Inservice Testing Symposium
NRC2014
June 23-25, 2014, Rockville, Maryland, USA
NRC2014-5015

Motor-Operated Valve Performance

Michael F. Farnan*
Component Performance, NDE & Testing Branch
Division of Engineering
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission

* This paper was prepared by staff of the U.S. Nuclear Regulatory Commission (NRC). It may present information that does not currently represent an agreed-on NRC staff position. The NRC has neither approved nor disapproved its technical content.

Abstract

Motor-operated valves (MOVs) play an important role in the safe and reliable operation of today's nuclear power plants. The purpose and scope of this paper is to review recent MOV operational experience events. The paper will discuss current findings and trends that relate to operation, maintenance, and surveillance testing of MOVs.

Introduction

Operating experience and research results for MOVs indicated that testing under static conditions does not always reveal how these valves will perform under operating and design basis conditions. A number of failures of MOVs have occurred as a result of inadequate design, installation, and maintenance. Concerns of the performance of MOVs resulted in the issuance of Generic Letter (GL) 89-10, "Safety-related Motor-Operated Valve Testing and Surveillances," which requested licensees to establish a program to ensure the operability 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 trending MOV problems. The NRC staff requested that licensees complete the GL 89-10 program within three refueling outages or 5 years from the issuance of the GL.

During the period of GL 89-10 program implementation, the NRC staff issued seven supplements to GL 89-10 that provided additional guidance and information on program scope, design basis reviews, switch settings, testing, periodic verification, trending, and schedule extensions. GL 89-10 and its supplements only provided limited guidance regarding periodic verification and the measures appropriate to assure preservation of design-basis capability. To improve the effort of maintaining a periodic verification program, the NRC staff issued GL 96-05, "Periodic Verification of Design-Basis Capability of Safety-Related Power-Operated Valves," which requested licensees to establish a program, or to ensure the effectiveness of its current program, to verify on a periodic basis that safety-related MOVs continue to be capable of performing their safety functions within the current licensing bases of the facility. The program should ensure that changes in required performance resulting in degradation (such as those caused by age) can be properly identified and accounted for. The provisions of GL 96-05 superseded GL 89-10.

In response to GL 96-05, the nuclear industry joined together to form the Joint Owners Group (JOG) MOV periodic verification program. The JOG program consisted of three elements: 1) an “interim” MOV periodic verification program for licensees to use in response to GL 96-05 during development of a long term program; 2) a 5-year MOV dynamic diagnostic test program; and 3) a long-term MOV periodic diagnostic test program to be based on the information from the dynamic testing program. The JOG effort was intended to answer the valve degradation question as it pertained to valve configuration, design, and system application. Upon completion of the 5-year MOV dynamic diagnostic test program, the JOG issued its final report and long-term program recommendations. The NRC staff reviewed the final report and approved the program, with conditions, on September 25, 2006 (Agencywide Documents Access and Management System (ADAMS) accession No. ML061280315). Plants that had participated in the JOG program (98 out of 103) had six years from the issuance of the NRC safety evaluation for the JOG final program to implement the final recommendations. Plants that did not participate in the JOG effort were individually inspected by the NRC staff for compliance.

MOV performance after the issuance of GL 89-10 yields that there has been a significant improvement in MOV performance and reliability. The scope of this report will look at the recent performance issues and trends.

Operating Experience/Technical Review Group

Management Directive (MD) 8.7, “Reactor Operating Experience Program,” sets forth the policy of the NRC for an effective coordinated program to systematically review operating experience (OpE), assess its significance, provide timely and effective communications to stakeholders and apply the lessons learned to regulatory decisions and programs affecting nuclear reactors. The Operating Experience Branch (IOEB) of the Office of Nuclear Reactor Regulation (NRR) provides a centralized function within the agency to collect, store, screen, prioritize, and distribute OpE information to interested users; facilitate and track OpE evaluation and application activities; assist the communication of OpE lessons learned; and coordinate NRC OpE activities among organizations performing OpE functions.

To increase the use of the vast amounts of information being gathered by the IOEB, multiple technical review groups (TRGs) were formed composed of members from across the agency with each group led by a subject matter expert. The TRGs review various OpE data such as license event reports (LER), inspection findings, international reports, Part 21 notifications, OpE communications posted by IOEB, and Institute of Nuclear Power Operations (INPO) Consolidated Event System (ICES) database. The TRGs maintain a continuous exchange of information with IOEB to identify possible emerging issues that may warrant further NRC review. The author of this paper is the current TRG lead for Pump and Valve Performance issues.

Recent Trends

The scope of this report covers operating experience data for the last five years. The following discussion will focus on recent trends over the five year period and not detail the facility reporting the events. It is recognized that many events occurred with components considered to be within non-safety related systems of nuclear power plants. However, the events are relevant with respect to component performance versus the cause of the component failure. For this reason, this report will not distinguish between safety-related and non safety-related components but rather focus on the component failure and its impact on overall plant operation.

At NRC headquarters, event data such as LER's, inspection reports, greater than green findings, and 10 CFR Part 21 reports are screened daily by the IOEB. Relevant events are forwarded to the TRG leads for their action to review and trend. Communication between the TRG lead reviewers, IOEB engineers, and individual plant inspectors is necessary to capture the correct history of the event. In addition, the event may be reviewed via INPO ICES database.

In the mid 1970's, INPO created the Nuclear Plant Reliability Data Systems (NPRDS) database. This database records and analyzes data on specific nuclear equipment and components. In the late 1990's, INPO created the Equipment Performance and Information Exchange (EPIX) to replace NPRDS. EPIX was developed to provide an industry wide database of information on Maintenance Rule components at all U.S. nuclear power plants. In 2013, INPO integrated the Nuclear Network Operating Experience (OE) with EPIX failure reporting into one consolidated event reporting and analysis platform called ICES.

INPO has granted the NRC staff access to the ICES database for tracking and trending purposes of component performance. Review of the INPO ICES database provides the NRC staff a broader perspective on possible emerging trends. This is due to the fact that the INPO ICES database contains many component events that didn't reach an importance level of an LER and/or inspection concern. For example, the five year window examined for this report, there were 40 MOV events noted in the IOEB database compared with 668 events noted in ICES over the same five year period. The five year window ICES report was generated using the common filters:

1. Component type equals Valve Operators

2. Component type equals Valves, dampers
3. Eng. Char equals Electric Motor – AC
4. Eng. Char equals Electric Motor – DC
5. Eng. Char equals Electric Motor/Servo (MOV)

Please note that the reported INPO 668 events involve a MOV but the MOV was not necessarily the main component that failed. Additional filters were applied to the ICES reports to focus on MOV failures and emerging trends. Data was first examined at the high level to determine possible recurring events. Event causes that exceeded five data points in LER's, inspection reports, and greater than green findings were selected to be further examined using INPO ICES database. The top trend setters were:

1. Failures due to contacts
2. Failures due to lubrication issues
3. Failures due to disc / stem separation

ICES has a unique analysis tool built into the database that provides statistics of the most frequent failed parts and causes for a filtered record set. Utilizing the same five filters noted above, key words were added as an additional filter to fine tune the query and focus only on the top trend setters.

Failure due to Contacts

This was the largest trend observed over the five year period. Failure of contacts contributed to the most MOV failures. The contact failures included: torque switch, limit switch, motor control center (MCC) contactor relay contacts, and MCC breaker cell contacts. A JIT report was generated with the key word "Contact" along with the other standard common filters. The report generated a total of 288 records of which 115 were included in the lessons learned. Most frequent failed parts were:

- Contact(s) – 80
- Contactor – 12
- Fuse – 10
- Limit Switch Rotor – 10
- Coil(s) – 10
- Wiring – 8
- Electrical Termination (Lug / Connector) – 8
- Disc – 7
- Switch – 7
- Gear(s) – 7

Most Frequent Causes:

- Process cause was not determined by Corrective Action Program – 26
- Preventive Maintenance task content not appropriate / less than adequate – 25
- Aging / Obsolescence Concern less than adequate – 23
- Manufacturer/Vendor Quality issues – 22
- Work activities incorrectly performed – 21
- Preventive maintenance task did not exist – 19
- Preventive maintenance task execution less than adequate – 15
- Preventive maintenance task frequency not appropriate – 14
- Previous corrective actions less than adequate or untimely – 13
- Failure to consider design inputs – 9

Another query was generated over the same time frame using the common filters and the exact phrase “Limit Switch.” The JIT report generated 112 total records of which 41 were included in the lessons learned. The most frequent failed parts were:

- Contact(s) – 21
- Limit Switch Rotor – 13
- Wiring – 6
- Stem – 6
- Electrical Termination (Lug / Connector) – 5
- Switch – 5
- Coil(s) – 4
- Circuit Board / Card – 4
- Latch / Lock / Interlock – 3
- Torque Plate – 3

Most Frequent Causes:

- Work planning, instructions, preparation less than adequate – 9
- Work activities incorrectly performed – 9
- Preventive Maintenance task content not appropriate / less than adequate – 7
- Preventive Maintenance task execution less than adequate – 7
- Process cause was not determined by Corrective Action Program - 6

Another query was generated over the same time frame using the common filters and the exact phrase “Torque Switch.” The JIT report generated 98 total records of which 38 were included in the lessons learned. The most frequent failed parts were:

- Contact(s) – 19
- Disc – 8
- Stem – 8
- Limit Switch Rotor – 7

- Wiring – 6
- Lubricant – 5
- Seat – 5
- Gear(s) – 4
- Torque Plate – 4
- Coil(s) – 3

Most Frequent Causes:

- Original design less than adequate – Component not appropriate for application – 11
- Process cause was not determined by Corrective Action Program – 10
- Preventive Maintenance task content not appropriate / less than adequate – 8
- Work planning, instructions, preparation less than adequate – 6
- Work activities incorrectly performed – 6
- Equipment aging – Metallic parts – Normal wear – 5
- Equipment aging – Non-Metallic parts – Electrical breakdown – 5
- Manufacturer/Vendor Quality issues – 5
- Preventive Maintenance task execution less than adequate – 4
- Aging / Obsolescence Concern less than adequate – 4

A final query was generated over the same time frame using the common filters and the exact phrase “contact oxidation.” The JIT report generated 18 total records of which 8 were included in the lessons learned. The most frequent failed parts were:

- Contact(s) – 11
- Electrical Termination (Lug / Connector) – 1
- Microswitch – 1
- Switch – 1
- Cam(s) – 1
- Contact Arm – 1
- Motor shaft – 1
- Stab connection – 1
- Contact block – 1
- Fuse clip – 1

Most Frequent Causes:

- Preventive Maintenance task did not exist – 5
- Preventive Maintenance task content not appropriate / less than adequate – 3
- Process cause was not determined by Corrective Action Program – 2
- Aging / Obsolescence Concern less than adequate – 2
- Manufacturer/Vendor Quality issues – 2

- Equipment aging – Metallic parts – Normal wear – 2
- Equipment aging – Metallic parts – Wastage / General Corrosion – 2
- Equipment aging – Metallic parts – Fatigue – 1
- Problems with Design implementation – 1
- Work planning, instructions, preparation less than adequate – 1

The common thread that appears in all the contact failure queries is that the preventive maintenance task was not appropriate and/or less than adequate. Minor adjustments to the preventive maintenance program should improve the failure rate.

Failures due to Lubrication

Poor lubrication yielded the second largest trend of MOV failures over the examination period. Lubrication failures were noted in: lack of lubrication in the stem-to-stem nut interface, hardened grease in the motor pinion gear area, hardened grease in the gear case, hardened grease on the stem, dried out lubricant in the MCC contactor, hardened grease in the MCC breaker assembly, and degraded grease due to inadvertent mixing of greases. A JIT report was generated with the key word “Lubricant” along with the other standard common filters. The report generated a total of 23 records of which 11 were included in the lessons learned. Most frequent failed parts were:

- Lubricant – 11
- Stem – 4
- Contact(s) – 3
- Blade – 2
- Linkage – 2
- Spring(s) – 1
- Declutch Mechanism – 1
- Guides – 1
- Stem/Plug Assembly – 1
- Worn Gear – 1

Most Frequent Causes:

- Preventive Maintenance task feedback not implemented – 4
- Process cause was not determined by Corrective Action Program – 3
- Preventive Maintenance task frequency not appropriate – 2
- Preventive Maintenance task did not exist – 2
- Inadequate control of maintenance activities – 2
- Unspecified design inadequacy – 1
- Equipment not operated within design – 1
- Aging / Obsolescence Concern less than adequate – 1
- Work activities incorrectly performed – 1
- Previous corrective actions less than adequate or untimely – 1

Similar to the contact failure report, the common deficiency among the failures is having the correct preventive maintenance task and interval.

Failures due to Stem / Disc Separation

The last major trend of failures in MOVs is the stem-to-disc separation. Failures occurred in: gate, globe and butterfly valves. Although there were not as many records of failures as compared to contacts and lubrication issues, the increase in overall valve failures (all valves without distinguishing the type of operator) due to stem-to-disc separation warranted an investigation. Focusing on MOVs only, a JIT report was generated with the key word "Separation" along with the other standard common filters. The report generated a total of 23 records of which 5 were included in the lessons learned. Most frequent failed parts were:

- Disc – 4
- Fuse – 3
- Seat – 3
- Stem/Plug Assembly – 3
- Pin(s) – 2
- Weld(s) – 2
- Gear(s) – 1
- Seat Ring – 1
- Rotor – 1
- Winding(s) – 1

Most Frequent Causes:

- Design - Equipment reliability not adequately addressed – 4
- Risks of decisions not completely assessed – 4
- Manufacturer/Vendor Quality issues – 3
- Aging / Obsolescence Concern less than adequate – 2
- Improper reassembly of component – 2
- Procedures – Omission of relevant information – 2
- Work planning – 1
- Training / qualification – 1
- Performance monitoring execution less than adequate – 1
- Work activities incorrectly performed – 1

This last trend required additional research to sort out the major contributors to the increase in valve stem-to-disc failures. Many of the failures did not reach a high level of awareness such as an LER or inspection finding. This was due in part to the fact that several failures occurred in non-safety systems and/or were identified during a maintenance activity performed offline and the subsequent safety analysis concluded that the valve would have performed its safety function. However, almost all valve failure events had an impact on plant availability. Failures resulted in delayed power ascension, forced reactor shutdowns, manual scrams, and unit power reductions. The valve failures major contributors were:

- Valve degradation due to internal parts being exposed to untreated water system
- System vibration caused by cavitation due to low flows
- System vibration caused by overall system performance
- Malfunction of valve actuator
- Pressure locking and Thermal binding
- Manufacturing defects
- Wear due to age and little preventive maintenance
- Material embrittlement

Conclusions

The INPO ICES database is a useful tool for tracking and trending component failures. The Just in Time report provides a quick assessment of possible trends. However, please note that the JIT report is based on lessons learned being reported by a plant individual and not all reports being inputted to the database include lessons learned.

Overall MOV performance noted over the last five years is considered to be normal. These trends are not considered to be a major concern. The three failure trends noted can be improved with simple changes to preventive maintenance activities and intervals. It is believed that the slight uptick in MOV failures is due to aggressive maintenance schedules coupled with many plants reaching 40 years of operation.