AEOD ENGINEERING EVALUATION REPORT*

UNIT:	Vermont Yankee	EE REPORT NO.:	AEOD/E702
DOCKET NO.:	50-271	DATE:	March 19, 1987
LICENSEE:	Vermont Yankee Nuclear Power Corporation	EVALUATOR/CONTACT:	E. J. Brown
NSSS/AE:	General Electric Company/Ebasco		

SUBJECT: MOV FAILURE DUE TO HYDRAULIC LOCKUP FROM EXCESSIVE GREASE IN SPRING PACK

EVENT DATE: June 6, 1986 (271/86-012-00 and 271/86-012-01)

SUMMARY

The purpose of this study is to investigate the phenomenon referred to as "hydraulic lockup" together with its effect on motor operated valve operation. The study was initiated as the result of the event at Vermont Yankee. The evidence confirms that hydraulic lockup can occur with Limitorque SMB motor operators. The phenomenon appears related to the use of EXXON NEBULA EP-0 grease which is one of two environmentally qualified greases and seems to be the preferred choice. The safety concern is that hydraulic lockup is a common mode failure mechanism for safety-related MOVs. In addition, the failure may tend to occur in a manner that could not be detected by plant operators because an apparently successful closure could render the MOV inoperable for the next demand (e.g. motor burnout, component damage due to overloading, or inability to open due to over tightening during closing).

Although hydraulic lockup appears to be associated with the use of EXXON NEBULA EP-0 grease, it also seems that the industry does not have an adequate understanding of the combination of parameters or conditions that cause the phenomenon. The situation can be separated into broad groups involving motor operators that were manufactured prior to approximately 1975 that need a modification kit installed to provide a grease relief path; motor operators manufactured subsequent to 1975 that have a design change to provide an internal grease relief path to prevent lockup, but that change may not be adequate; and misinformation or lack of awareness throughout the industry about the need for the modification kit or that hydraulic lockup has occurred in motor operators that have the design change intended to prevent such response. Further, current emphasis on the use of environmentally qualified grease may expose licensees to a greater risk of occurrence of hydraulic lockup if they are not aware of appropriate precautions.

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* This document supports ongoing AEOD and NRC activities and does not represent the position or requirements of the responsible NRC program office.

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Based on the fact that hydraulic lockup has occurred and that industry guidance may be inaccurate, it is recommended that IE issue an information notice to alert licensees about the complex situation. The report also recommends that immediate industry effort is needed to (1) identify conditions, sequences, or procedures that result in hydraulic lockup; (2) develop solutions for all motor operators currently in use (modification kits, design changes, etc.) and (3) disseminate the corrective action to all users. This effort should be coordinated through NUMARC as part of the overall program for industry action on MOVs.

INTRODUCTION

This study was initiated as the result of an event that involved a motor operated valve (MOV) assembly failure to open at the Vermont Yankee plant. The event was reported in LER 271/86-012 (Ref. 1) and LER 271/86-012-01 (Ref. 2). The valve assembly was in the suction line to the pump in the "B" recirculation loop for this BWR plant. The plant was not operating because it had been shutdown for refueling and replacement of recirculation piping.

The mode of failure was motor burnout that occurred after actuating a closure of the valve assembly; but the failure was not detected prior to subsequent attempts to reopen the valve. Although motor burnout has been reviewed extensively by AEOD (Ref. 3), the "root cause" of failure for this event was not addressed in the most recent AEOD report, C603 (Ref. 4), that requested industry action to address MOV performance and reliability problems. Licensee investigation of the event revealed that the MOV failure was related to the use of a new grease in the valve operator. The new grease is less viscous so that it could leak into the spring pack area. Subsequent operation of the valve assembly could result in a condition of "hydraulic lockup," with either incorrect operation or complete inoperability of the MOV and possible damage or failure. The safety concern is that the phenomenon is a potential common mode failure mechanism for Limitorque SMB valve motor operators at many operating plants. At Vermont Yankee, a total of 40 MOVs were affected and 32 were safety-related MOV assemblies.

DISCUSSION

As previously indicated, the Vermont Yankee plant was shutdown for refueling and replacement of recirculation piping when this event occurred. During this period of plant modifications, the licensee staff had entered into a program to refurbish MOVs and establish reference test data utilizing signature tracing equipment. There were 40 MOVs that were refurbished, including 32 safety-related MOVs, as part of this ongoing program. As a portion of this effort, the MOV actuator grease was removed and replaced with a new, less viscous grease. The revised LER (Ref. 2) indicated that the new grease was Mobil EP-0 and the old grease was Mobil EP-1. (As discussed later in the report, the new grease was determined to be EXXON NEBULA EP-0.)

The MOV failure to operate and motor burnout occurred during the operability testing subsequent to activities related to refurbishment. The MOV of interest, valve V2-43B, was presumed to be in the closed position when an operator in the control room attempted to reposition the recirculation loop "B" pump suction valve. The valve failed to open (based on remote position indication lights) with a signal from the control room. After a second attempt to open the valve, the position indication lights went out. The motor operator was disassembled and the rotor was found fused to the windings. As reported, electrical indications were not affected by the failed rotor; however, when power was applied (the second time) to open the MOV, the electrical overload tripped the breaker and the position indication lights in the control room went out.

Subsequent licensee investigation determined the "root cause" of failure to be related to the use of the new, less viscous grease in the valve operator. It was found that the less viscous grease had entered the spring pack area from the gear case. This grease created a condition of "hydraulic lockup" that prevented the spring pack from performing its intended function. This phenomenon was discovered during tests after the burned out motor had been replaced. The valve assembly was being tested with the signature tracing equipment attached when a locked rotor current was observed. However, the spring displacement measurement was negligible and thus inconsistent with the high load application. Later, grease was observed to migrate from the spring pack area, spring displacement occurred, and the torque switch actuated. Thus, the licensee staff concluded that the signature tracing equipment was instrumental in the "root cause" determination of the MOV failure to operate.

This "hydraulic lockup" phenomenon is a possible common mode failure mechanism for Limitorque SMB motor operators. The phenomenon also appears to have the potential for many types of MOV assembly failures. In addition to motor burnout, it could possibly lead to valve operator component or valve body failures due to excessive loads. The normal load application to operate the valve assembly is through the Bellville spring pack compression in reaction to the motor (or handwheel on SMB-0 and larger). The usual protection for the closing operation of the valve would be the torque switch trip based on the predetermined load and corresponding spring pack deflection based on the spring constant. If the spring pack area fills with grease that cannot escape when the spring compresses, then the spring constant effectively relates to the compressibility of a volume of grease (essentially incompressible) or "hydraulic lockup." Thus, the loads can increase dramatically and with no relationship to the spring deflection necessary to actuate the torque switch for protection of the MOV or completion of the desired MOV function.

The MOV refurbishment program at Vermont Yankee that used the new grease involved seven different Limitorque motor operator types. The type of motor operator and number of units for each type are as follows:

Operator Type	Number Refurbished
SMB-000	11
SMB-00	9
SMB-0	4
SMB-1	3
SMB-2	8
SMB-3	3
SMB-4	2

The valve that experienced hydraulic lockup, V2-43B, had an SMB-2 operator.

The systems affected by this MOV refurbishment program were the reactor recirculation system, residual heat removal system, reactor water cleanup system, high pressure coolant injection system, core spray system, reactor core isolation cooling system, and main steam and feedwater system. If all MOVs in the refurbishment program were susceptible to the failure mechanism exhibited by valve V2-43B, the ability of the Vermont Yankee plant to effectively cope with a design basis accident could have been severely compromised.

The licensee contacted the manufacturer of the motor operator, Limitorque, concerning recommended corrective action. Limitorque recommended that grease relief kits be installed. This provided a flow path for the grease via external tubing installed from the spring cartridge cap cover to an existing plug hole at the top of the operator. The intent of the flow path is to prevent "hydraulic lockup" of the grease by prohibiting constraint of the grease in the spring cartridge area. All 40 MOVs involved with the new grease were modified by installing the relief kits and they were performance tested prior to plant restart.

This event at Vermont Yankee was also the subject of an industry communication procedure to bring the significant issues to the attention of other operating plants. The primary issues involved corrective action procedures to prevent hydraulic lockup and information about various types of greases used with Limitorque motor operators. There were two methods discussed concerning corrective actions to permit flow of grease and prevent lockup. One method recommended was the installation of the modification kits discussed previously. The second method was a design change for the motor operator involving a notch machined into the spring cartridge to provide an internal grease relief path intended to "negate the need for the modification kits." It was further identified that motor operators with a serial number above a specified value would include this machined notch. Depending upon the type of operator, we understand that by 1975 motor operators with the machined notch were being shipped and that some types may have had the new design prior to 1975.

The information in the industry communication about grease included identification of the type of grease used at the Vermont Yankee plant as well as recommendations for the applications and locations of various greases. It was indicated that the grease used in the subject MOVs at the Vermont Yankee plant was changed to Mobil EP-0 from Mobil EP-1. Further, the information identified that "both Mobil EP-0 and EP-1 greases are acceptable and approved by Limitorque for use in non-safety-related applications." In addition, "EXXON NEBULA EP-0 and EP-1 have been qualified for safety-related applications both inside and outside primary containment."

Subsequent to the LERs and industry communication, the licensee submitted a notification of a potential design defect (10 CFR Part 21) related to this event (Ref. 5). The report by the licensee indicates that Limitorque had identified the lockup problem some years ago and developed the modification kit to correct the problem. It was also identified that neither Vermont Yankee nor Limitorque could find evidence to document that this information was ever disseminated to the industry. It was also stated that Limitorque had not been

able to reproduce this type of hydraulic lockup at their facilities, but acknowledged the potential for such occurrence. Further, the Part 21 submittal indicates that it appears no notification was provided to utilities concerning the possible need to retrofit motor operators if the less viscous EXXON NEBULA EP-0 grease is used even though an internal modification was implemented by Limitorque to prevent grease lockup.

Reference 5 (the Part 21 report) also mentioned that the new, less viscous grease used in the MOV refurbishment program at Vermont Yankee was NEBULA EP-0. This grease is made by EXXON and the statement about this grease is not consistent with previous reports by the licensee (LERs) and the industry communication pertaining to the use of Mobil EP-0. Recall also, that the Mobile grease was considered approved only for use in non-safety-related applications (discussed previously) while Reference 2 indicated that 32 of the 40 MOVs at Vermont Yankee were safety-related valves. In addition, the EXXON NEBULA EP-0 grease has been qualified for safety-related applications both inside and outside of primary containment. In order to clarify References 1, 2, and 5, with respect to which grease was actually used at Vermont Yankee these issues were discussed with the licensee staff as indicated in Reference 6.

Based on the discussions, we understand that those documents which refer to the new grease as either Mobil EP-0 or Mobil EP-1 are incorrect. It appears that it was not clear which grease had been in use since the MOVs have been installed. There was evidence that Mobil grease had been used during the last few years. Since the EXXON NEBULA EP-0 grease was qualified for use in safety-related MOVs, it appears that it was decided to use that type in the refurbishment program. Although it may be advisable to confirm this explanation, this information seems to resolve the concerns about the type of grease used in these 40 MOVs at Vermont Yankee. It was also revealed during the telephone discussions that Vermont Yankee conducted an investigation of the Mobil grease to assess use in safety-related applications with the result that they believe it is comparable to the EXXON NEBULA EP-0 grease. The bases for this determination were not investigated for this report, but the issue may be an appropriate subject for other NRC staff review. We understand the licensee will submit a revised LER to identify the correct grease in use at Vermont Yankee.

The issue concerning grease application was discussed in the industry communication mentioned previously in this report. Since the industry appears to indicate that the appropriate grease was specified by the manufacturer of the motor operator, Limitorque, this issue was discussed with a staff member as indicated in Reference 7. We understand that Limitorque considers EXXON NEBULA EP-0 and EP-1 grease qualified for use in safety-related MOV applications for both inside and outside containment and states this in the manual for SMB motor operators. We understand the support for qualification in this service is based on environmental qualification testing conducted in accordance with IEEE standards; i.e., the EXXON grease was used during the test program. It was also mentioned that substitute greases, including Mobil EP-0 and EP-1, are identified in the manual, but they are considered to be for non-safety-related

application. Since the communication with Limitorque was intended to confirm their recommendations, there was no effort to explore whether the limitations placed on substitute greases were related to technical deficiencies or just that they were not used in the environmental qualification test program. Thus, it would appear that individual licensees would have the responsibility to justify use of the substitute greases in any safety-related application. Some recent events in which non-qualified grease was identified in MOVs are discussed in References 8 and 9.

The investigation of the event at Vermont Yankee included a search to identify other confirmed occurrences involving hydraulic lockup of MOVs. A separate event involving hydraulic lockup of an MOV, HV-57-111, was confirmed at Limerick Unit 1 and identified in Reference 10. This event occurred prior to plant startup and thus it was not reported in an LER. The significance of this event is that the motor operator used with the valve was manufactured after the time frame identified by Limitorque to incorporate the design change with the internal groove to provide a relief flow path for the less viscous grease to prevent hydraulic lockup in the spring pack area. Inspection confirmed that the motor operator did have the internal notch grease relief path. However, hydraulic lockup was confirmed by test. A new fix developed by the licensee staff was to machine slots in the torque limiter sleeve as a grease relief path from the spring pack area. This approach was apparently acceptable to Limitorque. The MOV was operated successfully with the new grease relief path. It is not known whether these new slots would be appropriate on an individual basis without the other designed notches or whether the combined effect of the manufacturer-designed notches and new machined slots were successful. EXXON NEBULA EP-0 grease was used in this MOV.

Another hydraulic lockup event was confirmed at Limerick Unit 1 after the plant became operational and is discussed in References 11 and 12. Additional information is contained in the inspection reports identified in References 13 and 14. This event occurred on December 18, 1985 and involved containment spray header outboard isolation valve, HV-51-1F016A. The situation was discovered as part of a local leak rate test (LLRT) on penetration 39A. Both the inboard and outboard isolation valves were stroked normally and then pressurized to the test pressure of 44 psig. The penetration failed to hold pressure until the outboard isolation MOV (HV-51-1F016A) was manually closed. The LLRT was subsequently successful. A test with signature tracing equipment revealed that excessive grease in the spring pack area was possibly causing improper functioning. A supervisory block was applied to the hand switch in the control room, motor control center, and the manual handwheel to secure MOV HV-51-1F016A in a fully closed position and the motor was de-energized during plant operation. EXXON NEBULA EP-0 grease was used in this MOV.

During a six-week outage in May-June 1986, maintenance was performed on the subject MOV that included machining slots in the torque limiter sleeve (similar to the fix for HV-57-111). This allowed the release of any excess grease but the MOV still would not close sufficiently to prevent leakage. Thus, the valve was closed manually, the LLRT completed, and a similar supervisory block applied until the next planned shutdown in May 1987 when the MOV will be

repaired. Thus, although hydraulic lockup was confirmed, it was not the basic reason for failure of this MOV to close sufficiently tight to meet the LLRT requirements.

These events at Limerick and Vermont Yankee are indicative of a common mode failure mechanism that could render safety-related MOVs inoperable. Furthermore, it is not apparent that the industry has an adequate understanding of the combination of parameters that could influence or cause hydraulic lockup. From these events, it would seem that plant operating conditions, rate of load application, type of grease used in the motor operator, and motor operator design characteristics may have an impact on whether hydraulic lockup will occur. However, the events at Limerick suggest that the design change (internal relief path) introduced by the manufacturer (Limitorque) of the motor operator will not be effective to prevent hydraulic lockup under all circumstances of MOV operation. Thus, the information provided by the industry communication that implies the use of motor operators with the design change would "negate the need for the modification kit (external fix)" appears to be inaccurate or at least could provide a false sense of security concerning a potential MOV failure mode.

A review of possible MOV responses was conducted in an attempt to identify operational characteristics and relate this to potential safety concerns. Based on operating characteristics of the motor operator, it would appear that hydraulic lockup could occur during either a closing or opening stroke for an MOV. The primary effect is that lockup can result in excessive load application to both motor operator components (including extended high current in the motor) and the valve body because the torque switch cannot be activated to provide the intended protection. Thus, those MOV functions accomplished by torque switch actuation (trip) such as protection and de-energizing the motor at specified times to complete a stroke could be unavailable.

Since most MOVs stop the closing stroke with a torque switch actuation, it would be anticipated that a valve assembly closure stroke would be the most probable time when lockup may occur or have an adverse effect. However, this lockup would most likely not prevent or adversely affect closure of an MOV, but rather close the valve excessively tight, damage valve assembly components, or cause motor burnout because the motor was not de-energized. In either case, the MOV may not operate (it would not operate if burnout occurred) during the next demand and plant operators may have no indication of this unavailability (this issue of unavailability for the next demand was raised in AEOD/C603, Ref. 4). This situation could have potentially adverse effects on dual purpose MOVs. Lockup during an opening stroke would probably differ from the closing stroke because many MOVs shut the motor off with a limit switch setting rather than a torque switch. However, torque switch protection would be lost and if excessive loads were necessary, effects such as burnout could occur. If the opening stroke was set to terminate on torque switch, excessive loads could adversely affect the motor, stem, or backseat of the MOV.

Overview

The operational events discussed in this study illustrate and confirm that hydraulic lockup can occur with Limitorque SMB motor operators. The phenomenon appears related to the use of EXXON NEBULA EP-0 grease. This grease is less viscous than the NEBULA EP-1 grease. The NEBULA EP-0 and EP-1 greases are the only greases considered environmentally qualified by Limitorque for use in their motor operators used in safety-related applications inside and outside of reactor containment. It appears that the less viscous grease (NEBULA EP-0) may also be the preferred grease so that operating plants may be changing to the less viscous grease either as part of the normal maintenance program or to comply with environmental qualification recommendations.

The evidence suggests that motor operators manufactured before approximately 1975 (these can be identified specifically by serial number) may need to be fitted with a modification kit to protect against hydraulic lockup when NEBULA EP-0 grease is used in the motor operator. However, Reference 5 (Part 21 report) indicates this information does not appear to have been communicated to the users of such equipment. An industry communication indicated that a design change to alleviate hydraulic lockup was implemented on motor operators manufactured after a certain date as identified by serial number. This change was intended to "negate the need for a modification kit." However, the events at Limerick involved hydraulic lockup with motor operators that included the design change. An additional modification was implemented by the licensee to prevent hydraulic lockup. Thus, the manufacturer's design change incorporated in the motor operator apparently will not prevent hydraulic lockup under all operating conditions. In this context, operating plant staff could be mislead concerning the appropriate course for corrective action, determining whether an action is necessary, or excluding consideration of a possible failure mode during root cause failure evaluations of MOVs.

The operating experience, therefore, indicates that hydraulic lockup is a potential common mode failure mechanism for Limitorque SMB motor operators. Some possible modes of failure involve motor burnout, component damage due to overloading, or inability to operate a valve assembly due to over tightening during closing. The phenomenon is difficult to detect, but for the events reviewed, each licensee indicated that signature tracing equipment was useful for the root cause determination.

A recent submittal to NRC illustrates a situation involving the Palisades plant that may portend widespread implications if other licensees change the motor operator gear case grease to a certain environmentally qualified grease. One issue addressed by Reference 15 involved the MOV maintenance program, Item 2.2.3, that identified environmentally qualified MOVs that were found to have grease that was not environmentally qualified. The unqualified grease was identified as SUN EP50. This issue was discussed with NRC Region III staff and they have confirmed that the replacement grease used was EXXON NEBULA EP-0. In addition, the Palisades plant is approximately the same vintage as Vermont Yankee which suggests that the motor operators in use may need the modification kit installation for protection against hydraulic lockup. We are not aware

that the modification kits are in use at Palisades. Therefore, if operating plants convert to environmentally qualified NEBULA EP-0 grease, there may be a potential for widespread adverse effects on MOV operability. Thus, it would appear prudent that industry take action to review the hydraulic lockup phenomenon; identify operating conditions, sequences, or procedures that result in hydraulic lockup; develop solutions for all motor operators; and disseminate the corrective action program to all users.

FINDINGS AND CONCLUSIONS

The events reviewed illustrate the occurrence of hydraulic lockup with Limitorque SMB motor operators. The situation can lead to damage or loss of MOV capability to perform the intended function. The following findings are provided:

1. The event at Vermont Yankee demonstrated the occurrence of hydraulic lockup of a Limitorque motor operator when a less viscous, but approved, grease was used as replacement for the old grease.

2. The hydraulic lockup appears related to use of the less viscous EXXON NEBULA EP-0 grease. At Vermont Yankee, this grease was introduced as a replacement for some form of Mobil grease during a scheduled MOV refurbishment program.

3. The licensee determined that, if the less viscous grease was used, a modification kit involving installation of external tubing on the motor operator was necessary to prevent hydraulic lockup in motor operators manufactured prior to approximately 1975. Neither the licensee nor motor operator manufacturer could find documentation that this information was officially disseminated to users of the equipment. (A recent industry communication suggests consideration for installation of the modification kit.)

4. At Vermont Yankee, seven different types of Limitorque motor operators were affected by installation of the less viscous grease. The systems that contained these MOVs and could have been adversely affected were the high pressure coolant injection system, core spray system, residual heat removal system, reactor water cleanup system, reactor recirculation system, and feedwater system.

5. The various reports submitted by Vermont Yankee concerning the event involving hydraulic lockup are inconsistent relative to the type of grease(s) used now and in the past.

6. A design change involving an internal grease relief path to alleviate hydraulic lockup of motor operators was incorporated by Limitorque for motor operators delivered after approximately 1975.

7. The events with hydraulic lockup at Limerick involved motor operators

that had incorporated the design change with the internal grease release path. The licensee incorporated an additional relief path to alleviate hydraulic lockup.

8. These events at Limerick suggest that the design change incorporated to alleviate hydraulic lockup, and negate the need for the modification kit installation used on older motor operators, may not be adequate to prevent hydraulic lockup under all conditions. In this context, the industry communication appears to provide inaccurate or misleading guidance to licensees.

9. The motor operator manufacturer, Limitorque, indicates that EXXON NEBULA EP-0 and EP-1 are the only greases environmentally qualified for use in MOVs for safety-related service both inside and outside of reactor containment.

10. The confirmed events with hydraulic lockup have all involved EXXON NEBULA EP-0 grease. This is one of only two greases considered environmentally qualified by Limitorque.

Based on this review and findings, it is evident that hydraulic lockup of Limitorque SMB motor operators has occurred. The phenomenon appears to be a common mode failure mechanism for MOVs. In addition, the failure may tend to occur on a closure stroke, the failure may not be detected, and the MOV would not be available for the next demand. This information leads to the conclusion that operating plants are not adequately aware of the hydraulic lockup phenomenon and appear to be inadequately prepared to assess, evaluate or ensure MOV operability in this situation. Also, the industry guidance may even mislead or result in a false sense of security about the problem. Furthermore, current emphasis about use of environmentally qualified grease may expose licensees to a greater risk of occurrence of hydraulic lockup if they are not aware of the appropriate precautions concerning the motor operators.

Although the conditions that create hydraulic lockup are not fully defined, it appears to be associated with the use of EXXON NEBULA EP-0 grease. The situation can be separated into broad groups involving motor operators that were manufactured prior to approximately 1975 that need a modification kit installed; motor operators manufactured subsequent to 1975 that have a design change to alleviate lockup, but that change may not be adequate; and mis-information or lack of awareness throughout the industry about the need for the modification kit or that hydraulic lockup has occurred in motor operators that have the design change intended to prevent such operator response.

SUGGESTED ACTION

The available information illustrates that hydraulic lockup can occur in Limitorque SMB motor operators. Although the information was partially addressed by an industry communication to licensees, it appears that the effort did not have the benefit of some events discovered in this study so that the guidance appears to be inaccurate and possibly may mislead operating staff concerning whether certain corrective action was warranted. Therefore, it is

recommended that an IE information notice be prepared to alert licensees about the phenomenon and provide a description of the lockup events. This report should also be transmitted to INPO to convey the reasons for NRC concerns so that the industry communication could be revised to address this issue.

This hydraulic lockup phenomenon represents a common mode failure mechanism that was not addressed in the recent AEOD report, C603 (Ref. 4), which was transmitted to NUMARC with a request for industry action (Ref. 16) on motor operated valves. We believe this issue needs immediate attention by industry. The effort should involve both the user (licensees) and designer (Limitorque). We believe the effort should identify conditions, sequences, or procedures that result in hydraulic lockup; develop solutions for all motor operators currently in use (modification kits, design changes, etc.); and disseminate the corrective action program to all users. It is recommended that this effort be coordinated through NUMARC as part of the overall program for industry action on motor operated valves. The information should also be distributed to NRR for information and consideration in the effort on Generic Issue II.E.6.1.

REFERENCES

1. LER 271/86-012-00, Submitted for Vermont Yankee on July 10, 1986.

2. LER 271/86-012-01, Submitted for Vermont Yankee on August 22, 1986.

3. U.S. Nuclear Regulatory Commission, E. J. Brown, "Evaluation of Recent Valve Operator Motor Burnout Events," AEOD/S503, September 1985.

4. U.S. Nuclear Regulatory Commission, E. J. Brown, "A Review of Motor-Operated Valve Performance," AEOD/C603, December 1986.

5. Letter to T. E. Murley from W. P. Murphy, Vermont Yankee Nuclear Power Corporation, "Notification of Potential Existence of a Design Defect in accordance with 10 CFR 21.21," November 10, 1986.

6. Telecommunication between E. J. Brown, NRC, and R. Lopriore, et. al., Vermont Yankee, January 9, 1987.

7. Telecommunication between E. J. Brown, NRC, and D. Warsing, Limitorque, January 8, 1987.

8. LER 454/85-072, Submitted for Byron 1 for an event on July 17, 1985.

9. LER 397/86-019, Submitted for WPPSS 2 for an event on June 6, 1986.

10. Nonconformance Report (NCR) 9504 for Limerick Unit 1, February 24, 1984, Valve HV-57-111.

11. LER 352/85-102, Submitted for Limerick Unit 1 for an event on December 18, 1985 (report date January 21, 1986).

12. LER 352/85-102, Revision 1, Submitted for Limerick Unit 1 on August 20, 1986.

13. U.S. Nuclear Regulatory Commission, Inspection Report for Limerick Unit 1, 50/352 86-03, April 10, 1986.

14. U.S. Nuclear Regulatory Commission, Inspection Report for Limerick Unit 1, 50/352 86-23, December 23, 1986.

15. Letter to USNRC from K. W. Berry, Consumer Power, "Response to Safety System Functional Inspection Report Number 50-255/86-029," January 21, 1987.

16. U.S. Nuclear Regulatory Commission, Letter to W. Owen, NUMARC, from V. Stello, Request for initiatives to remedy motor-operated valve performance and reliability problems, December 10, 1986.