An Examination of Motor-Operated Valve Failures With Application to Increasing the Surveillance Testing Period at Texas Utilities Company

Comanche Peak, Units 1 and 2

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Prepared for
U.S. Nuclear Regulatory Commission

9703030018-XA

Background

In response to a request by Texas Utilities Company to extend the time interval between surveillance testing for certain motor-operated valves that have been determined to be of low safety significance, Oak Ridge National Laboratory has analyzed historical failures of motor-operated valves at Comanche Peak, units 1 and 2. Failure data were obtained from the Nuclear Plant Reliability Data System (NPRDS). Each failure narrative was reviewed and the failure characterized at ORNL by the five parameters shown in Table 1.

Limitations

If the reader is to draw accurate and useful conclusions from the data presented it is important that the limitations of the data be clearly explained and understood. There are two limitations that should be explored.

Table 1 - Coding parameters for failure characterization

Parameter	Description
Component	The failure was assigned to one of three affected areas - the valve, actuator, or electrical support.
Problem	There are three potential problem types addressed in the characterization. Problems that caused a loss of operability[1] or functionality Problems that did not cause a loss of operability or functionality Leakage related problems.
Symptom	This parameter refers to the observed condition that indicated component degradation has occurred. Typical symptoms include failure to open, failure to close or close completely, leakage (seat or packing), or in the case of degradation discovered during maintenance, no symptom at all.
Cause	The information entered here identifies the immediate cause of the observed symptom.
Method of Detection	The method of detection category identifies the activities in progress at the time of failure discovery. One of the following five activities was assigned to each failure. Demand - failures that occurred when the component was called on to function. Maintenance - failures that were discovered during preventive or corrective maintenance. Observation - assigned to failures that were detected during walkdowns or other programmatic events established to detect visible system degradation. This is most effective for detecting leakage related problems. Testing - assigned to failures that were discovered as a result of surveillance, inservice, post maintenance, or any other testing. Unknown - assigned to failures where the narrative did not give a clear indication of the activities that resulted in the detection of the failure.

[1] The term "operability," as used here is not a determination of the ability of the component to perform a safety function. The use of the term is limited to describing a loss of ability to perform a function that is part of the manufacturers design. Again, there is no attempt to determine "operability" from the licensing standpoint.

a. The data collected do not indicate the number of actuations for the given components. Therefore absolute failure rates, defined as successful actuations per attempted actuations, cannot be calculated. Relative failure rates may be calculated when there a significant number of failures attributed to the parameter in question.

b. Data that establish subcomponent replacements made during preventive maintenance are not available. For motor operated valves this means that any combination of motor, gears, or switches could be replaced during preventive or corrective maintenance, thus refurbishing the component, without the component being designated as a new component. Therefore, a component could be rebuilt to "like new" condition, but never be replaced.

Based on the above it is easily understood why the component "age" is an indeterminate parameter. Inspection and test intervals, flow conditions, and the operating environment are all unknowns. Also, since the Mean Time Between Failures (MTBF) is defined as the "Mean time between successive failures of a repairable product"[2] and only two components have more than one failure noted, MTBF will not be calculated.

Analysis

Comanche Peak is a relatively new plant, and as expected, there were very few failures for consideration. A search of the NPRDS data base identified a total of 38 failures from 1990 to 1995. This data is presented in Table 2.

The list of MOV failures was compared to the list of valves for which Texas Utilities was requesting an extension in the surveillance interval. Of the 38 valves that are identified in NPRDS as having failed, 3 are on the extension list see Appendix A). Three failures is insufficient in size to establish meaningful trends or patterns in the failure record. Therefore, the failure record for the plant (38 failures) instead of failures of valves for which an extension has been requested, will form the basis for this work.

The data show that actuator failures comprise the largest group of failures overall (Fig. 1), and for five of the six years for which there are failure data (Fig. 2). In 1990 there were more valve failures than actuator failures. Examination of the data indicate that all three of the valve failures were classified as external leakage.

Table 2 - MOV Failures by component area and year

Component	1990	1991	1992	1993	1994	1995	Total by component
Valve	3	3	2	1	1	0	10
Actuator	2	5	3	6	4	3	23
Electrical	0	4	0	0	1	0	5
Total by year	5	12	5	7	6	3	38

[2]*Quality Planning and Analysis, From Product Development through Use*, 2nd edition, p 174, J. M. Juran and F. M. Gryna, Jr., McGraw-Hill Book Company, 1980

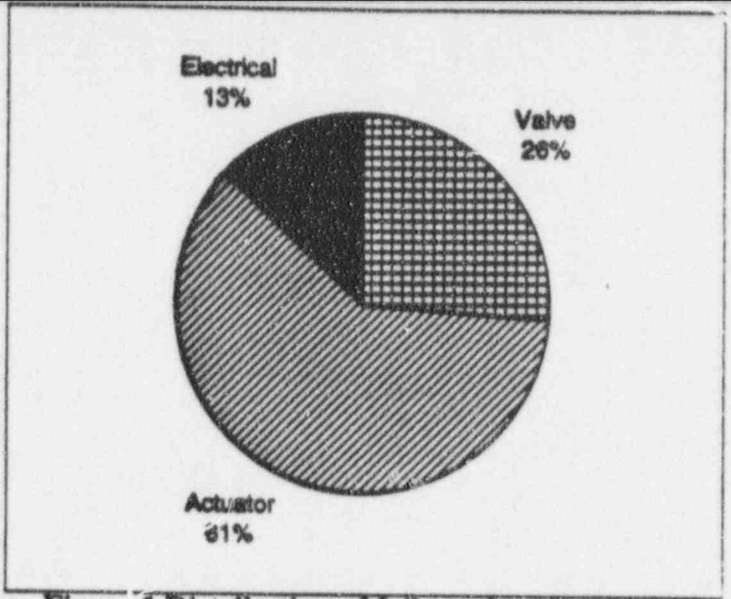

Figure 1 Distribution of failures by affected area

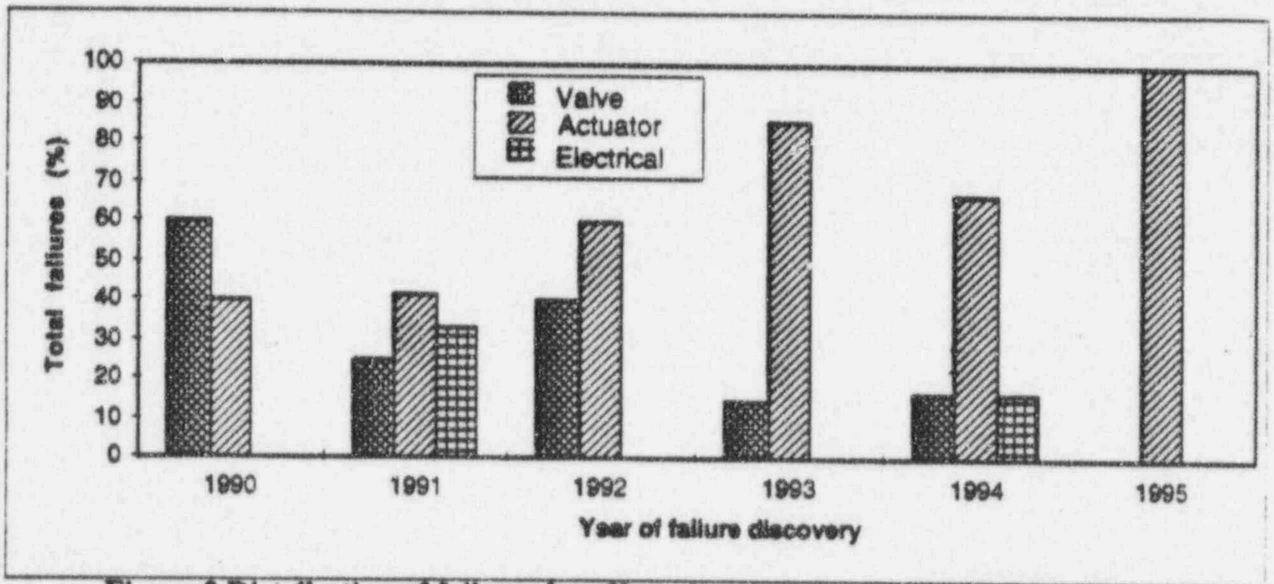

Figure 2 Distribution of failures by affected area and year of failure discovery

Two of the three leaks were at the body to bonnet joint. The other leak was the result of a casting defect in the valve body. It is reasonable to state then that the *significant* failures (failures that compromised the ability of the actuator to perform its designated function) for 1990 were the result of actuator degradation.

The number of failures per year is relatively consistent with the exception of 1991. Further examination of the data indicate four of the failures are the result of a blown fuse in the circuit for one actuator. One of the four failure narratives indicated that operations repeatedly replaced the fuse without the benefit of maintenance action to determine the cause of the degradation. Since the problem disappeared after maintenance action we can reasonably assume that three of the four blown fuses could have been avoided by proper personnel action. Dismissing the three leakage related failures as not significant, and excluding three of the four blown fuses as failures that are related to personnel error and not degradation of the equipment results in six failures for 1991. This is more consistent with the number of failures for the other years.

The data in Table 3 show the distribution of failures by symptom and year of failure. The symptoms, from a macroscopic viewpoint may be reduced from nine to four groups to allow easier graphic representation Fig. 3.

Table 3 - Failures by symptom and year

Symptom	1990	1991	1992	1993	1994	1995	Total
Failure to open or close	2	1	3	1	1	1	9
Failure to open or close completely	0	2	1	1	2	2	8
Failure to operate	0	5	0	0	0	0	5
External leakage	3	2	0	0	1	0	6
Internal leakage	0	0	1	0	0	0	1
Packing leak	0	1	0	0	0	0	1
Limit switch failed to trip	0	0	0	2	0	0	2
Motor burnout	0	0	0	2	2	0	4
None	0	1	0	1	0	0	2
Total by year	5	12	5	7	6	3	38

The first three can be grouped together and considered a "degraded stroke." All leakage related events are combined to make the second category, while limit switch and motor problems are considered degraded subcomponents. Those failures that displayed no symptom prior to discovery are left as an individual class.

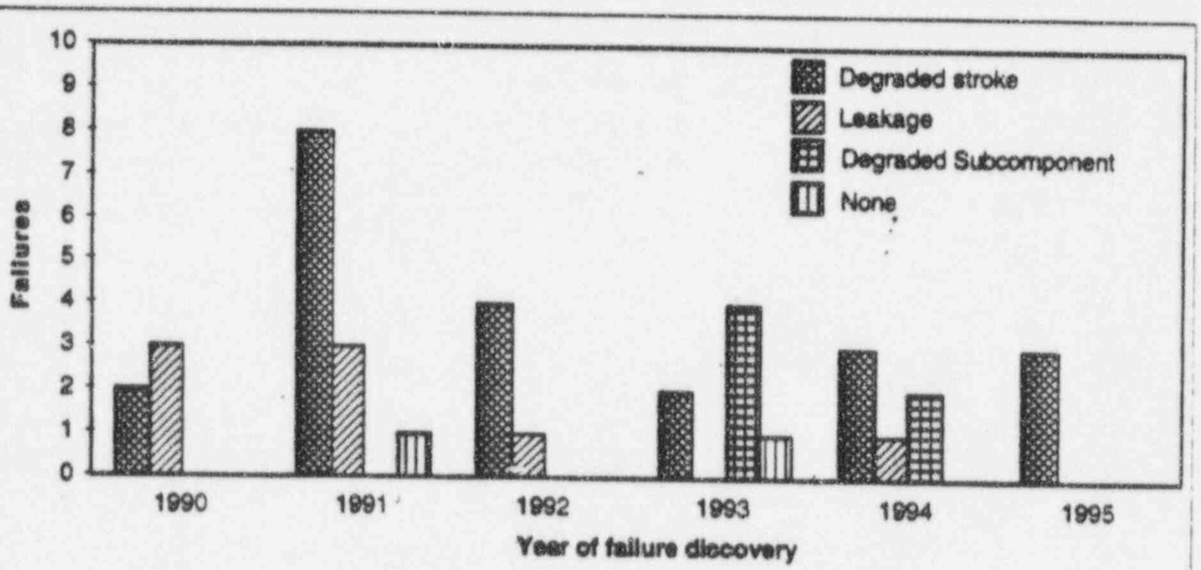

Figure 3 - Distribution of failures by symptom and year

It can be readily seen that failures that affect the ability of the actuator to complete a full stroke of the valve comprise the largest category for each year except 1990 and 1993. Again, 60% of the valve failures for that year are leakage related, and not considered significant. It is a noteworthy observation that almost 55% (12/22) of the "degraded stroke" failures, which make up the largest single category of failures, are directly related to either the failure or misadjustment of torque or limit switches.

An examination of the data by failure cause and year of failure do not reveal any single failure cause as dominant in any particular year (Table 4). The 4 failures due to a blown fuse in 1991 were previously discussed and it was determined that 3 of the 4 failures were not attributable to equipment degradation. Additionally, none of the 3 failures with where the cause is listed as unknown involved the same subcomponents, symptom of failure, or any other parameter that would relate them.

Table 4 - Failures by cause and year

Cause of Failure	1990	1991	1992	1993	1994	1995	Total
Blown fuse	0	4	0	0	0	0	4
Connector loose or damaged	0	0	0	1	0	0	1
Damaged pinion key	0	1	0	0	0	0	1
Degraded packing	0	0	0	1	0	0	1
Dirty contact	0	0	1	0	0	0	1
Improper assembly	3	0	1	0	0	0	4
Incorrect TS setting	0	1	0	2	0	1	4
LS failure	0	0	0	2	0	0	2
LS setpoint shift	1	0	1	1	2	1	6
Mfg. defect	0	1	0	0	1	0	2
Normal wear/aging	0	1	0	0	0	0	1
Previous Maintenance	0	1	0	0	0	0	1
Previous maintenance	0	0	0	0	1	0	1
Seat/disc wear	0	0	1	0	0	0	1
Single phase in MCC	0	0	0	0	2	0	2
TS setpoint shift	1	0	0	0	0	0	1
unknown	0	3	1	0	0	1	5
Total by year	5	12	5	7	6	3	38

The comparison of symptom and method of detection (Table 5) indicate that 88% of the failures detected in demand situations are related to either a complete failure of, or a degraded stroke. For these categories (failure to open/close, failure to open/close completely, or failure to operate) demand failures account for 68% of the total failures for the these categories, and 39% of the total failures for the plant.

Table 5 Symptom of failure and method of detection

Symptom	Method of Detection					Total
	Demand	Maintenance	Observation	Testing	Unknown	
External Leakage	0	1	5	0	0	6
FC	4	0	0	2	0	6
FCC	4	1	0	2	0	7
FO	2	0	0	1	0	3
FOC	0	0	0	0	1	1
FOp	5	0	0	0	0	5
Internal Leakage	0	0	0	1	0	1
LS fail to trip	0	0	0	2	0	2
Motor burnout	2	0	0	2	0	4
None	0	2	0	0	0	2
Packing leak	0	1	0	0	0	1
Total by method of detection	17	5	5	10	1	38

FO Failure to open
FOC Failure to open completely
FC Failure to close
FCC Failure to close completely
FOp Failure to operate

A tabulation of cause of failure vs. method of detection shows that the limit and torque switches account for approximately 45% of the failures. Sixteen of these failures are highlighted in Table 6. The other failure involving a switch had an unknown cause. Note that no single cause accounts for more than 16%

of the failures. Also, while demand failures account for the largest group of failures when grouped by method of detection, no single cause accounts for more than 24% of the demand failures.

Table 7 shows the data tabulated by cause and symptom of failure. Again, no single pair of parameters constitutes a significant fraction of the failures.

Table 6 Cause of failure and method of detection

Cause	Method of Detection					Total
	Demand	Maintenance	Observation	Testing	Unknown	
Blown fuse	4	0	0	0	0	4
Connector loose or damaged	0	0	0	1	0	1
Damaged pinion key	0	1	0	0	0	1
Degraded packing	0	1	0	0	0	1
Dirty contact	1	0	0	0	0	1
Improper assembly	1	1	2	0	0	4
Incorrect TS setting	0	0	0	3	1	4
LS failure	2	0	0	0	0	2
LS setpoint shift	4	0	0	2	0	6
Mfg. defect	0	0	2	0	0	2
Normal wear/aging	0	1	0	0	0	1
Previous Maintenance	0	0	1	1	0	2
Seat/disc wear	0	0	0	1	0	1
Single phase in MCC	1	0	0	1	0	2
TS setpoint shift	1	0	0	0	0	1
unknown	3	1	0	1	0	5
Total by method of detection	17	5	5	.10	1	38

Table 7 Symptom and cause of failure

Cause	Symptom							Total
	Leakage	FO/FC	FCC/FOC	FOp	LS Fail	Motor Burnout	None	
Blown fuse	0	0	0	4	0	0	0	4
Connector loose or damaged	0	0	1	0	0	0	0	1
Damaged pinion key	0	0	0	0	0	0	1	1
Degraded packing	0	0	0	0	0	0	1	1
Dirty contact	0	1	0	0	0	0	0	1
Improper assembly	3	1	0	0	0	0	0	4
Incorrect TS setting	0	0	2	0	2	0	0	4
LS failure	0	0	0	0	0	2	0	2
LS setpoint shift	0	3	3	0	0	0	0	6
Mfg. defect	2	0	0	0	0	0	0	2
Normal wear/aging	1	0	0	0	0	0	0	1
Previous Maintenance	1	0	0	0	0	1	0	2
Seat/disc wear	1	0	0	0	0	0	0	1
Single phase in MCC	0	1	0	0	0	1	0	2
TS setpoint shift	0	1	0	0	0	0	0	1
unknown	0	2	2	1	0	0	0	5
Total by symptom	8	9	8	5	2	4	2	38

Conclusions

Although the above examination was rather cursory in nature, ample evidence exists to question the technical validity of extending the inspection interval for the requested valves. The degree of wear displayed at these units does not support extending the inspection interval without further analysis of the failures, their causes, and actions implemented to prevent recurrence.

Examination of the data indicate that there is insufficient information available to conclude that there are any aging related trends for motor operated valves at Comanche Peak. It should be noted that valve components in contact with the fluid may not see aging related failures without additional service wear. It may be possible to draw some valid conclusions about the long term performance of these valves by carefully comparing data from other plants that involve valves with similar function, environment, use, test, and preventive maintenance practices.

Appendix A

The following valves are listed on the extension list from Comanche Peak and are also listed in the failure data as having failed between 1990 and 1995.

Table A1

Unit	Component ID	Cause of failure	System
1	FV-4772-1	Limit switch adjustment	Containment Spray
1	FV-4772-2	Packing leak	Containment Spray
1	HV-2492B	Body/bonnet leak	Auxiliary Feedwater

Note that only FV-4772-1 had a failure that may be considered significant