Kewaunee Nuclear Power Plant

Motor-Operated Valve

Valve Factor

and

Load Sensitive Behavior

Evaluation

C10836

MOV VALVE FACTOR AND LOAD SENSITIVE BEHAVIOR EVALUATION

1.0 PURPOSE

The purpose of this evaluation is to group safety related motor-operated valves (MOVs) into valve families and determine an appropriate valve factor and load sensitive behavior percentage for each valve family. This will be completed by performing a review of diagnostic test data for MOVs that were tested under both static and dynamic conditions. In addition, for valve families that did not have a representative sample of MOVs tested under dynamic conditions, appropriate valve factor and load sensitive behavior percentage assumptions will be determined based on industry data or industry accepted values. This evaluation is being performed to support the KNPP MOV Program in response to NRC Generic Letter (GL) 89-10.

2.0 BACKGROUND

NRC GL 89-10 recommended that nuclear plants verify the capability of their MOVs to perform their intended safety function as standard industry assumptions were determined to be non-conservative. One assumption is the valve factor, which is considered to be the valve friction coefficient under dynamic conditions. This factor accounts for loads on the valve such as differential pressure, sealing, disc and stem weight, and torque reaction. Another assumption is the load sensitive behavior percentage (LSB%), which is the difference in thrust capability between static and dynamic conditions. The LSB% is determined by comparing the thrust at torque switch trip from the static and dynamic tests. The LSB% cannot be determined for MOVs in which the torque switch is not wired into the closing control circuit.

3.0 INPUTS and ASSUMPTIONS

All safety related MOVs are grouped into families. Valve families are based on manufacturer and type; the MOVs are further grouped into sub-families based on valve size and pressure class. The list of valve families is shown in Table 1.

The KNPP valve factor determination methodology has been refined since the first MOVs were tested under dynamic conditions in 1993. The revised methodology is described in GMP 236-02, Original, for the closing valve factor. As a result of the NRC GL 89-10 Closeout Inspection performed in May, 1995, an open valve factor methodology was developed for this evaluation. Open valve factors will not be calculated for globe valves. KNPP's globe valves tested under dynamic conditions are oriented with flow under the seat, which tends to assist the actuator during the opening stroke; a true open valve factor cannot be calculated. The valve factor assumptions will be determined for each family based on either a representative sample of MOVs that were tested under both static and dynamic conditions or on available industry information.

The EPRI methodology considers the valve wedge angle to calculate the "apparent" valve factor; KNPP, as well as most other utilities, does not include the wedge angle in valve factor calculations. One utility developed a method to convert EPRI's apparent valve factor to the industry defined valve factor. This method was described at the EPRI MOV Program Review Meeting at the DFW Airport Hyatt, December 1, 1993. Table 2 shows the formulas for the conversion and the tabulated results comparing EPRI apparent valve factors to typical industry defined open and close valve factors based on the half-wedge angle, or seat angle. Of the gate valve types tested by EPRI, only the data from Anchor/Darling, Crane-Aloyco, Velan and Westinghouse valves can be applied to KNPP. A review of weak link analysis reports indicates that Crane/Aloyco and Velan gate valves have a disc half-wedge angle of 5 degrees. Per telephone conversation with an Anchor/Darling Company representative, Anchor gate valves also have a 5° half-wedge angle. KNPP's Westinghouse valve data sheets indicate a half-wedge angle of 7 degrees.

For globe valves, the orifice area can be either based on the guide or the seat area. Using the incorrect area can result in underestimating the thrust requirement. A globe valve is considered "guide-based" if the guide isolates or limits the flow prior to the disc/plug meeting the valve seat. KNPP has four types of motor-operated globe valves: 2" Rockwell/Edwards, 2" Velan, 3" Crane, and 10" Copes-Vulcan. Visual inspection of the internal components of the Edwards valves determined that they are guide-based; this conclusion is confirmed by the EPRI MOV Performance Prediction Program Implementation Guide (IG), Appendix D.

The EPRI IG states that all Y-pattern globe valves should be considered to be guide-based, however, dynamic diagnostic test traces of KNPP's Velan valves indicates that they are seat-based. The shape of the seating areas of the traces correspond very well to the EPRI IG Figure D-1, "Typical Thrust Trace for a Seat-Based Globe Valve with Flow Under the Seat," i.e. no sign of a significant peak just prior to hard seat contact. In addition, another utility indicated that they also use seat area for most globe valves including Velan valves; guide area is only used for Rockwell/Edwards and small (1" or smaller) valves. EPRI did not perform testing on any Velan Y-pattern valves.

EPRI evaluated a Crane, T-pattern, pin-guided, globe valve as being seat-based; although KNPP's Crane globe valves are not of the same Figure No., the valve design is nearly identical and will be considered seat-based. EPRI did not evaluate any Copes-Vulcan balanced plug globe valves, but review of the KNPP vendor drawing XK-113540-1 indicates that these valves should be considered seat-based.

4.0 REFERENCES

4.1 "Flow Loop Test Matrix and Test Results Data Tables" and "Assessment of Potential Implications for Installed MOV's" (partial), EPRI MOV Program Review Meeting, DFW Airport Hyatt, Dec. 1-2, 1993 (Attachment 2)

4.3 EPRI MOV Performance Prediction Program Implementation Guide, TR-103244, November, 1994

4.4 NRC Inspection Report 95-006, KNPP GL 89-10 Closeout Inspection, June 15, 1995

4.5 Telephone Conversation Documentation Sheets (Attachment 3)

5.0 CALCULATION/EVALUATION and RESULTS

The GMP 236-02 Dynamic Test Calculation Sheet was used to normalize all previous dynamic test data. The completed sheet includes the static and dynamic test data required to determine the closing valve factor and LSB%. A data sheet was also completed for each gate valve to calculate the opening valve factor; the calculation methodology is shown on the data sheets. All data sheets are included as Attachment 1 to this evaluation.

For valve families without dynamic test data, the LSB% will be assumed to be 10%, which bounds test data for 32 of 33 DP tested valves in typical MOV configurations; the four MOVs located in atypical piping configurations exhibited a LSB% that is bounded by 20%. These valves are considered a special case and will be discussed in more detail in the section on Family 7.

Table 1 indicates the calculated valve factors and LSB percentage as determined from the actual test data as well as the assumptions that may be applied to the individual MOV families as a result of this evaluation. It also indicates whether or not the MOV is within the scope of the GL 89-10 Program at KNPP. A discussion of the valve factor and LSB% assumptions for each family follows.

5.0 CALCULATION/EVALUATION and RESULTS (Cont'd.)

For discussions below, "valve factor" in reference to EPRI data is written to include the conversion from EPRI's "apparent" valve factor to the KNPP defined "valve factor." Note, after the conversion opening valve factors are smaller and closing valve factors are larger as shown in Table 2.

Where other plants were contacted to obtain valve factor data, the valve factor calculation methodology was discussed for similarity to KNPP's. Items such as the orifice diameter assumption, point of valve stroke where the valve factor was determined, running load values, and piston effect can affect the valve factor calculation. In general, other plants are using a methodology that is sufficiently similar to KNPP's for the purpose of this evaluation.

Family 1 - Aloyco Double Disc (Ball and Socket) Gate Valves

Testing at three plants indicated that the disc orientation can have an effect on the valve factor. As a result of the system configuration at one plant, the valves could be tested with flow from either direction. This plant found that the valve factors ranged from 0.134 to 0.671 for four 6 inch, 150 lb, valves tested with flow in both directions with an average valve factor of 0.287 closing and 0.290 opening. One valve indicated an unusual trace with the male disc downstream, therefore, the valve was disassembled and damage was found to the ball. This plant also performed bi-directional flow testing on four 8 inch, 300 lb, valves and found the valve factors ranged from 0.288 to 0.677 with an average of 0.519 closing and 0.437 opening. They found that the valve factor was typically slightly higher in one direction than the other and they concluded that this would be with the male disc downstream based on the test results of the damaged valve. This suggests that the female disc downstream is the "preferred" configuration. However, the disc orientation was not verified by disassembly or radiography of the valves with the exception of the damaged valve.

The two other plants tested valves with the male disc both upstream and downstream and found that valve performance was better with the male disc downstream in all cases. One of these plants also disassembled a few of their valves after testing and did not find any damage. The other plant performed limited testing on a 6" valve which indicated a valve factor of approximately 0.3 with the male disc downstream; they conservatively assume 0.55 for their Aloyco valve family. The other plant found the valve factor to range from 0.24 to 0.32 closing and 0.22 to 0.74 opening with the male disc downstream; these values are based on the pipe diameter. The tested valves are the identical design to KNPP's 6" valves, therefore, recalculating the valve factor using the mean seat diameter provided to KNPP by the valve manufacturer changes these ranges to 0.21 to 0.28 closing and 0.19 to 0.64 opening (reference Attachment 3). This plant believes the higher opening valve factor found during one test is due to a slight misalignment within the valve; it will be considered an outlier. Testing at this plant with the male disc upstream indicated a valve factor of 0.58 to 0.78 after the conversion using the mean seat diameter rather than the pipe diameter.

5.0 CALCULATION/EVALUATION and RESULTS (Cont'd.)

EPRI testing of Valve No. 15, a 4" Aloyco valve, indicated the valve factor to be bounded by 0.31. EPRI was contacted and verified that the valve is an Aloyco double disc (ball and socket) valve that was tested with the male disc (ball) oriented downstream. EPRI did not perform testing on this valve with the male disc upstream. EPRI/MPR Associates' preliminary Aloyco gate valve model equations indicate that the valve would perform better with the female disc downstream, which would result in lower valve factors than found during the testing with the male disc downstream. However, they do not have test data to support this conclusion.

The KNPP Aloyco valve family consists of sub-families, 1a, 1b, and 1c, for each of the three valve sizes, 3, 6, and 12 inch, respectively. The 6" valves will be discussed first.

KNPP performed an opening hydrostatic test on two 6" valves and determined the opening valve factor to be bounded by 0.25. The low valve factors would indicate that these valves are installed in their "preferred" configuration. These valves are normally closed with a safety function to open after the plant is aligned for containment sump recirculation. Electrical control interlocks with other MOVs prevent the inadvertent opening of these valves before they are required to open. Therefore, inadvertent opening need not be considered and the closing valve factor need not be justified further. Since these valves have a safety function to open, the open hydro testing and additional conservatism provides a basis for assuming a valve factor of 0.55 for these valves. The LSB% will be assumed to be 10%.

No plants contacted have tested any 3 inch, 150 lb Class, Aloyco double disc gate valves under dynamic conditions. The EPRI data for the 4" valve may be the most applicable data for this valve sub-family, in which case a valve factor of 0.31 is bounding. Assuming the female disc is downstream and EPRI's conclusion that the valve factor would improve with the female disc downstream, then 0.31 would still be a conservative valve factor. One of the two valves in this sub-family was disassembled for valve maintenance about 1.5 years ago. One of the mechanics who worked on the valve had drawn a sketch of the disc, but did not indicate the flow direction. After a review of the sketch and walkdown of the valve, the mechanic indicated that the male disc would be downstream. It ean be reasonably assumed that both valves in this family are oriented the same way as both these valves were installed during original construction. As discussed above, testing on 6 inch, 150 lb Class, valves at one plant indicated an average valve factor less than 0.3, which corresponds well with the EPRI 4" valve data. Based on EPRI testing and the testing at the other plants, it would appear that the valve factor increases with increasing size and pressure class for Aloyco double disc valves. Therefore, a valve factor of 0.55 is appropriate for this valve sub-family. The LSB% will be assumed to be 10%.

The 12" valves are not included in the MOV Program and do not need to be considered further. The assumed valve factor will be 0.55 and the LSB% will be 10% for consistency with the other two valve sub-families.

5.0 CALCULATION/EVALUATION and RESULTS (Cont'd.)

Family 2 - Anchor Flexible Wedge Gate Valves

All the valves in this family are 150 lb class, however, only the 6" valves are included in the MOV Program. Data from nine utilities consisting of 97 separate tests performed on Anchor flexible wedge gate valves was compiled by another utility. The utility concluded that a valve factor of 0.55 is representative for valve sizes larger than 4 inches in both the opening and closing directions. Review of the compiled test data by KNPP indicates that a 0.55 valve factor would also be appropriate for 4 inch valves, but the valve factor was typically higher for valve sizes 3 inches or less. EPRI Valve No. 3 is a 6 inch, 900 lb Class, Anchor/Darling flexible wedge gate valve and indicated a slightly higher apparent valve factor under certain system conditions, however, it appears that EPRI Valve No. 2 is a better match to KNPP's 2b sub-family in that it is a 6 inch, 150 lb Class, Anchor/Darling flexible wedge gate valve. This valve indicated a valve factor less than 0.3 under all tested conditions. In addition, the design basis DP for the valves in family 2b is less than 250 psid; compared to EPRI Valve No. 3 which was tested at 600-1900 psid. EPRI Valve No. 2 was tested at 90 psid and at 275 psid, which is closer to the KNPP design basis DP for the 6" valves. Therefore, based on the available data a 0.55 valve factor will be the assumed value for the valves in this family. The LSB% will be assumed to be 10%.

Family 3 - Atwood & Morrill Parallel Slide Gate Valves

KNPP has one Atwood & Morrill parallel slide gate valve, which was tested dynamically. The calculated closing valve factor was 0.35, which bounds the calculated opening valve factor. The assumed valve factor will be 0.4 to provide valve degradation margin as this valve was installed new during the 1993 refueling outagc. This MOV is wired to turn off the motor based on valve position, therefore, the LSB% could not be determined for this valve as its design does not allow for torque seating. Therefore, the LSB% will be assumed to be 10%.

Family 4 - Contromatics Ball Valves

No ball valves were tested under dynamic conditions and none are presently included in KNPP's MOV Program. No valve factor or LSB% assumptions were determined for these valves; none are required to meet GL 89-10 recommendations.

Family 5 - Copes-Vulcan Balanced Plug Globe Valves

Dynamic testing was performed on both of the Copes-Vulcan balanced plug globe valves, however, due to their design the valve factor could not be calculated using KNPP's methodology. The valve plug is considered balanced because system pressure is equalized above and below the plug resulting in little or no differential pressure acting on the plug. Although a true valve factor cannot be calculated, a valve factor of 1.1 will be assumed for this valve group for calculation purposes. These valves have a safety function to open only and are normally closed. In addition, they were tested at

5.0 CALCULATION/EVALUATION and RESULTS (Cont'd.)

approximately 75% of the calculated worst case desigu basis DP in the opening direction and the calculated actuator torque capability at degraded voltage exceeds the unseating torque during the DP test by over 15 times. Dynamic testing indicates that the LSB% is bounded by 10%.

Family 6 - Crane Globe Valves

Dynamic testing was not performed on any Crane globe valves, therefore, several plants were contacted in an attempt to obtain dynamic test results for KNPP's 3 inch, 600 lb class valves. Test data from one plant from four 6 inch, 300 lb, globe valves indicated an average valve factor of 1.04 and an average load sensitive behavior percentage of 3.25%. The valve manufacturer confirmed that although the pressure class ratings are different, KNPP's valve design is identical to the design of the tested valves at the other plant. A valve factor of 1.1 will be assumed for this valve group. The LSB% will be assumed to be 10%. These valves are normally closed, which is their required safety position, with their power breakers locked in the off position. The only time period when these valves are opened is during plant start-up to warm the main steam lines. It is highly improbable that these would be required to isolate a main steam line break during steam line warming. Therefore, the valve factor and LSB assumptions are appropriate.

Family 7 - Crane Solid Wedge Gate Valves

Each valve in this family was tested under dynamic conditions and a 0.6 valve factor was found to be bounding in the opening and closing directions.

The LSB% was found to be less than 1% on four of the seven MOVs in this family, however, the LSB% was found to be greater than 15%, but less than 20%, on three of the MOVs. These three, plus one other valve of this family, are located in the internal containment spray (ICS) system configured with two valves in parallel with each other and is series with the discharge of each ICS pump. As LSB is a little understood phenomenon, there are several thcories regarding its canse. One theory states that it is caused by a change in stem factor due to the different rates of loading that occurs under static and dynamic conditions. Another theory states that it may be due to side loading on the stem as a result of differential pressure and flow acting on the valve disc and stem during the closing valve stroke under dynamic conditions. It is also probable that other presently unknown causes also effect the LSB%. Six of the seven MOVs in this family are identical, i.e. same valve manufacturer, type, size, figure number, and actuator including the four ICS valves. As a result of dynamic testing of these six MOVs, it is concluded that the LSB% is not strictly dependent on the valve and/or actuator type, but may also be partly dependent on the system configuration. This parallel valve configuration is not typical at KNPP and may explain why the LSB% is unusually high for these valves. It is not presently understood why one of the four parallel valves exhibited a negative LSB%; it will be considered an outlier. Therefore, the assumed LSB% for the four ICS valves will be 20% and rest of the family will be 10%. The

5.0 CALCULATION/EVALUATION and RESULTS (Cont'd.)

10% allowance is overly conservative based on the test results of the other three MOVs, however, due to the unusually high LSB% of the ICS valves this value provides appropriate conservatism.

Family 8 - Crane Flexible Wedge Gate Valves

EPRI testing of Valve No. 14, a 6" Crane, 900 lb, flexible wedge gate valve, indicated that the valve factor was bounded by 0.49 under all conditions except blowdown. None of the valves in this family are required to operate under blowdown conditions. In addition, the untested valves at KNPP are 300 lb Class, not 900 lb, and are 8" or larger, not 6", therefore, the EPRI test data may not be directly applicable to these valves.

KNPP tested one 8" Crane flexible wedge gate valve and found the valve factors to be bounded by 0.21. This valve is a 150 lb Class and the untested valves are 300 lb Class, therefore, the data may not be directly applicable to the untested valves.

Several other nuclear plants were contacted regarding Crane flexible wedge gate valves, however, these types of valves do not appear to be prevalent in industry. The plants that do have them typically do not have dynamic test data on them, therefore, the available data is scarce. One plant tested three 4 inch valves and found the valve factor to be 0.3 or less in both directions for two of the valves and greater than 0.6 on the other valve. The latter is considered an outlier as it is a newly installed valve, which may contribute to the calculated high valve factor. KNPP's valves were installed during original construction.

Another plant provided test data for three 10" valves, but the plant itself does not calculate a valve factor. Therefore, the KNPP valve factor methodology was applied to the plant data and the valve factor was found to be bounded by 0.38 in all cases except one. The exception was in the opening direction at a value of 0.58. The opening thrust value used in the open valve factor calculation was twice that of the thrust at flow cut-off in the closing direction, therefore, this is most likely the value at the unseating peak and not representative of the thrust required to overcome the DP force which occurs just after disc unseating.

A single test on a 10" valve at another plant found the valve factor to be 0.67 opening and 0.71 closing, however, these values are based on the pipe size not the mean seat diameter of the valve. Using the mean seat diameter, the values become 0.61 and 0.64, respectively. This dynamic test was performed at less than 40 psid, therefore, the data may not accurately represent the DP forces due to data scatter.

Based on all the data collected, a 0.55 valve factor is representative of this valve design. The LSB% will be assumed to be 10%.

5.0 CALCULATION/EVALUATION and RESULTS (Cont'd.)

Family 9 - Darling Parallel Double Disc Gate Valves

KNPP has one Darling parallel double disc gate valve, which was tested dynamically. The calculated valve factor was 0.39 and the assumed valve factor will be 0.4. It is not expected that the valve factor will degrade due to the age of this valve. This value is considered acceptable for this family. The test LSB percentage is bounded by 5%. In addition, this valve is not required for accident mitigation; it is used for normal cooldown, and for long term heat removal following an accident.

Family 10 - Rockwell Edwards Globe Valves

All four valves in this family were tested under dynamic conditions, however, due to blowdown conditions and test instrumentation limitations, a valid valve factor could not be determined for two of the valves. Under blowdown conditions, the water flashes to steam. Since the piping is aligned to a standpipe, the steam condenses causing the downstream pressure to decrease after flow isolation. Therefore, a pressure "reading" at the instant of flow cutoff could not be accurately determined on the downstream gauge. However, for the other two valves, temporarily installed pressure transducers were installed downstream or upstream and downstream of the valve, which provide direct and continuous pressure readings over the valve stroke. This allowed for the determination of an accurate differential pressure value at the point of flow isolation. Dynamic testing of these two valves indicated that a 0.9 valve factor is bounding for this valve group using the guide area as the orifice area. Dynamic testing of all four valves indicated that a LSB% of 5% is also bounding. EPRI testing of Valve No. 48, a Rockwell/Edwards, 2 inch, 1500 lb Class, globe, indicated a valve factor of 0.922 at 50 ft/sec, 2500 psid, and a factor of 1.480 under blowdown conditions with a maximum DP of 2500 psid using the guide based methodology. This data is not considered to be applicable to KNPP since the pressure applied to the valves is twice that of the design basis pressure assumed for KNPP's Edwards valves. In addition, the pressure applied to the EPRI valve exceeded its ANSI Pressure Class Rating of 1500 lb by 67%. The valves in this family would be subjected to a blowdown pressure less than the valve design pressure rating, therefore, the assumed 0.9 valve factor is appropriate for this family.

Families 11 - Henry Pratt Butterfly Valves

No butterfly valves were tested under dynamic conditions and none are presently included in KNPP's MOV Program. No valve factor or LSB% assumptions were determined for these valves; none are required to meet GL 89-10 recommendations.

Family 12 - Velan Flexible Wedge Gate Valves

This valve family consists of four sub-families, a-d, for 3, 6, 8, and 12 inch valves. Dynamic testing was performed on two of the 3" valves and on the two 6" valves. One plant has test data that indicates a valve factor of 0.55 is appropriate for valves that are

5.0 CALCULATION/EVALUATION and RESULTS (Cont'd.)

required to operate at greater than 250 psid. All the KNPP valves in this family are required to operate at 450 psid or greater. Further justification for assuming a 0.55 valve factor is provided as follows.

The valve factors calculated for one of the 3" valves were unusually low, however, the results of the other valve test indicated that the opening and closing valve factors are bounded by 0.53. The two tested valves are normally open; the valve that indicated the low valve factors is not included in the KNPP MOV Program and the other is required to remain open to perform its safety function. Therefore, the in-situ test data is the best available data for these valves and no further justification is required. The two non-DP testable valves in this sub-family are identical to the tested valves. However, since one of the tested valves indicated atypical results the EPRI test data on a similar valve will be considered. Since these two valves are normally open with a safety function to close, only the closing valve factor assumption must be justified. EPRI did not test any 3" Velan valves, however, EPRI testing of Valve No. 13, a Velan 2.5 inch, 1500 lb, FWG valve, indicated a closing valve factor less than 0.52 and less than 0.3 at isolation. Therefore, an assumed valve factor of 0.55 is appropriate for these valves, also.

Testing of the 6" valves indicates that the valve factors are bounded by 0.55, except in the case of one valve in the closing direction, which was 0.58. The assumption will be 0.55 for this sub-family, since these valves are normally open with a safety function to remain open during a design basis event and are not required to close to mitigate any accident. Therefore, failure to close and isolate flow is a non-event. The valve could immediately be re-opened to perform its safety function. Although the testing was performed at less than 30% of the design basis opening DP, this data is considered the best available. EPRI testing of Valve No. 24, a 6 inch, 900 lb, FWG, indicated that the opening valve factor under high DP performance was equal to or less than the valve factor under low DP performance at the same velocity and temperature for all six tests; several of EPRI's low DP tests were less than 30% of the high DP tests. Therefore, it can be reasoned that KNPP's test data may be appropriately extrapolated to 100% of the design basis DP. The valve factors cannot be directly applied to KNPP since the EPRI valve is a 900 lb Class and KNPP's are 1500 lb Class.

The valves in sub-family 12c are normally closed and required to remain closed during all postulated events. The valves are required to open for long term core cooling. Therefore, these valves must only be evaluated for an opening mispositioning event to re-close. One plant tested two 8" Velan, 150 lb Class, flexible wedge gate valves and determined the closing valve factors to be bounded by 0.30. The opening factors were 0.5 and 0.68. This data may not be directly applicable to KNPP, since the valves in this family are 1500 lb rated. Another plant apparently tested five 8" valves, but all are located in vertical piping systems. The orientation of the valve can have a significant effect in the static and dynamic test results, therefore, this data could not be applied to KNPP. An assumed valve factor of 0.55 is appropriate for these valves based on the available data and safety function of these valves.

5.0 CALCULATION/EVALUATION and RESULTS (Cont'd.)

The valves in sub-family 12d are outside the scope of GL 89-10 and are not included in KNPP's MOV Program, therefore, no further evaluation is required.

A valve factor of 0.55 will be assumed to be representative of this entire valve family based on in-plant test results and industry information as discussed above. Dynamic testing of the four DP testable MOVs indicates that the LSB% is bounded by 10%, which will serve as the assumption for the family.

Family 13 - Velan Globe Valves

Two of the nine MOVs in this family were tested under dynamic conditions. This is considered a representative number since only three are included within the scope of KNPP's GL 89-10 Program. An assumed valve factor of 1.2 is considered to be representative for this family based on the test results. Dynamic test results indicate that the LSB% is bounded by 0%.

Family 14 - Westinghouse Flexible Wedge Gate Valves

EPRI testing of Valve No. 34, a Westinghouse 3 inch, FWG valve, indicated that the opening and closing valve factors are bounded by 0.46. However, the data is for a 1500 lb Class valve and KNPP's are 1525 lb. Six dynamic tests at other plants performed on 3" 1500 lb and 1525 lb Class valves indicated closing valve factors ranging from 0.12 to 0.90. If the 0.12 and 0.90 outliers are excluded, the average valve factor of the four remaining tests is 0.5475; including the outliers the average value becomes 0.535. These tests were performed in excess of 2500 psid. Opening valve factors were not calculated by the utility that provided this data. The KNPP valves are normally closed and required to remain closed during an accident, therefore, only the closing valve factor must be considered for an inadvertent mispositioning event. In response to an inadvertent mispositioning, these valves are only required to operate against a maximum DP of 14 psid. This pressure is nearly negligible, therefore, based on the data and low design basis DP, a valve factor assumption of 0.55 is appropriate. The LSB% will be assumed to be 10%.

Family 15 - Wm. Powell Flexible Wedge Gate Valves

This family consists of 16 inch, 900 lb Class, valves. EPRI did not perform tests on any valves of this type. A survey was performed by another utility to obtain data on Wm. Powell valves. Review of the survey results indicate that dynamic test data for 900 lb Class flexible wedge gate valves is non-existent. However, two plants performed testing on 12" and 24" valves. Testing on the 12" valves indicated that the closing valve factor was bounded by 0.50 in three of four tests and was 0.6 for the other; the average of all four tests was 0.5045. Opening valve factors were not calculated. Valve factors were determined for two 24" valves with an orifice diameter of 16", however, the results are not considered representative of KNPP's 16" valves since they are not connected to 24" piping, which could significantly affect the valve performance under dynamic conditions.

5.0 CALCULATION/EVALUATION and RESULTS (Cont'd.)

The valve factors calculated for two 24" valves were bounded by 0.56 in the opening and closing directions and at hard seat contact. These test results indicate that a valve factor assumption of 0.55 is appropriate for this valve family. The LSB% assumption will be 10%.

<u>Family 16 - Wm. Powell Solid Wedge Gate Valves</u>

Of the nineteen MOVs in this family sixteen were tested under dynamic conditions.

Dynamic tests were performed on each valve in sub-family 16a. The AFW valves failed their original dynamic tests, therefore, they were rewired to bypass the torque switch in the closing direction to a point between flow cut-off and hard seat contact and maintenance was performed on the valves in attempt to improve the valve factor. As a result of the valve maintenance and improved test instrumentation for measuring upstream and downstream pressure, the valve factors were determined to be less than 0.4 for both valves. These valves are considered outliers and due to their low margin a periodic preventative maintenance program may be implemented to maintain their low valve factors. One valve exhibited a LSB% of 11.8%; the other was determined to be 9.1%. Therefore, the valve factor for these valves will be assumed to be 0.5 with a LSB% of 12%. One of the other two valves indicated a 0.66 valve factor in both the opening and closing directions and the other was bounded by 0.52. Therefore, a valve factor of 0.66 will be applied to the former and the valve factor assumption for the other valve will be 0.60. Although the LSB% was negative for both tests, 5% will be assumed for conservatism.

Only one valve of sub-family 16b was tested under dynamic conditions. The closing valve factor was calculated to be 0.35 and the opening was 0.21. The LSB% was determined to be 4.5%. The other three valves in this sub-family are normally closed with a safety function to open only. An inadvertent opening will cause an economic impact, but has no safety impact, therefore, only the opening valve factor must be justified. In addition, the calculated actuator torque capability at degraded voltage for each valve more than doubles the torque required to unseat the valves per the last static diagnostic test results. Assuming a valve factor of 0.6 for these valves, coupled with the high available margin, is conservative. The assumed LSB% will be 10% for this sub-family.

All of the sub-family 16c valves were DP tested. A 0.5 valve factor was generally bounding, however, two valves exhibited opening valve factors greater than 0.6 and one closing factor was calculated to be 0.96. As a result of the testing, a 0.60 valve factor will be applied to the entire group, except for valves where this valve factor assumption is exceeded. For those valves, the valve specific valve factor should be used in thrust calculations. An assumed LSB% of 10% bounds test data for all valves.

Each of the sub-family 16d valves were DP tested. The valve factors were bounded by 0.51 in all cases except one where the closing valve factor was 0.75. As a result of the

5.0 CALCULATION/EVALUATION and RESULTS (Cont'd.)

testing, a 0.60 valve factor will be applied to the entire group, except for the case where the calculated valve factor exceeds this assumption. An assumed LSB% of 10% bounds test data for all valves.

KNPP has only one valve is sub-family 16e and it was DP tested. The valve factors are bounded by 0.56 and will be assumed to be 0.60. An assumed LSB% of 10% bounds test data.

The two valves in sub-family 16f were found to have negative valve factors. These two MOVs are mounted horizontally with flow from underneath the valve disc. It is believed that this configuration reduces the friction due to the weight of the stem and disc under dynamic conditions when compared to static conditions. The opening valve factors were bounded by 0.50. Therefore, a valve factor assumption of 0.6 is conservative for these valves.

6.0 CONCLUSIONS and RECOMMENDATIONS

The valve factor and load sensitive behavior percentage assumptions determined in this evaluation may be applied to MOVs within the valve families as described, except where the valve factor calculated from test data exceeds the assumed valve factor for the family. This evaluation is consistent with the intent of KNPP's MOV Program.

TABLE 1 - MOV Valve Factor and L[illegible]ensitive Behavior Evalnation

Group No.	Valve Number	GL 89-10	Normal Position	Safety Position	Valve Manufacturer	Valve Type	Valve Size	Valve Psr. Class	WPS Drawing No.	Calculated Fvc	Calculated Fvo	Calculated LSB%	Assumed Fv,LSB%
1a	CVC-211	Y	Open	Closed	Aloyco	DDG	3	150	XK100-2390	NA	NA	NA	0.55,
	CVC-212	Y	Open	Closed	Aloyco	DDG	3	150	XK100-864	NA	NA	NA	10%
1b	RHR-300A	Y	Closed	Open/Closed	Aloyco	DDG	6	300	XK100-1377	NA	0.15	NA	0.55,
	RHR-300B	Y	Closed	Open/Closed	Aloyco	DDG	6	300	XK100-1377	NA	0.25	NA	10%
1c	SI-4A	N	Open	Open	Aloyco	DDG	12	150	XK100-860	NA	NA	NA	0.55,
	SI-4B	N	Open	Open	Aloyco	DDG	12	150	XK100-860	NA	NA	NA	10%
2a	CVC-1	N	Open	None	Anchor	FWG	4	150	XK100-1280	NA	NA	NA	0.55,
	CVC-301	N	Closed	None	Anchor	FWG	4	150	XK100-1280	NA	NA	NA	10%
2b	SI-5A	Y	Open	Open/Closed	Anchor	FWG	6	150	XK100-1282	NA	NA	NA	0.55,
	SI-5B	Y	Open	Open/Closed	Anchor	FWG	6	150	XK100-1282	NA	NA	NA	10%
2c	SI-2A	N	Closed	None	Anchor	FWG	8	150	XK100-1284	NA	NA	NA	0.55,
	SI-2B	N	Closed	None	Anchor	FWG	8	150	XK100-1284	NA	NA	NA	10%
	SI-3	N	Closed	None	Anchor	FWG	8	150	XK100-1284	NA	NA	NA	
3	MS-102	Y	Closed	Open	Atwood&Morrill	PSG	3	900	XK-121910-1	0.31	0.33	NA	0.4,10%
4	LOCA-2A	N	Closed	Open/Closed	Contromatics	Ball	2	NF	XK565-1	NA	NA	NA	
	LOCA-2B	N	Closed	Open/Closed	Contromatics	Ball	2	NF	XK565-1	NA	NA	NA	NA,
	SA-7003A	N	Closed	Open/Closed	Contromatics	Ball	2	NF	XK565-1	NA	NA	NA	NA
	SA-7003B	N	Closed	Open/Closed	Contromatics	Ball	2	NF	XK565-1	NA	NA	NA	
5	SW-1300A	Y	Closed	Open	Copes-Vulcan	BPG	10	150	XK113540-1	NA	NA	0.2	1.1,
	SW-1300B	Y	Closed	Open	Copes-Vulcan	BPG	10	150	XK-113540-1	NA	NA	7.3	10%
6	MS-2A	Y	Closed	Closed	Crane	Globe	3	600	XK205-2,-6	NA	NA	NA	1.1,
	MS-2B	Y	Closed	Closed	Crane	Globe	3	600	XK205-2,-6	NA	NA	NA	10%
7a	ICS-5A	Y	Closed	Open	Crane	SWG	6	300	XK204-108	0.53	0.49	18.1	
	ICS-5B	Y	Closed	Open	Crane	SWG	6	300	XK204-108	0.60	0.48	18.5	0.6,
	ICS-6A	Y	Closed	Open	Crane	SWG	6	300	XK204-108	0.52	0.43	-2.6	20%
	ICS-6B	Y	Closed	Open	Crane	SWG	6	300	XK204-108	0.55	0.43	16.7	
7b	RHR-400A	Y	Closed	Open/Closed	Crane	SWG	6	300	XK204-108	0.15	0.13	0.6	0.6,
	RHR-400B	Y	Closed	Open/Closed	Crane	SWG	6	300	XK204-108	0.41	0.22	-1.1	10%
7c	CC-400A	Y	Closed	Open	Crane	SWG	10	150	XK100-970	0.58	0.59	-6.1	0.6, 10%

SWG = Solid Wedge Gate
FWG = Flexible Wedge Gate
DDG = Double Disc Gate
PSG = Parallel Slide Gate

PDDG = Parallel Double Disc Gate
BPG = Balanced Plug Globe
NA = Not Available/Not Applicable
NF = Not Found

Fvc = Closing Valve Factor
Fvo = Opening Valve Factor
Fv = Assumed Valve Factor for both directions
LSB% = Load Sensitive Behavior Percentage

TABLE 1 - MOV Valve Factor and [illegible]ensitive Behavior Evaluation

Group No.	Valve Number	GL 89-10	Normal Position	Safety Position	Valve Manufacturer	Valve Type	Valve Size	Valve Psr. Class	WPS Drawing No.	Calculated Fvc	Calculated Fvo	Calculated LSB %	Assumed Fv,LSB %
8a	CC-600	Y	Open	Open	Crane	FWG	8	150	XK100-2380	0.19	0.21	1.3	.55, 10%
8b	ICS-2A	Y	Open	Open/Closed	Crane	FWG (Split)	8	300	XK204-109	NA	NA	NA	0.55,
	ICS-2B	Y	Open	Open/Closed	Crane	FWG (Split)	8	300	XK204-109	NA	NA	NA	10%
8c	SI-300A	Y	Open	Open/Closed	Crane	FWG (Split)	10	300	XK100-972	NA	NA	NA	0.55,
	SI-300B	Y	Open	Open/Closed	Crane	FWG (Split)	10	300	XK100-972	NA	NA	NA	10%
8d	SI-350A	Y	Closed	Open	Crane	FWG (Split)	12	300	XK100-976	NA	NA	NA	
	SI-350B	Y	Closed	Open	Crane	FWG (Split)	12	300	XK100-976	NA	NA	NA	0.55,
	SI-351A	Y	Closed	Open	Crane	FWG (Split)	12	300	XK100-976	NA	NA	NA	10%
	SI-351B	Y	Closed	Open	Crane	FWG (Split)	12	300	XK100-976	NA	NA	NA	
9	RHR-11	Y	Closed	Open/Closed	Darling	PDDG	10x8x10	1500	XK100-870	0.39	0.50	1.7	0.4, 5%
10	BT-2A	Y	Open	Closed	Edwards	Globe	2	1500	XK204-2011	NA	NA	1.3	
	BT-2B	Y	Open	Closed	Edwards	Globe	2	1500	XK204-2011	NA	NA	2.2	0.9,
	BT-3A	Y	Open	Closed	Edwards	Globe	2	1500	XK204-2011	0.85	NA	-0.8	5%
	BT-3B	Y	Open	Closed	Edwards	Globe	2	1500	XK204-2011	0.71	NA	2.4	
11	SW-10A	N	Open	Open	Henry Pratt	Butterfly	16	150	XK252-2,-14	NA	NA	NA	NA,
	SW-10B	N	Open	Open	Henry Pratt	Butterfly	16	150	XK252-2,-14	NA	NA	NA	NA
12a	PR-1A	Y	Open	Closed	Velan	FWG	3	1500	XK100-908	NA	NA	NA	
	PR-1B	Y	Open	Closed	Velan	FWG	3	1500	XK100-908	NA	NA	NA	0.55,
	SI-9A	Y	Open	Open	Velan	FWG	3	1500	XK100-908	0.42	0.53	5.6	10%
	SI-9B	N	Open	None	Velan	FWG	3	1500	XK100-908	-0.08	0.10	7.2	
12b	SI-302A	Y	Open	Open	Velan	FWG	6	1500	XK100-910	0.48	0.36	-0.3	0.55,
	SI-302B	Y	Open	Open	Velan	FWG	6	1500	XK100-910	0.58	0.43	-1.1	10%
12c	RHR-1A	Y	Closed	Open/Closed	Velan	FWG	8	1500	XK100-911	NA	NA	NA	
	RHR-1B	Y	Closed	Open/Closed	Velan	FWG	8	1500	XK100-911	NA	NA	NA	0.55,
	RHR-2A	Y	Closed	Open/Closed	Velan	FWG	8	1500	XK100-911	NA	NA	NA	10%
	RHR-2B	Y	Closed	Open/Closed	Velan	FWG	8	1500	XK100-911	NA	NA	NA	
12d	SI-20A	N	Open	Open	Velan	FWG	12	1500	XK100-915	NA	NA	NA	0.55,
	SI-20B	N	Open	Open	Velan	FWG	12	1500	XK100-915	NA	NA	NA	10%

NOTES

1. Some family 8 valves are called "Split Wedge" by the manufacturer; the vendor drawing depicts a typical flexible wedge.
2. A Valve Factor could not be determined for BT-2A/B due to Blowdown conditions and test instrumentation.

TABLE 1 - MOV Valve Factor and [illegible]ensitive Behavior Evaluation

Group No.	Valve Number	GL 89-10	Normal Position	Safety Position	Valve Manufacturer	Valve Type	Valve Size	Valve Psr. Class	WPS Drawing No.	Calculated Fvc	Calculated Fvo	Calculated LSB%	Assumed Fv,LSB%
13	CVC-440	N	Closed	None	Velan	Globe	2	1500	XK100-905	NA	NA	NA	1.2, 0%
	LD-60	N	Closed	None	Velan	Globe	2	1500	XK100-905	NA	NA	NA	
	SI-11A	N	Open	Open	Velan	Globe	2	1500	XK100-905	NA	NA	NA	
	SI-11B	N	Open	Open	Velan	Globe	2	1500	XK100-905	NA	NA	NA	
	SI-15A	N	Closed	Open	Velan	Globe	2	1500	XK100-905	NA	NA	NA	
	SI-15B	N	Closed	Open	Velan	Globe	2	1500	XK100-905	NA	NA	NA	
	SI-208	Y	Open	Open/Closed	Velan	Globe	2	1500	XK100-905	0.31	NA	-0.4	
	SI-209	Y	Open	Open/Closed	Velan	Globe	2	1500	XK100-905	1.23	NA	-0.7	
	SW-1400	Y	Closed	Open	Velan	Globe	2	1500	XK100-905	NA	NA	NA	
14	MD(R)-323A	Y	Closed	Closed	Westinghouse	FWG	3	1525	XK-05572-19	NA	NA	NA	0.55, 10%
	MD(R)-323B	Y	Closed	Closed	Westinghouse	FWG	3	1525	XK-05572-19	NA	NA	NA	
15	FW-12A	Y	Open	Closed	Wm. Powell	FWG	16	900	XK124-17	NA	NA	NA	0.55, 10%
	FW-12B	Y	Open	Closed	Wm. Powell	FWG	16	900	XK124-17	NA	NA	NA	
16a	AFW-10A	Y	Open	Open/Closed	Wm. Powell	SWG	3	900	XK204-1640-1	0.24	0.24	11.8	0.5, 12%
	AFW-10B	Y	Open	Open/Closed	Wm. Powell	SWG	3	900	XK204-1640-1	0.37	0.23	9.1	
	MS-100A	Y	Open	Open/Closed	Wm. Powell	SWG	3	900	XK204-1638-1	0.66	0.66	-0.2	0.6, 5%
	MS-100B	Y	Open	Open/Closed	Wm. Powell	SWG	3	900	XK204-1638-1	0.40	0.52	-2.4	
16b	CC-653	Y	Open	Close	Wm. Powell	SWG	3	150	XK204-1675-1	0.21	0.35	4.5	0.6, 10%
	SW-502	Y	Closed	Open	Wm. Powell	SWG	3	150	XK204-1668-1	NA	NA	NA	
	SW-601A	Y	Closed	Open	Wm. Powell	SWG	3	150	XK204-1649-1	NA	NA	NA	
	SW-601B	Y	Closed	Open	Wm. Powell	SWG	3	150	XK204-1649-1	NA	NA	NA	
16c	CC-601A	Y	Open	Open	Wm. Powell	SWG	4	150	XK204-1674-1	0.27	0.66	6.6	0.6, 10%
	CC-601B	Y	Open	Open	Wm. Powell	SWG	4	150	XK204-1674-1	0.96	0.64	-6.4	
	CC-612A	Y	Open	Open	Wm. Powell	SWG	4	150	XK204-1674-1	0.47	0.28	-2.0	
	CC-612B	Y	Open	Open	Wm. Powell	SWG	4	150	XK204-1674-1	0.29	0.23	4.3	
16d	SW-903A	Y	Open	Open	Wm. Powell	SWG	8	150	XK124-57	0.36	0.49	7.9	0.6, 10%
	SW-903B	Y	Open	Open	Wm. Powell	SWG	8	150	XK124-57	0.75	0.35	7.7	
	SW-903C	Y	Open	Open	Wm. Powell	SWG	8	150	XK124-57	0.37	0.32	7.8	
	SW-903D	Y	Open	Open	Wm. Powell	SWG	8	150	XK124-57	0.51	0.33	3.4	
16e	CC-400B	Y	Closed	Open	Wm. Powell	SWG	10	150	XK204-1673-1	0.47	0.56	5.8	0.6, 10%
16f	CC-6A	Y	Open	Open	Wm. Powell	SWG	12	150	XK204-1752	-0.52	0.48	-3.0	0.6, 10%
	CC-6B	Y	Open	Open	Wm. Powell	SWG	12	150	XK204-1752	-0.12	0.08	-4.2	

TABLE 2- EPRI Apparent" Valve Factor Conversion

EPRI u	a = 5° = 0.08727 rad		a = 7° = 0.12217 rad	
	Fvc	Fvc	Fvc	Fvo
0.30	0.31	0.29	0.31	0.29
0.31	0.32	0.30	0.32	0.30
0.32	0.33	0.31	0.34	0.31
0.33	0.34	0.32	0.35	0.32
0.34	0.35	0.33	0.36	0.33
0.35	0.36	0.34	0.37	0.34
0.36	0.37	0.35	0.38	0.35
0.37	0.38	0.36	0.39	0.36
0.38	0.39	0.37	0.40	0.37
0.39	0.41	0.38	0.41	0.37
0.40	0.42	0.39	0.42	0.38
0.41	0.43	0.40	0.43	0.39
0.42	0.44	0.41	0.45	0.40
0.43	0.45	0.42	0.46	0.41
0.44	0.46	0.43	0.47	0.42
0.45	0.47	0.43	0.48	0.43
0.46	0.48	0.44	0.49	0.44
0.47	0.49	0.45	0.50	0.45
0.48	0.50	0.46	0.51	0.46
0.49	0.51	0.47	0.53	0.47
0.50	0.52	0.48	0.54	0.47
0.51	0.54	0.49	0.55	0.48
0.52	0.55	0.50	0.56	0.49
0.53	0.56	0.51	0.57	0.50
0.54	0.57	0.52	0.58	0.51
0.55	0.58	0.53	0.59	0.52
0.56	0.59	0.54	0.61	0.53
0.57	0.60	0.54	0.62	0.54
0.58	0.61	0.55	0.63	0.55
0.59	0.62	0.56	0.64	0.55
0.60	0.64	0.57	0.65	0.56

Formulas (Reference 1)

u = EPRI "Apparent" Valve Factor

Fvc = Closing Valve Factor = u/(cosa-usina)

Fvo = Opening Valve Factor = u/(cosa+usina)

a = disc half-wedge angle

References

1) "Assessment of Potential Implications for Installed MOVs," EPRI MOV Program Review Meeting, DFW Airport Hyatt, Dec. 1, 1993

2) P.O. 97686, Velan Thrust and Weak Link Calculation

3) P.O. 97687, Crane-Alcyco Thrust and Weak Link Calculation

4) P.O. 77363, Westinghouse Gate Valve Data Sheets