KVAP

The Leading AOV/MOV Software...

...Serving the Energy Industries

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Table of Contents

Introduction to KVAP

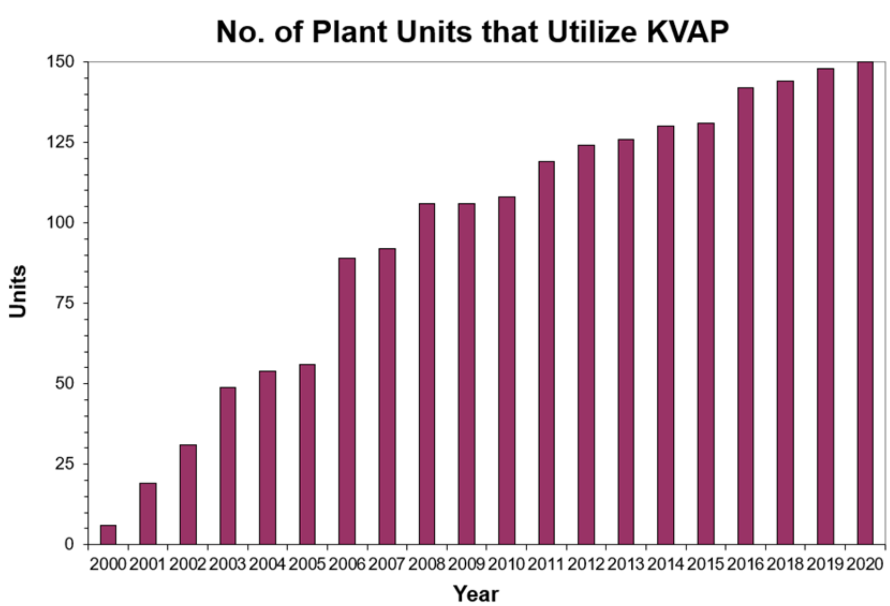
…*The Leading AOV/MOV Software in the Industry*

KVAP, the Kalsi Valve & Actuator Program, is a state-of-the-art software developed by Kalsi Engineering, Inc. (KEI) for performing reliable design basis calculations for all common types of valves and actuators used in air operated valves (AOVs) and motor operated valves (MOVs).

The KVAP software represents a significant advancement over all other AOV/MOV design basis calculation software packages available in the industry (e.g. EPRI MOV PPM, ACE, Teledyne-Midas, as well as spreadsheets used by plants) because it incorporates ***validated models that the industry was lacking*** for many different types of valves commonly used in AOV/MOV applications. These validated models are the outcome of a very ***comprehensive flow loop testing program*** conducted by KEI to overcome the limitations of valve manufacturers' data, and the new database of torque/flow coefficients in KVAP, based upon four years of extensive flow loop testing on a wide range of valve designs, provides more accurate, position dependent bounding predictions, while eliminating excessive conservatism, as well as, non-conservatism found in the EPRI MOV PPM software (see the Part 21 and EPRI Error Notices in the proposal). *This is especially important in satisfying new design basis verification requirements of ASME O&M Code Mandatory Appendices III & IV.*

KVAP was developed by the same KEI valve specialists who previously developed the EPRI MOV PPM and software modules. All testing, analytical model development, software development, and verification and validation activities were rigorously performed under the KEI Quality Assurance program, which meets 10CFR50 Appendix B requirements.

KVAP software is routinely updated to incorporate new industry issues and user feedback. For example, threshold friction coefficients from the Joint Owners' Group (JOG) Motor Operated Valve (MOV) Periodic Verification (PV) program have been included in the latest KVAP release. Because of continuous enhancements, KVAP has become the leading industry software, as shown in the figure below.



KVAP Benefits

Key advantages offered by KVAP to its users at over 150 nuclear power plant units:

- KVAP is the only software that includes validated valve models with position dependent accuracy (necessary for AOV evaluations) that the industry was lacking; these enable *reliable* design basis calculations for accurately quantifying AOV/MOV margins, not possible with previous industry models.
- KVAP models are based upon/validated against a comprehensive database of 10CFR50 Appendix B test results for incompressible flow and compressible flow tests performed on all common types of quarter-turn valves (***over 2500 tests***), that provide *reliable predictions* while *eliminating excessive conservatism* in earlier models (e.g., EPRI MOV PPM). KVAP models provide more accurate, bounding predictions that typically result in larger margins in AOVs/MOVs. **This will meet ASME OM Code, Mandatory Appendices III & IV requirements without the need for the plant to perform dynamic stroke tests.**
- The larger margins in AOVs/MOVs provided by KVAP eliminate unnecessary equipment modifications, especially those, resulting from excessively conservative methodologies (e.g., EPRI MOV PPM) in many applications
- The larger margins in AOVs/MOVs provided by KVAP reduce the frequency of periodic verification testing required to meet the Joint Owners Groups recommendations
- KVAP validated models eliminate the need for expensive in-situ dynamic testing, resulting in savings of thousands of dollars per valve
- The user-friendly graphic interface eliminates potential errors commonly made during calculations, enabling a more efficient completion of evaluations
- KVAP does not have the non-conservatism found, and limitations imposed in the use of the EPRI MOV PPM models as identified in the following Part 21 and Error Notices :
    - PPM Software Error Notice 2010-1 (Potential Non-Conservatism in Ball and Plug Valve Torque Predictions) *Note: EPRI has withdrawn this model from the PPM.*
    - 10CFR21 Notification by EPRI Regarding Potential Non-Conservatism of EPRI's MOV Performance Prediction Methodology (PPM) Butterfly Valve Model under Compressible Flow Conditions, 13-April-07
    - PPM Software Error Notice 2007-1 (Potential Non-Conservatism in Butterfly Valve Model Predictions under Compressible Flow Conditions) 12-Mar-07
    - PPM Software Error Notice 2005-1 (Minimum Required Thrust Unconservative in Self Actuating Portion of Stroke)
    - PPM Software Error Notice 2004-2 (Potential Non-Conservatism in Butterfly Valve Model Predictions under Compressible Flow Conditions) 22-Oct-04
    - PPM Software Error Notice 2003-2 (Required Adjustments to Butterfly Valve Disc Angle Dependent Torque Predictions) 19-Dec-03
    - PPM Software Error Notice 2003-1 Version 3.0 (Build 3.0.50) and Version 3.1 (Build 3.1.8) (Proximity of Upstream Disturbances) 9-Apr-03
    - PPM Software Information Notice 2002-1 (Prediction of Butterfly Valve Design Basis Required Torque as a Function of Disk Position) 6-May-02
    - PPM Version 3.0 (Build 3.0.50) Software Error Notice 2001-1 (Butterfly Valve Stem Orientation) 6-Nov-01

Cost Savings

Many KVAP users have reported savings in excess of $500,000 achieved by avoiding unwarranted equipment replacement in valves previously determined to have negative or low margins, ALARA savings and elimination of dynamic testing requirements. The enhanced models in KVAP can also potentially yield increased MOV margins that can help extend static periodic verification test intervals.

Continuity of Service to our Clients

KVAP software was developed by a team of KEI specialists who are recognized as leaders in the industry for technological advances in AOVs and MOVs, and for providing continuous service to our clients. The software is backed by comprehensive training and technical support offered by this highly capable KVAP team.

KEI staff prides itself in successfully and cost effectively meeting our client’s goals and continuously serving the industry for over 40 years.

Overview of Kalsi Engineering Flow Loop Testing and Validated Model Development Program for KVAP

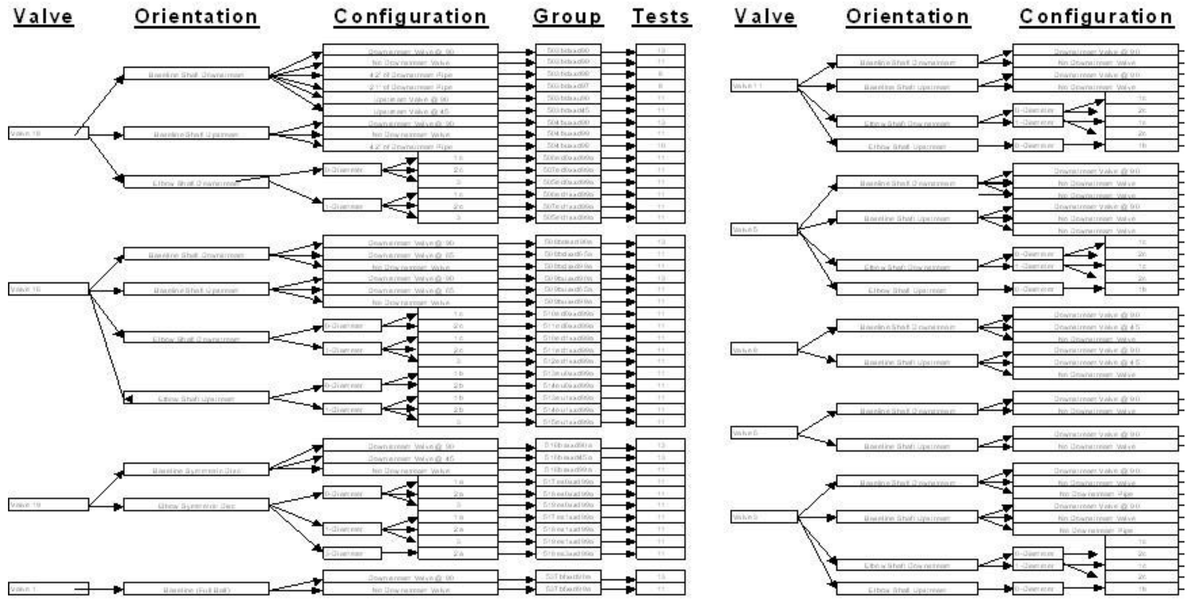
As summarized in USNRC Regulatory Issue Summary 2000-03, problems with power-operated valves have resulted in an increased emphasis by USNRC on improving their performance reliability and predictability. In response, the Joint Owners Group for Air-Operated Valves (JOG AOV) developed a document to provide guidance and define minimum requirements to the utilities for implementing valve programs. Additionally, four utilities performed design basis calculations under EPRI's pilot programs. This resulted in a calculation methodology which is documented in the EPRI AOV Evaluation Guide (TR107322).

These EPRI AOV pilot plant programs, and the implementation of the AOV Evaluation Guide methodologies at other plants, revealed three key problems:

- There are *no validated models* for several types of quarter-turn valves (e.g., spherical ball, V-notch ball, eccentric plug) that constitute a large AOV population; *unvalidated* approaches had to be used for design basis calculations. This can lead to unreliable AOV performance, based on industry experience and lessons learned from MOVs.
- EPRI MOV PPP methodology for symmetric and many single-offset butterfly valves was found to *provide negative margin* for AOVs. The original PPM models were based on a very limited amount of butterfly valve tests in incompressible flow applications. To cover valve applications that were not tested and uncertainties, additional conservatism was added in the PPM. This excessive conservatism caused the EPRI methodology to predict low or negative margins for AOVs that, in fact, have larger margins and capability to operate under design basis conditions.
- Subsequent compressible flow testing performed by Kalsi Engineering revealed that the EPRI MOV PPP methodology was *non-conservative* in compressible flow applications (See Part 21 and EPRI Error Notices on page 3).

This testing led to improved and validated methodologies that accurately predict torque requirements for all types of quarter-turn valves prevalent in nuclear applications.

A comprehensive matrix of flow loop testing was performed to develop more accurate validated models for AOVs incorporated in KVAP.

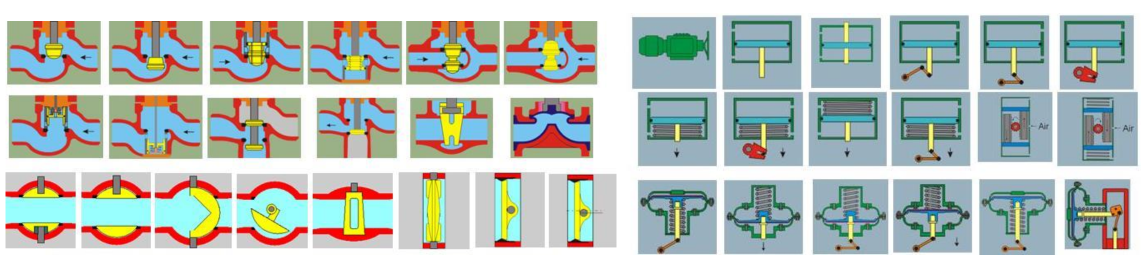


Quarter-turn Valve Test Matrix

Incompressible: 15 Valve Designs, 71 Configurations, 1,272 Tests

Compressible: 9 Valve Designs, 84 Configurations, 1,116 Tests

The KVAP software and its extensive database capabilities incorporate the new validated models for quarter-turn valves developed under this program. KVAP also includes validated/first principles based industry established models for all other common types of globe, gate, and diaphragm valves and actuators to offer a complete software package for reliable and efficient calculations. KVAP software development, analytical models, flow loop test program, and verification and validation meet the requirements of 10CFR50 Appendix B.



KVAP includes models for all common types of linear (globe, gate, diaphragm) and quarter-turn (butterfly, ball, plug) valves & actuators.

KVAP Software Capabilities

The Kalsi Valve & Actuator Program is a state-of-the-art software that efficiently performs reliable design basis calculations for all common types of globe, gate, diaphragm, butterfly, ball, and plug valves as well as linear and quarter-turn actuators used in POV applications.

KVAP is the only POV software in the industry that includes a number of new validated valve models based on first principles supported by extensive CFD analyses and 10CFR50 Appendix B testing. These new models are applicable to several types of valves that are common to AOV applications which had not been addressed by the EPRI MOV PPM, JOG AOV, NSSS Owners Groups, valve manufacturers, or other organizations marketing competing software.

KVAP includes a comprehensive database of 10CFRR50 Appendix B test results to accurately predict torque/thrust requirements for various types of POVs under design basis conditions. The flow loop test matrix to support KVAP development and validation included over 2,000 static and dynamic tests to cover variations in valve/disc geometry, elbow orientation, elbow distance, flow direction, flow rates, and maximum ΔP. KVAP provides geometry-specific torque and flow coefficients for baseline conditions and for elbow effects.

In many POV applications, the new KVAP models for quarter-turn valves provide a substantial increase in margin between valve requirements and actuator capabilities, thus eliminating unnecessary equipment modifications. ***The KVAP database and the more accurate models have already demonstrated substantial cost savings for the plants.***

From inception, KVAP software development was planned with a well-structured modular approach to minimize the cost and time associated with the V&V effort for upgrades and revisions. ***This ensures that new data and improvements to address emerging industry issues for POVs can be efficiently incorporated, verified, and validated in KVAP.***

The KVAP software input and output screens are heavily supported by graphics that illustrate critical features and dimensions of the valve being analyzed, valve orientation, flow direction, elbow orientation, required valve thrust/torque throughout the stroke, minimum and maximum actuator capability throughout the stroke, and margin throughout the stroke. ***This user-friendly graphic interface eliminates mistakes and errors commonly made during POV calculations.***

KVAP was developed by a team of Kalsi senior specialists who are recognized as leaders in the industry for technological advances in valves and actuators. Our specialists have more than 30 years of continuous involvement in R&D to develop validated first principles models and software for valves and actuators to address generic industry-wide issues, including the EPRI MOV Performance Prediction Program and MOV guides. This experience is supplemented by performing design basis calculations and implementing MOV, AOV and Check Valve and Condition Monitoring programs at the majority of the U.S. nuclear power plants.

KVAP Scope of Valves and Actuators

KVAP software is capable of evaluating *all* common types of AOV/MOV valves and actuators:

Valve Types

Linear (direct & reverse acting, as applicable)

- Gate-Solid, Flexible, Parallel Slide
- Gate-Aloyco Split Wedge
- Gate-Anchor-Darling Double Disc
- Globe-Unbalanced
- Globe-Balanced, Cage
- Globe-Balanced, Double Disc
- Globe-Balanced, Pilot
- Globe-3-way Converging, Single Disc
- Globe-3-way Converging, Double Disc
- Globe-3-way Diverging, Single Disc
- Globe-3-way Diverging, Double Disc
- Rising & Rotating Globe Valves
- Diaphragm

Quarter-Turn

- Symmetric Butterfly
- Single-Offset Butterfly
- Double-Offset Butterfly
- Triple-Offset Butterfly
- Segmented V-Ball
- Spherical Ball
  - *floating and trunnion mounted*
- Eccentric Plug
- Tapered/Cylinder Plug

Other

- External Data

Actuator Types

Linear

- Cylinder
  - *Single acting w/spring*
  - *Double acting*
  - *Double acting, double ended*
  - *Double acting w/spring*
- Diaphragm
  - *Single acting w/spring*

Quarter-Turn

- Scotch Yoke
  - *Single acting w/spring*
  - *Double acting*
- Rack & Pinion
  - *Single acting w/spring*
  - *Double acting*
- Cylinder with Linkage (2 types)
  - *Single acting w/spring*
  - *Double acting*
- Diaphragm with Lever
  - *Single acting w/spring*
- Pivot Cylinder

Electric Motor

- Limitorque
- Rotork
- Auma,
- Autotork

Other

- External Data
  - *any air, hydraulic, or electric motor actuator with defined output vs. stroke*

Other KVAP Features/Capabilities

- Analyzes incompressible, compressible, choking, flashing flow
- Includes *valve geometry-specific* upstream elbow effect coefficients for butterfly, ball, and plug valves
- Evaluates mid-stroke margins
- Provides extremely user-friendly, intuitive *graphical* user interface and comprehensive database capabilities
- Well planned modular structure for efficient V&V to support upgrades/new capabilities
- Operates on Windows operating systems

Applications, Advantages, and Benefits

- Performs *reliable* POV design basis calculations, including minimum required thrust/torque, actuator capabilities and margin
- Eliminates the need for dynamic ΔP testing, saving tens of thousands of dollars per valve
- Provides models for double-offset butterfly, full ball, segmented ball, and plug valves, for which no validated models were available in the industry
- Eliminates excessive conservatism in EPRI PPM models; increases margin
- Eliminates unnecessary equipment modifications and/or repeat calculations to address low/negative margins
- Extremely intuitive, user-friendly graphical interface improves efficiency and eliminates errors
- Troubleshoots valve performance problems

Continuous Enhancements Based on User/Industry Feedback

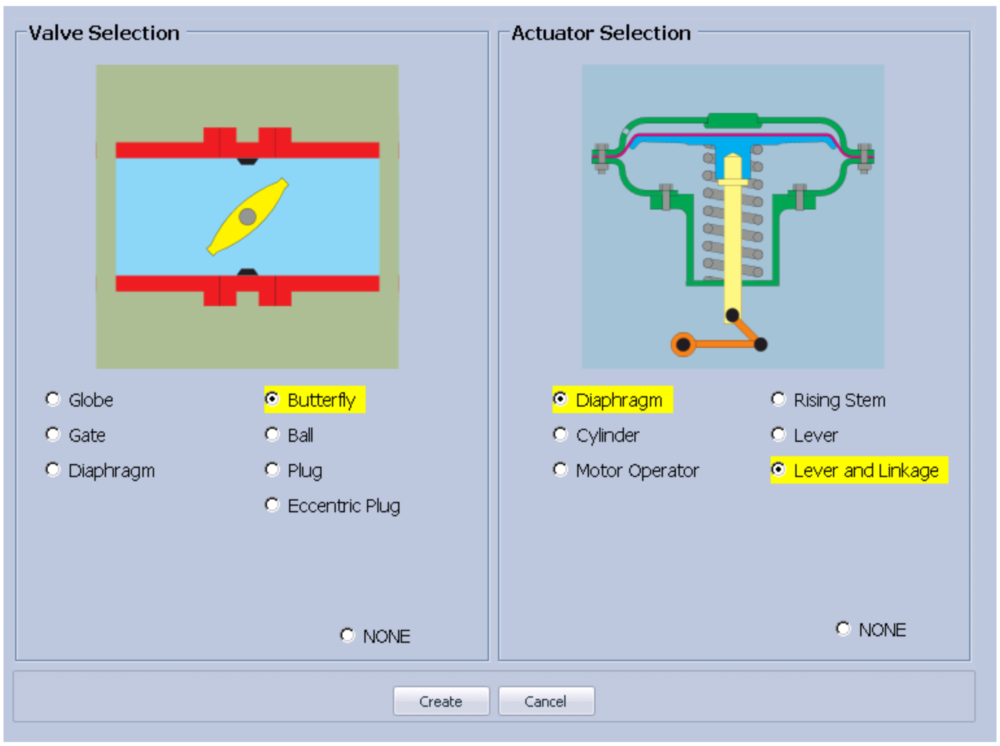
KVAP is being actively expanded/enhanced and supported to address industry wide emerging issues and requirements and feedback from its 50+ current users. Some of the recent enhancements include the AOV Setup Box and set point data sheets for efficient implementation and verification of the design basis calculations in the field, efficient implementation of the Joint Owners Group MOV Periodic Verification recommendations.

Typical **KVAP** Screens

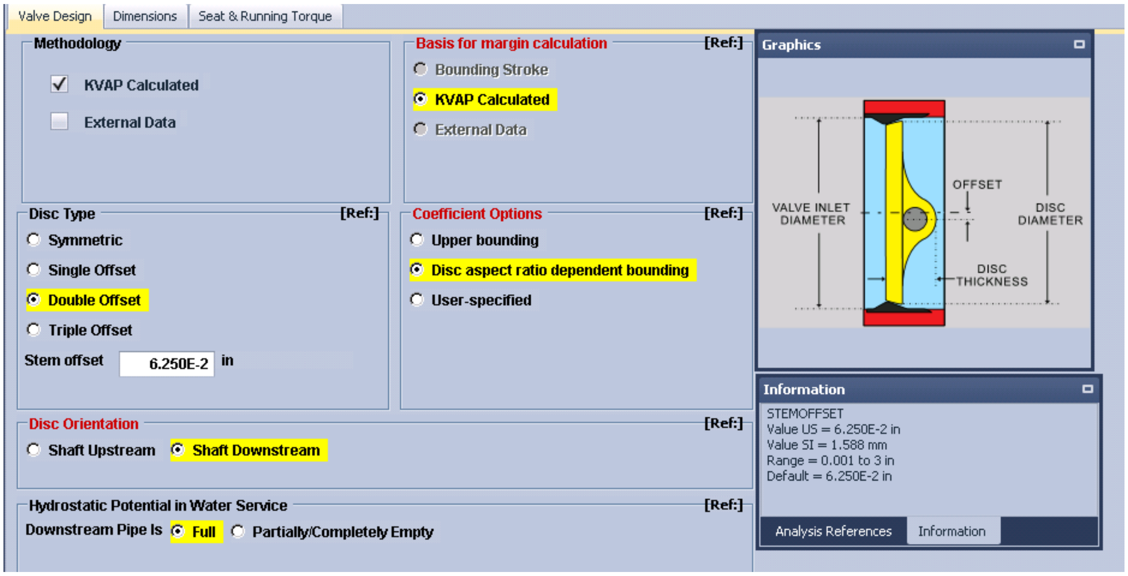
The KVAP software input and output screens are heavily supported by graphics that illustrate critical features and dimensions of the valve being analyzed, valve orientation, flow direction, elbow orientation, required valve thrust/torque throughout the stroke, minimum and maximum actuator capability throughout the stroke, and margin throughout the stroke. ***This user-friendly graphic interface eliminates the potential for errors commonly made during POV calculations.***

Some examples of input and output screens follow:

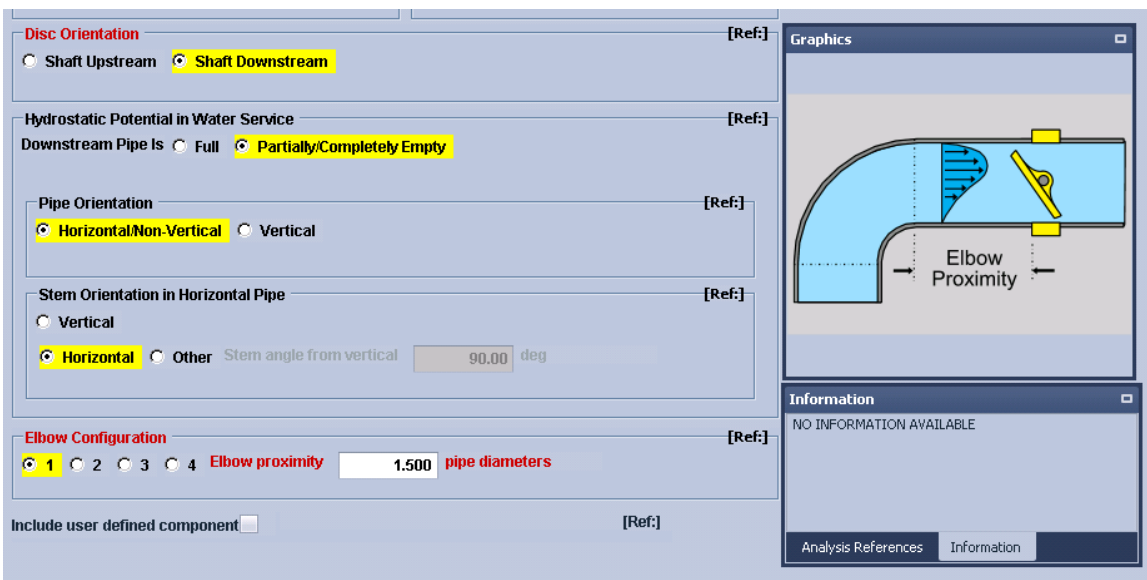
KVAP Main Menu



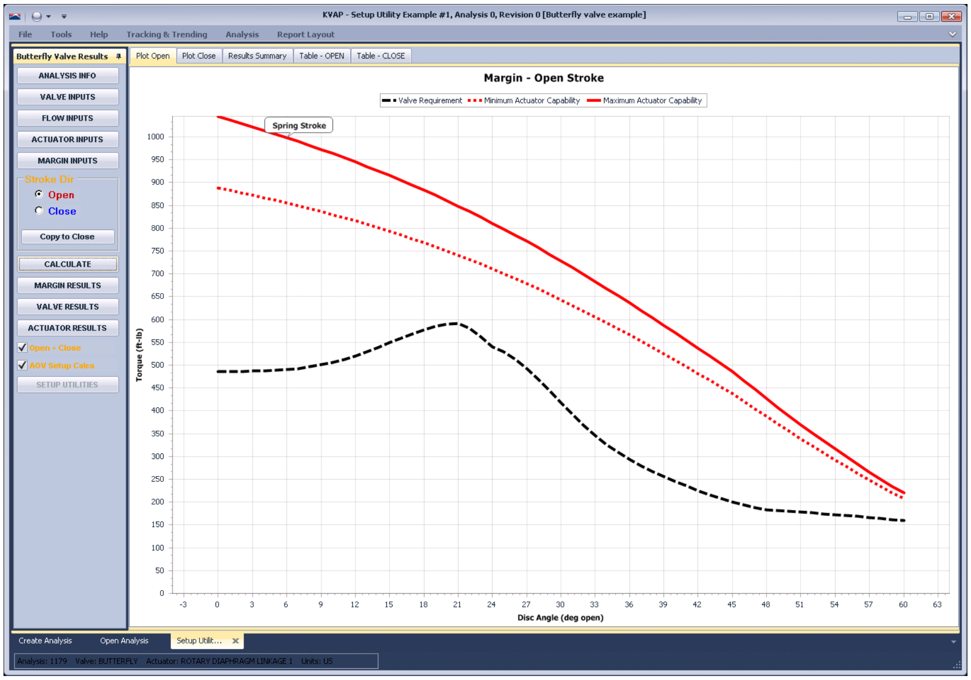
Valve Design



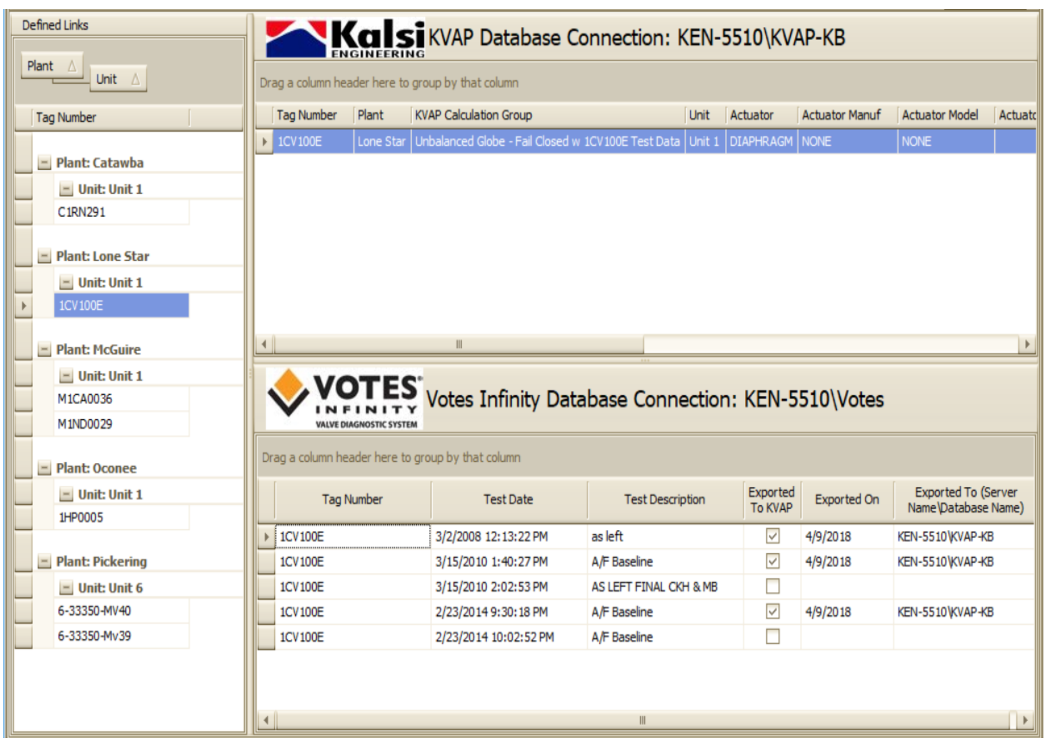
Valve Installation



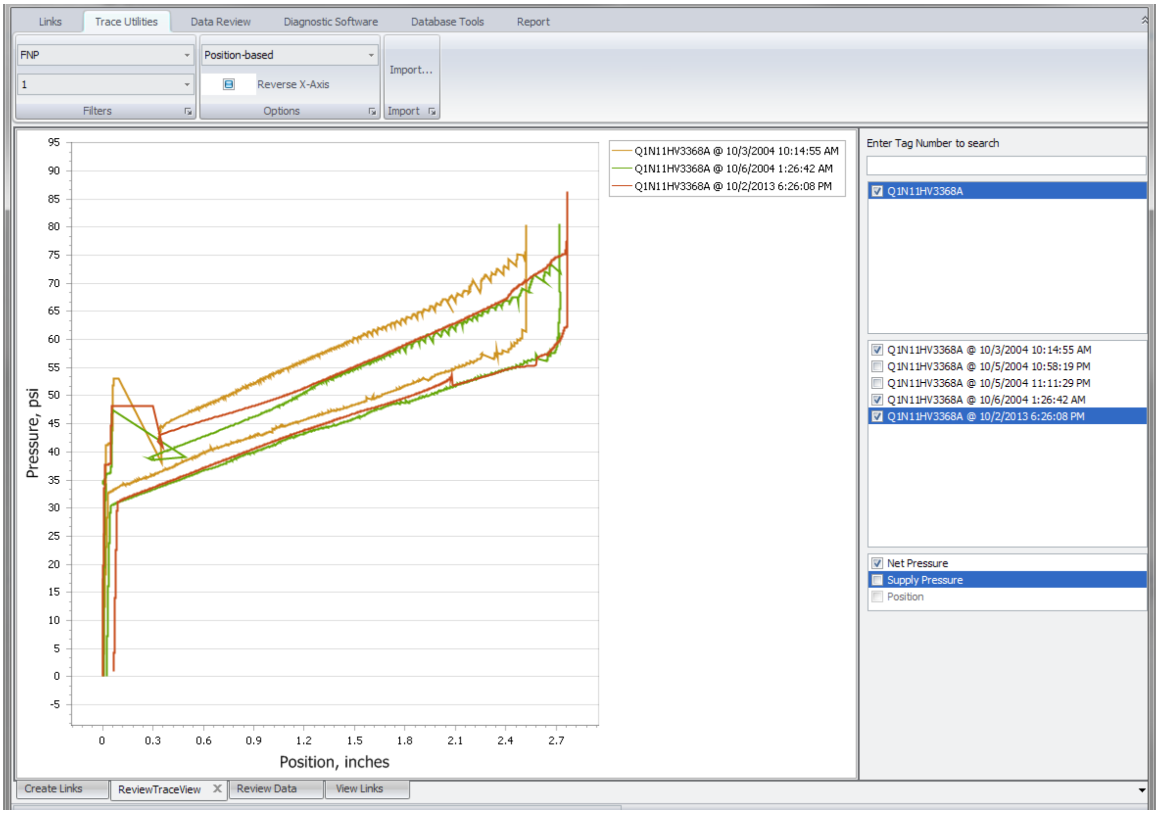
Margin Plot



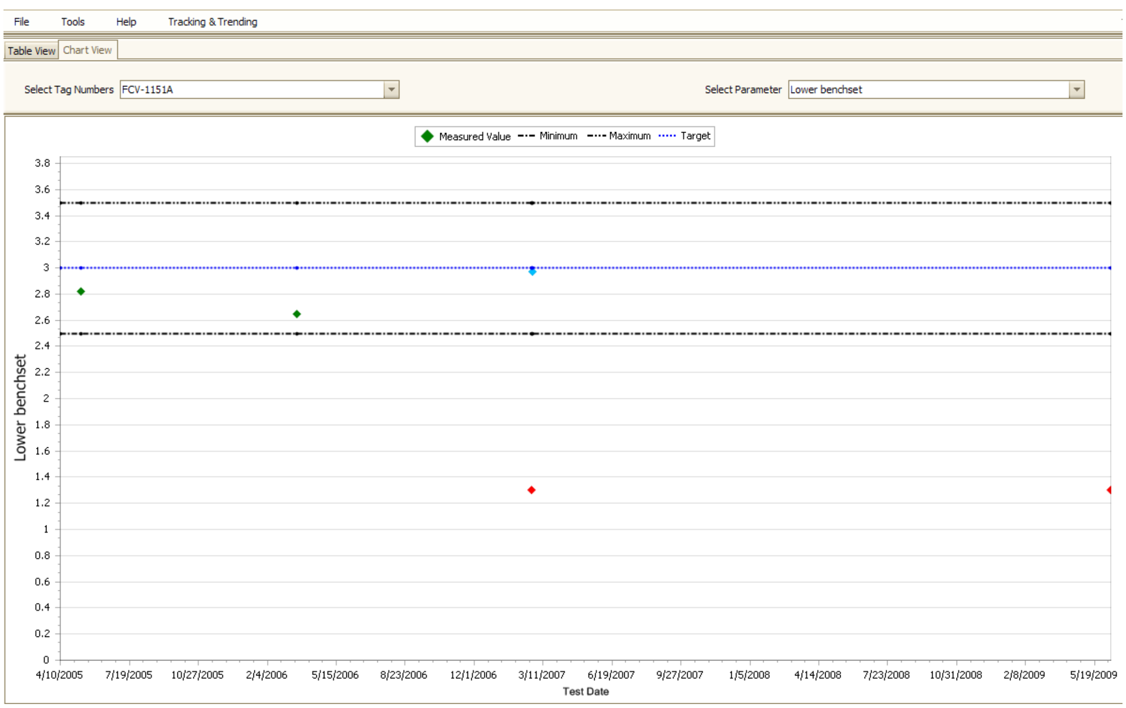
KVAP / Diagnostic Database Direct Link



Diagnostic Overlay Feature



Test Data Tracking & Trending Screen



Company Background and Experience Relevant to AOVs, MOVs, and Check Valves

Valve design, analysis, testing, model development, application, and problem solving are areas of special competence at Kalsi Engineering. Our personnel have in-depth knowledge, extensive experience, and an established track record of supporting all US and Canadian nuclear power utilities, and contributing to EPRI, and NSSS Owners' Groups in developing generic models/methodologies to address industry-wide issues; performing design basis reviews; and implementing plant-wide programs related to MOVs, AOVs, and check valves.

The depth, diversity, and continuity of our experience in addressing valve and actuator issues for nuclear power utilities over the last 40 years is unique in the industry. The insight and expertise of our personnel benefit our clients by identifying and implementing the most technically sound and cost-effective approach that can be fully justified to the regulatory authorities.

Our consulting engineering offices as well as the testing laboratories are located in Sugar Land, Texas (Houston metropolitan area). The combination of our design, analysis, and testing expertise facilitates the development of the most optimum approach for the client.

The following factors make Kalsi Engineering the most capable organization to efficiently support your valve and actuator related projects:

- ***Personnel with Strong Technical Background, Experience, and Continuity.*** Our key personnel have more than 30 years of experience directly related to solving problems with all types of valves. Their continuity of involvement in addressing valve/actuator problems and depth of experience makes them immediately productive on new projects.

- ***EPRI MOV Performance Prediction Program (PPP) Models/Software and NMAC Guides.*** Based upon our unique background, Kalsi Engineering was selected by EPRI/NMAC to develop validated models, software, and testing for the EPRI MOV PPP methodologies and guides for gate, globe, and butterfly valves that are widely used by all nuclear utilities (see Table 1).

  The same KEI senior specialists who developed the EPRI MOV PPM models are responsible for the development of new and more accurate models for POVs to meet industry needs.

- ***Improved and Validated Models for Quarter-Turn Valves***. Recognizing that the industry was lacking validated models for a wide variety of quarter-turn valves, KEI undertook a very comprehensive program to develop such models to accurately quantify the torque requirements for all common types of ball, butterfly, and plug valves used in nuclear power plants. The program also focused on developing more accurate, validated models for symmetric and single offset butterfly valves to eliminate the excessive conservatism in the EPRI MOV PPP models that were developed specifically for MOVs. The new models provide a substantial increase in margins between valve requirements and actuator capabilities, thus eliminating unnecessary equipment modifications.

  The test program was conducted under 10CFR50 Appendix B QA requirements to develop the torque and flow coefficients, including the effect of elbows. The test matrix included over 2,500 static and dynamic tests to cover variations in disc geometry, elbow orientation, elbow distance, flow direction, flow rates, and maximum ΔP. The validated methodologies as well as torque coefficients, flow coefficients, and elbow influence factors are incorporated in KVAP, the Kalsi Valve & Actuator Program.

- ***Design Basis Reviews, Analyses, and Implementation of MOV, AOV, and Check Valve Programs.*** Kalsi Engineering personnel have worked with over 50 U.S. nuclear power utilities in performing design basis calculations and reviews of MOV, AOV, and check valves to improve margins and address NRC GL 89-10, GL 95-07, GL 96-05 (JOG MOV PV Program), NRC IE Bulletin 85-03, and INPO SOER 86-03, and JOG AOV program guidelines. Many of these projects have employed advanced analytical methods (e.g., CFD and FEA) or special tests to qualify valves that cannot be tested in-situ.

- ***Safety Relief Valve (SRV) Evaluations and Improvements***. Kalsi Engineering has performed root cause evaluations of problems with SRVs at several BWR and PWR plants. Significant insights have been gained related to valve designs of different valve manufacturers, valve operation issues, and system operation issues that can contribute to valve failures. In the recent years, KEI was selected by several U.S. BWR plants (e.g. Limerick Generation Station, Pilgrim, Hope Creek) to perform root-cause investigations of Safety Relief Valve failures. These investigations included identifying and resolving issues related to:
  - Spurious openings due to progressive failures,
  - Setpoint drift due to corrosion bonding, pilot seat leakage, and thermal growth of key valve components,
  - Valve design/installation leading to marginal valve performance for the given operating conditions,
  - Spurious openings due to system/valve interaction.

- ***Credibility with USNRC***. Due to our strong technical background and rigorous approach in supporting utilities and industry-wide technical programs, Kalsi Engineering has established an excellent credibility with the NRC over the years. This has been a significant factor in obtaining NRC approval on a number of critical industry-wide programs and individual utility issues. Kalsi Engineering has successfully supported numerous utilities in NRC closures, inspections, and enforcement conferences.

- ***Root Cause Analysis and Problem Solving Experience***. In our root cause analyses and problem-solving experiences at nuclear power plants and petrochemical plants, we have performed in-depth investigations of valves and actuators made by all the major manufacturers. This has provided our personnel with significant insight into the critical differences between similar-looking designs made by different manufacturers that can have a major impact on valve performance. Kalsi Engineering can provide complete design modification support to solve valve/actuator problems.

Since 1988, KEI has performed many industry-significant research & development projects and has developed many guides for valves, actuators, and seals as summarized in Table 1.

Table 1: EPRI Projects & Guides Developed by KEI

	EPRI Report Title	Date	Report No.
1	Application Guide for Check Valves in Nuclear Power Plants	1988	NP-5479, Rev 0
2	Guide for the Application and Use of Valves in Power Plant Systems	1990	NP-6516, Rev 0
3	Motor-Operated Valve Margin Improvement Guide	1992	TR-100449
4	Application Guide for Check Valves in Nuclear Power Plants	1993	NP-5479 Rev 1
5	Gate Valve Model Report	1994	TR-103229
6	Butterfly Valve Model Description Report	1994	TR-103224
7	Gate Valve Design Effects Testing Results	1994	TR-103255
8	Butterfly Valve Design, Elbow, and Scaling Effects Test Report	1994	TR-103257
9	Stem Thrust Prediction Method for Westinghouse Flexible Wedge Gate Valves	1995	TR-103233
10	Stem Thrust Prediction Method for W-K-M Parallel Expanding Gate Valves	1995	TR-103236
11	Guide for the Application, Use, and Maintenance of Valves in Power Plants	1999	TR-105852-V1
12	U.S. Nuclear Industry Approaches to Address Gate Valve Pressure Locking, Thermal Binding, and Related Issues	1999	TR-114051
13	Mechanical Seal Maintenance and Application Guide	2000	1000987
14	Gate Valve Thermal Binding Unwedging Thrust Methodology	2001	1006676 E210203 Vol 1-4
15	Non-Metallic Bearing Friction Test Program for Quarter-Turn Valves	2002	TR-113561
16	Assessment and Recommendations for Using EPRI MOV PPM Butterfly Model for Applications with Variable Actuator Output Torque Capability	2004	TR-1009227
17	Application Guide for Motor-Operated Gate and Globe Valves in Nuclear Power Plants, Rev. 2	2007	1015396 Vol 1
18	Application Guide for Motor-Operated Butterfly Valves in Nuclear Power Plants, Rev. 2	2007	1015396 Vol 2
19	Limitorque Actuator Fatigue Life Extension	2008	1016701
20	Air-Operated Valve Evaluation Guide: Revision 1	2011	1022646
21	Turbine Valve Condition Monitoring	2015	3002006235
22	Application Guide for Air-Operated Valves Rev. 2	2016	3002008056
23	Evaluation Guide for Valve Thrust & Torque Requirements	2016	3002008055
24	Balanced & Unbalanced Globe Valve Methodology Including a Validated Approach for Balance Disc Valves	2016	3002009050
25	Evaluation of Condition Monitoring Methods for Steam Turbine Valves; Phase II – Sensors and Data	2016	3002008457
26	Evaluation of Condition Monitoring Methods for Steam Turbine Valves; Phase III, Part 1 Proof of Concept: Test Fixture Design and Verification of Analytics	2017	30020010527
27	Check Valve Application and Maintenance Guide	2019	3002015818

- ***Independent Assessment of Utilities' MOV, AOV, and Check Valve Programs***. Kalsi Engineering personnel have performed independent assessments of valve programs to address NRC Generic Letters 89-10, 95-07, and 96-05 concerns, check valve programs to address INPO SOER 86-03 issues, and AOV programs to address JOG AOV program recommendations and INPO SER 1-99 recommendations for several utilities.

- ***AOV Actuator Sizing/Stability Criteria and Modifications.*** AOV instabilities that are often unrecognized create premature degradation of packings and fatigue failure of AOV components, resulting in substantial cost penalties due to unscheduled downtime and maintenance. Based on AOV actuator stability problems encountered in various plants with balanced and unbalanced design globe valves, Kalsi Engineering has developed technical criteria to ensure stability of the AOV actuators. These criteria are based on first principle models verified by laboratory testing and in-situ plant performance. Kalsi Engineering personnel have performed tests on diaphragm actuators to determine effective diaphragm area from the actuator output versus stroke curves. KEI has implemented modifications in diaphragm actuators, including unique tandem configurations, to meet higher thrust requirements while eliminating instability.

- ***Limitorque Actuator Rating Increase Program and Software***. Under multiple-utility and NSSS Owners' Group sponsorship, Kalsi Engineering conducted the Limitorque Actuator Rating Increase Program, which has been *recognized as one of the most valuable and cost effective program* by all participating utilities. Recognizing the benefits offered by this program, virtually all U.S. nuclear power utilities joined in the program. The program results permitted the utilities to technically evaluate and continue to use their existing actuators at thrust and torque ratings well above Limitorque's standard published ratings without any safety concerns. The LiFE software was developed and validated to determine allowable cycles in operation under over-torque conditions in MOVs, thus eliminating the need for actuator modifications.

- ***MOV, AOV, and Check Valve Training Seminars for Utilities and NMAC.*** Kalsi Engineering has presented numerous seminars to provide basic and advanced MOV, AOV, and check valve training to utilities and the EPRI/NMAC organization. Seminars can be custom tailored and scheduled to meet the individual utility's needs, including needs arising from reorganization or new personnel being assigned to the valve projects. Seminars can be conducted at either the plant or the Kalsi Engineering facility. Our facility offers the advantage of hands-on experience/testing at our flow loop, including the use of diagnostic tools and the opportunity to discuss your plant's problems with several of our senior specialists who are recognized as leading industry experts.

- ***Improved Model for Pressure Locking and Pressure-Induced Binding of Gate Valves.*** Under the sponsorship of selected utilities from the BWR Owners' Group, Kalsi Engineering developed a validated methodology to accurately predict gate valve unwedging thrust performance under traditional pressure locking and even under pressure-induced binding conditions as reported in INPO OE10318 dated October 13, 1999. KEI's methodology eliminates potentially large uncertainties associated with other industry methodologies and is particularly valuable for predicting unwedging thrust requirements for AOV gate valves that typically have small margins.

- ***Thermal Binding Methodology.*** Kalsi Engineering developed a comprehensive first-principles model for thermal binding of gate valves, which was validated by flow loop testing under a variety of thermal binding scenarios (See Table 2 of EPRI Report E210203).
- ***Development of EPRI Check Valve Application Guidelines (EPRI NP-5479).*** Kalsi Engineering was contracted by NSSS Joint Owners' Group and EPRI to develop a comprehensive guide for the application and use of check valves in the industry. This guide was the first such publication to fully address problems/failures related to check valves. It also included guidance regarding how to systematically review and improve the design, application, installation, inspection, testing, and maintenance practices to prevent check valve failures. A large matrix of tests was performed to quantify the effect of variations in design, upstream flow disturbances, and flow conditions on the check valve performance and life. The guide was revised to include results from extensive wear and fatigue tests performed at Kalsi Engineering's flow loop and application experience gained at more than 20 plants.
- ***Condition Monitoring/Preventive Maintenance Based on Check Valve Analyses and Prioritization (CVAP®) Program.*** We have developed the Check Valve Analysis and Prioritization (CVAP) program, which is based upon extensive data from the EPRI Check Valve Guidelines developed by Kalsi Engineering; our root cause analyses from many failures; and our continuing, systematic wear and fatigue testing on check valves at our flow test facility. CVAP allows us to perform a thorough, efficient, and very cost-effective analysis of various types of valves and provide *quantitative* information regarding relative degradation trends. This methodology has proven to be very useful in prioritizing valves from the standpoint of their adverse effect on safety and reliability as well as in developing a condition monitoring-based preventive maintenance program with suitable maintenance/ inspection intervals for each valve. This methodology referred to by INPO as a "model for the industry" has been used to analyze over 3,500 check valves at more than 20 US nuclear power plants. It is a valuable resource for fulfilling the requirements for condition monitoring (ASME OMa Code 1996, ISTC 4.5.5, and Appendix II).
- ***Improved Gate Valve Design***. Kalsi Engineering developed an improved gate valve product line for GE Nuclear Energy for critical service applications in nuclear power plants. The new designs have been proven to repeatedly withstand severe blowdown conditions without any degradation of performance. Several patents were awarded for proprietary features of this design. The valves have been installed at several U.S. and foreign utilities, including Boston Edison/Pilgrim Nuclear Power Station, which was the lead utility that cooperated with KEI and GE in the development, testing, and installation of the improved gate valve. The new designs have accumulated a history of excellent performance for more than 15 years and have been implemented at several US and international plants.
- ***Teaming Arrangements to Provide Best Expertise to the Client***. Kalsi Engineering has an established relationship with other internationally recognized organizations and, when required, can team up to provide the optimum combination of talent to meet a client's technical goals and schedule requirements efficiently.
- ***Special Valve Test Facilities and Flow Loops***. Kalsi Engineering has a variety of unique test fixtures and flow loops to perform special tests on valves and actuators. A gate valve design effects test fixture capable of faithfully simulating the performance of gate valves under specified ΔP and flow conditions was developed to cost-effectively support the development

of EPRI models. This fixture is available for characterizing the performance of gate valve discs, seats, and guides, and is particularly suited for qualifying non-testable gate valves. Additionally, a number of actuator thrust, torque, and cyclic fatigue test fixtures are available to determine the performance characteristics and life of actuator components. A water flow loop capable of pressures up to 300 psi and flow rates up to 3,000 gpm is available at KEI test facilities. Kalsi Engineering has access to two additional flow loops in close proximity that permit flow testing with water up to 2,000 psi and 450 gpm and with steam up to 650°F.

- ***Development of Innovations Related to Valves and Seals***. Over 35 patents have been granted to Kalsi Engineering personnel, most of which are related to valves and seals. Several of these patents are assigned to valve manufacturers and are in commercial use. Patents relating to seals are in commercial use in harsh, abrasive fluid media, high differential pressure rotary seal applications.

- ***Expert Witness Experience in Legal Testimony.*** Kalsi Engineering has provided expert witness support and testimony for legal issues related to valves, seals, rotating equipment, and other mechanical equipment. Based on our strong background, experience, and insight in valves and actuators, we have established an impeccable record of supporting our clients and bringing each lawsuit to a favorable conclusion to date. This has covered a wide range of valve and actuator designs made by different manufacturers and used in different industries, including petrochemical and manufacturing plants.

- ***Intimate Familiarity with Design of Valves***. Kalsi Engineering has in-depth experience in the detail design, typical tolerances, materials, manufacturing, and development of complete product lines of gate, globe, butterfly, ball, check, and safety relief valves. These product lines have included:

  – Motor operated gate valves for nuclear service

  – Main steam and feedwater isolation gate valves for nuclear service

  – Motor- or air-operated globe valves

  – End-entry ball valves, both trunnion mounted and floating ball designs

  – Rectangular body gate valves of fabricated design for high temperature cyclic service in petrochemical plant applications

  – Trunnion mounted top entry ball valves for high pressure (5,000 psi) gathering manifolds in oil and gas production

  – High performance fire-safe butterfly valves for power generation and industrial applications

  – High-pressure gate valves for 30,000 psi sour gas critical service in oil field wellhead applications

  – Geothermal gate valves for 600°F steam service

  – Catalytic cracker slide valves used in petrochemical plants for temperatures up to 1,100°F

  – Quarter-turn tapered plug valves capable of withstanding pressure transients without taper-locking problems typically encountered with conventional plug valves under water hammer conditions.

- ***Extensive Design, Analysis, and Testing Experience***. In supporting the development of various valve product lines, Kalsi Engineering personnel have utilized systematic design, advanced analyses, and testing approaches for many years. Some of the more important accomplishments are described below:

  – *Detailed stress and deflection analysis* of the major components of many types and sizes of valves under pressure, external pipe loads, thermal transients, seismic, and pipe rupture loads. Finite element analysis techniques were widely employed to gain a thorough understanding of valve distortions and stresses under combined loads and to quantify their effect on operability.

  – *Instrumented bending moment tests* on several types of gate, globe, and ball valves. Internal seat distortions and changes in clearances were measured to quantify and provide adequate design clearances and operating thrust margins under worst combination of loads.

  – *Sliding friction tests* between several seat/gate material combinations to determine coefficient of friction threshold of galling stress and wear rates, which cause degradation of the seating faces. These tests were conducted on standard friction test machines using standard specimens as well as by sliding prototypical valve components.

  – *Flow Tests* for various shapes and sizes of valves to develop and refine flow resistance and scaling methods, and quantify torque coefficients, and upstream flow disturbance effects.

  – *Performance prediction of butterfly valves:* Developed analytical methods to account for the effect of piping installations, upstream and downstream resistance, and flow conditions including pump flow, pipe rupture, and parallel branches on butterfly valve performance.

  – *Development of flexible metal-to-metal seats and wedge discs* to accommodate anticipated seat distortions and displacements under pressure and thermal transients without significantly increasing operating thrusts and degrading the shut-off characteristics.

  – *Seismic qualification* of several actuators and valve product lines using combined finite element dynamic analysis and testing techniques.

  – *Strain gage instrumented tests* to determine impact stresses during fast-closing operation of MSIVs and FWIVs.

  – *Operating thrust measurements* by instrumented cycle testing on gate valves using nitrogen (up to 1,000°F), water, and steam (up to 600°F) under various differential pressures.

  – *Water slug impact tests* on control valve plugs; design improvements to make them resistant to impact stresses caused by slug-type water hammer.

  – *Cavitation, noise, and flashing tests* on high pressure drop control valves. Developed noise prediction methods for control valves in both incompressible and compressible fluid service. Developed a low noise, high pressure drop trim design.

  – *Stability analysis of air-operated control valves*; developed techniques to predict and avoid instabilities caused by negative stem force gradients encountered in high ΔP applications. A hydraulic force test simulator was developed to faithfully duplicate many complex stem force curves observed in actual plant conditions on different types of control valves/actuator assemblies.

– *Check valve wear and fatigue research.* We continue to be involved in and at the forefront of the development and refinement of methodology to predict degradation of check valve internals. An extensive matrix of long-term wear and fatigue tests was performed to refine the predictive models for hinge pin wear and disc stud fatigue.

– *Cyclic overload qualification of Limitorque actuators* has been done by applying fracture mechanics and fatigue analysis techniques and by testing with specially instrumented test fixtures capable of simulating different valve stiffnesses.

Key Personnel

Kalsi Engineering, Inc. has a staff of over 30 personnel. Qualifications of our key personnel are summarized below.

Dr. M. S. Kalsi holds a B.S., M.S., and Ph.D. degrees in mechanical engineering. He is the President of Kalsi Engineering Inc. and has over 40 years of experience in valve design, analysis, and testing. Prior to starting Kalsi Engineering, he was manager of research and development at a major U.S. valve manufacturing company. He has been awarded over 35 patents and has published more than 60 technical papers. He has provided management and technical guidance to his staff in implementing valve programs and performing design basis reviews for MOVs, AOVs, and check valves at numerous nuclear power plants. He has served as a project manager as well as a principal investigator in many large scale, industry-wide valve programs for EPRI (including EPRI's MOV PPP), nuclear power utilities, NSSS Owners Groups, and Small Business Innovation Research Phase I and II projects awarded to Kalsi Engineering, Inc. by NRC, DOD, DOE, and NASA.

Dr. Kalsi has worked with many nuclear power plants and valve manufacturers in resolving valve issues for all types of valves, seals, and other mechanical equipment. Dr. Kalsi has worked extensively in the following areas: detail design, prototype fabrication, testing, research and development, structural and operability analysis, valve instability analysis, fluid-induced vibration, tribology and quantitative wear prediction, response of valve disc or plug to pressure transients, water hammer analysis, flow characteristics and pressure drop across valves, life cycle testing to determine performance degradation, establishing surveillance testing requirements to ensure operability, and root cause analysis of failures. With an equally strong background in analysis, testing, and project management, Dr. Kalsi has the expertise to plan and develop the most suitable technical approach to meet the project objectives at a minimum cost.

Mr. Neal Estep holds a B.S. and M.S. in mechanical engineering and is a licensed PE. He is a Sr. Vice President with over 30 years of mechanical equipment experience. He served as the corporate lead for implementation of the GL 89-10 MOV program at Duke Power (Oconee, McGuire and Catawba). In this position he participated in the development of MOV diagnostic test equipment (MOVATS™ and Liberty VOTES™ systems), and developed program documents and engineering standards for actuator maintenance, testing, data review and performing design basis sizing calculations. In addition, he performed and reviewed design basis sizing calculations, performed in-situ and flow loop testing of valves using diagnostic test equipment, and analyzed and interpreted test data. He was also involved in developing the KEI actuator torque test stands for Duke Power.

Mr. Estep served as the co-chairman for the EPRI MOV Performance Prediction Program, with specific focus on the flow loop testing portion of the program. He served on the ASME O&M committee for MOVs, was active in the MOV User's Group and served on the NEI committee to address industry resolution of NRC MOV concerns.

His background includes resolution of valve problems at fossil and hydro power plants, and he served as rotating equipment engineer at Catawba Nuclear Station, engineering supervisor at Catawba Nuclear Station over the valve area, and held project management and equipment support positions at a refinery and chemical plant.

Mr. Ken Beasley holds a B.S. degree in mechanical engineering and holds Professional Engineering registration in the states of North Carolina and South Carolina. He is a Principal Consultant with over 25 years of experience in the commercial nuclear power industry with a focus on valves and other mechanical equipment. He also worked for a major valve manufacturer for several years. Mr. Beasley has served on multiple industry committees such as the AOV-JOG core team and the AOV User's Group steering committee. He serves on the ASME O&M App. IV committee for AOVs. He has worked for over 15 years at a large utility and led their implementation of regulatory requirements and industry initiatives in valve testing, design basis reviews, and maintenance strategies. Additionally, he has extensive experience with valve diagnostics and served on many root cause evaluation teams.

Mr. Michael Cloninger is a Principal Consultant at Kalsi Engineering with almost 30 years of experience in the commercial nuclear power industry. He holds a B.S. degree in mechanical engineering and holds Professional Engineering registration in the state of North Carolina. He has over 20 years of experience on the utility side of the nuclear industry as a design engineer, component engineer, modification engineer, AOV Program Lead, and Valve/Mechanical Equipment Group engineering supervisor. During his engineering career at the utility he had component responsibility for valves, pumps, turbines, heat exchangers and participated in numerous root cause evaluations, component/system trouble shooting, valve/actuator sizing and testing for AOVs/MOVs as well as maintenance support for valves and mechanical equipment.

While at the utility, Mr. Cloninger also held a Senior Reactor Operator (SRO) license at Oconee Nuclear Station. During this time as an SRO he performed duties as a control room supervisor and Shift Technical Advisor. This provided him with hands-on experience in the operation of valves and equipment for a better understanding of the challenges facing nuclear operators.

Prior to joining Kalsi Engineering, Mr. Cloninger was a Project Engineer involved in the engineering, procurement and construction of new build nuclear plants. This experience provided him insight into the issues and challenges facing new build construction. This experience reinforced to him the importance of sound engineering analysis and design, clear and comprehensive procurement specifications, and simple construction/maintenance strategies that can be implemented to support a nuclear industry challenged to control costs while maintaining nuclear safety.

Mr. Zachary Leutwyler is a Vice President at Kalsi Engineering, Inc. with more than 18 years of experience in the valve industry and holds a B.S. and M.S. in mechanical engineering. He has special expertise in Computational Fluid Dynamics (CFD) and Thermal-Fluid Sciences. His graduate work was focused on computational, thermal, and fluid sciences and included a computational study of the compressible flow field and the flow-induced resultant force and torque on various butterfly disc geometries using two- and three-dimensional computational models. His thermal science background includes conduction, convection, and radiation heat transfer. His background in fluid mechanics includes gas dynamics (theoretical and computational), boundary-layer theory, turbulent flow, potential flow, viscous flow, and fundamental fluid mechanics.

Mr. Leutwyler's experience includes performing root-cause investigations, developing dynamic and kinematic equations of motion to predict transient performance of valves/actuators, developing analytical models to predict valve and/or actuator capability, developing and executing test procedures, performing computational fluid dynamics (CFD) analysis of butterfly, check, and globe valves of different shapes and other piping system components, performing finite element analyses (FEA) and coupled fluid-structure and thermal interactions analyses, designing test fixtures and analyzing valve modifications.

His recent projects included performing root-cause investigations of various valve failures including main seat leakage in Main Steam Safety Relief Valves (MSRV) related to marginal seat contact aggravated by thermal and mechanical loading, pilot seat leakage and setpoint drift failures in MSRVs due to marginal seat contact pressure that was sensitive to side loading and thermal distortions, and butterfly disc-pin loss due to disc flutter resulting from upstream disturbances. The root-cause investigation of the pilot-operated MSRV main seat leakage included developing a 3-D model of the valve and performing a thermal structural analysis of the valve during system startup. The analysis modeled the initiation and progression of the thermal distortion due to small seat leakage consistent with marginal seating capability at low system pressure.

Recent project experience also included modeling and analysis of swing disc type Main Steam Isolation Valves (MSIV) and Main Steam Check Valves (MSCV) under power uprate conditions using RELAP to predict disc impact velocities under pipe break and spurious closure.

Mr. Ryan Sicking holds a B.S. degree in mechanical engineering. He is a Principal Consultant with over 23 years of experience in analysis, design, testing, and capability evaluations of MOVs, AOVs, and check valves. Mr. Sicking has served on the ASME OM Appendix II Committee for check valves and been a project leader on numerous high-volume AOV, MOV, and check valve evaluations. Mr. Sicking is an industry trainer and responsible for customer support for KEI software such as KVAP, CVAP, LiFE, and COMMAND. He has led industry testing initiatives to quantify internal degradation of check valves and butterfly valve bearings. Mr. Sicking has supported several cases in expert witness litigation related to valve incidents.

Mr. Aaron Richie holds a B.S. and M.S. degree in mechanical engineering. He is a Vice President with more than 18 years of experience in analysis, modeling, and capability evaluations of MOVs, AOVs, and check valves. He has extensive experience in design and innovative development of high-pressure rotary equipment and rotary seal applications. Mr. Richie was the test engineer for the KEI AOV/MOV compressible flow testing program. He has performed numerous flow loop tests on a variety of check valves. He also supports the development, maintenance and enhancement of the Kalsi Valve and Actuator Program (KVAP) software.

Mr. Nimish Jagtap is a Sr. Specialist with over 15 years of experience with Kalsi Engineering Inc. (KEI) in the areas of design and analysis of AOVs, MOVs, MSIVs, SRVs and other mechanical components in the nuclear, petroleum and valve industry. He holds a master's degree with a focus on solid mechanics. Mr. Jagtap has performed weak link analyses, stress analyses and seismic analyses that required the application of ASME BPV Code, API Code and SAE fatigue criteria. The finite element analysis (FEA) projects that Mr. Jagtap has worked on involved structural and elasto-plastic FEA, modal analysis, impact analysis, contact analysis, hyper-elastic and thermal FEA. Additionally, he has also performed fluid analyses using computational fluid dynamics (CFD) and RELAP. Mr. Jagtap has been involved in the design and optimization of the various seal products in the seals division of KEI.

Mr. Mital Mistry is a Sr. Consultant at Kalsi Engineering, Inc. holds a B.S. and M.S. in mechanical engineering. Mr. Mistry has more than 10 years of experience related to valves, seals, and other mechanical equipment used in the power generation (nuclear and fossil), oilfield, and drilling industries. He has extensive experience in the design, analysis, and testing of valves, actuators, and rotary seals used in down-hole tools.

He has performed numerous design basis calculations for valves and actuators used in air-operated valves (AOVs) and motor-operated valves (MOVs) using KVAP.

Mr. Mistry has designed several test fixtures and performed instrumented tests on valves and valve components, actuators, rotary seals, and other down-hole tools under conditions simulating loads, pressures, flows, and temperatures.

Mr. Mistry's experience include development of mathematical models of the multi-physics problems, development of analytical models to predict rotary seals performance, performing finite element analyses (FEA) and computational fluid dynamic (CFD) analyses of the valve and other mechanical structures.

His structure mechanics background includes stress, deflection, modal and fatigue analysis. His thermal science background includes conduction, convection, and radiation heat transfer. His background in fluid mechanics includes boundary-layer theory, turbulent flow, viscous flow, and fundamental fluid mechanics.

His recent projects include performing CFD analysis to support plant operability of MSRV valves at several US nuclear power plants and CFD analysis to provide insights into globe valve behavior under dynamic flow conditions, which supports updating EPRI guidance for the soon-to-be-released AOV Application Guide. The root-cause investigation to determine accelerated degradation of the MSRV piston included developing a 3-D model of the valve and performing a dynamic analysis of the valve assembly during actuation.

Mr. Emil Leutwyler is a Specialist at Kalsi Engineering and has over 9 years of mechanical design, analysis, and testing experience for the nuclear, petro-chemical, and valve industries. Mr. Leutwyler's experience includes performing design basis evaluations, developing and executing test procedures, 3-D CAD modeling, performing finite element analyses (FEA), and designing test fixtures. He is also very involved in the KVAP software development programming and verification and validation processes.

Mr. Leutwyler has performed an extensive number of KVAP analyses for several nuclear plants and has extensive hands-on experience with valves and actuator. He has performed AOV Quarter-Turn testing to support the development and validation of quarter turn actuator efficiency models, performed effective diaphragm area testing for air operated valve actuators, performed actuator and valve qualification testing for new products to be installed in nuclear power plants.

Mr. Alexander Beliaevski is a Sr. Software Engineer at Kalsi Engineering, Inc. holds a B.S. and M.S. in Mechanical Engineering. Mr. Beliaevski holds a Programming-Microcomputer Certificate. Mr. Beliaevski has over 21 years of experience designing and developing software. He contributed to the development of Kalsi Engineering proprietary software programs CVAP, KVAP, LiFE, COMMAND and JarPro. He is an industry trainer in the use of JarPro. He provides KVAP and JarPro customer support.

Ms. Darshita Mistry is a Software Architect at Kalsi Engineering, Inc. holds a B.S. and M.S. in electrical engineering and an M.S. in computer science. Ms. Mistry has more than 4 years of experience in cloud computing, design and development of big data analytics application for large scale seismic data and oil field streaming data. She also has an experience in Machine learning/Deep learning algorithms for pattern recognitions. She is a primary developer of KVAP software and KVAP database migration. She oversees Azure DevOps server and creates customized workflows to manage software development at KEI. She provides KVAP customer support.

KVAP Documents for Software Development, Models, Flow Loop Testing, Verification, and Validation

The following is a list of references supporting the development of KVAP, EPRI MOV Performance Prediction Program models and EPRI/NMAC Guides developed by Kalsi Engineering, and other related references.

KVAP Software Development, Verification and Validation

1. KEI Document No. 2092C, *KVAP Software: Software Quality Assurance Plan.*
2. KEI Document No. 2093C, *KVAP Software: Software Requirements Specification*.
3. KEI Document No. 2094C, *KVAP Software: Software Design Specification*
4. KEI Document No. 2094C, Attachment 1: *KVAP Software: Software Design Specification - User Interface Module.*
5. KEI Document No. 2094C, Attachment 2: *KVAP Software: Software Design Specification - System Flow Module*.
6. KEI Document No. 2094C, Attachment 3: *KVAP Software: Software Design Specification – Air-Operated Actuator Module.*
7. KEI Document No. 2094C, Attachment 4: *KVAP Software: Software Design Specification - Gate Valve Module.*
8. KEI Document No. 2094C, Attachment 5: *KVAP Software: Software Design Specification - Globe Valve Module.*
9. KEI Document No. 2094C, Attachment 6: *KVAP Software: Software Design Specification - Diaphragm Valve Module.*
10. KEI Document No. 2094C, Attachment 7: *KVAP Software: Software Design Specification - Butterfly Valve Module.*
11. KEI Document No. 2094C, Attachment 8: *KVAP Software: Software Design Specification – Ball/Plug Valve Module.*
12. KEI Document No. 2094C, Attachment 9: *KVAP Software: Software Design Specification – KVAP Global Module.*
13. KEI Document No. 2094C, Attachment 10: *KVAP Software: Software Design Specification - Margin Module.*
14. KEI Document No. 2094C, Attachment 11: *KVAP Software: Software Design Specification - Default Flow and Torque Coefficients Module for Butterfly*.
15. KEI Document No. 2094C, Attachment 12: *KVAP Software: Software Design Specification – Motor Operator*.
16. KEI Document No. 2095C: *KVAP Software: Program Code Listing*:
17. KEI Document No. 2096C: *KVAP Software: Verfication and Validation Plan*.
18. KEI Document No. 2097C: *KVAP Software: V&V Report:* Attachments 1 through 11.

KVAP Models & Methodologies

19. KEI Document No. 2098C, Attachment 1: *KVAP Software: Model Description Report - User Interface Module.*

20. KEI Document No. 2098C, Attachment 2: *KVAP Software: Model Description Report - System Flow Module.*

21. KEI Document No. 2098C, Attachment 3: *KVAP Software: Model Description Report - Air-Operated Actuator Module.*

22. KEI Document No. 2098C, Attachment 4: *KVAP Software: Model Description Report - Gate Valve Module.*

23. KEI Document No. 2098C, Attachment 5: *KVAP Software: Model Description Report - Globe Valve Module.*

24. KEI Document No. 2098C, Attachment 6: *KVAP Software: Model Description Report - Diaphragm Valve Module.*

25. KEI Document No. 2098C, Attachment 7: *KVAP Software: Model Description Report - Butterfly Valve Module*

26. KEI Document No. 2098C, Attachment 8: *KVAP Software: Model Description Report – Ball/Plug Valve Module.*

27. KEI Document No. 2098C, Attachment 10: *KVAP Software*: *Model Description Report: Margin Module*.

28. KEI Document No. 2098C, Attachment 11: *Model Description Report: Default Coefficient Module - Butterfly Valves*.

29. KEI Document No. 2098C, Attachment 12: *Model Description Report: Motor Operator Module.*

30. KEI Document No. 2111C, *CFD Modeling Methodology Validation for Quarter-Turn Valves*.

31. KEI Document No. 2122C, *Verification and Validation Plan for ANSYS/ FLOTRAN 5-5 CFD Elements*.

32. KEI Document No. 2121C, *Verification and Validation Report for ANSYS/ FLOTRAN 5-5 CFD Elements*.

KVAP Flow Loop Test Program

33. KEI Document No. 2101C, *Procedure for Kalsi AOV/MOV Validation Testing*.

34. KEI Document No. 2118C, *Kalsi AOV/MOV Model Validation Test Data Report*.

35. KEI Document No. 2119C, *Kalsi AOV/MOV Test Data*.

36. KEI Document No. 2119C, Attachment 1: Spherical Ball Valve (Assembly 1).

37. KEI Document No. 2119C, Attachment 2: Segmented Ball Valve (Assembly 2).

38. KEI Document No. 2119C, Attachment 3: Double Offset Butterfly Valve (Assembly 3).

39. KEI Document No. 2119C, Attachment 4: Kalsi Test Fixture (Assembly 4) Symmetric Disc 0.15 Aspect Ratio.

40. KEI Document No. 2119C, Attachment 5: Kalsi Test Fixture (Assembly 5) Nonsymmetric Disc 0.15 Aspect Ratio.

41. KEI Document No. 2119C, Attachment 6: Kalsi Test Fixture (Assembly 6) Nonsymmetric Disc 0.25 Aspect Ratio.

42. KEI Document No. 2119C, Attachment 7: Kalsi Butterfly Valve Test Fixture Nonsymmetric Disc 0.25 Aspect Ratio (Assembly 7). Double Offset: 0.090" Lateral (Stem), 40% axial (Seat).

43. KEI Document No. 2119C, Attachment 8: Kalsi Butterfly Valve Test Fixture Nonsymmetric Disc 0.25 Aspect Ratio (Assembly 8). Double Offset: 0.090" Lateral (Stem), 60% axial (Seat).

44. KEI Document No. 2119C, Attachment 9: Kalsi Butterfly Valve Test Fixture Nonsymmetric Disc 0.25 Aspect Ratio (Assembly 9). Double Offset: 0.045" Lateral (Stem), 40% axial (Seat).

45. KEI Document No. 2119C, Attachment 10: Kalsi Butterfly Valve Test Fixture Nonsymmetric Disc 0.25 Aspect Ratio (Assembly 10). Double Offset: 0.045" Lateral (Stem), 60% axial (Seat).

46. KEI Document No. 2119C, Attachment 11: Spherical Q-Ball Valve with QOM Insert (Assembly 12).

47. KEI Document No. 2119C, Attachment 12: Kalsi Butterfly Valve Test Fixture Nonsymmetric Disc 0.24 Aspect Ratio (Assembly 13). Triple Offset: 0.364" Lateral, 59% axial, 16-deg cone.

48. KEI Document No. 2119C, Attachment 13: Kalsi Butterfly Valve Test Fixture Nonsymmetric Disc 0.30 Aspect Ratio (Assembly 14). Triple Offset: 0.632" Lateral (Stem), 67% axial (Seat).

49. KEI Document No. 2205C, *Procedure for Kalsi AOV/MOV Model Validation Testing*, July 2000.

50. KEI Document No. 2120C, Kalsi AOV/MOV Model Validation Testing- Lab Notebooks, Volumes 1-14.

51. KEI Document No. 2221C, Kalsi AOV/MOV Model Validation Testing- Lab Notebooks, Volumes 1-11.

52. KEI Document No. 2222C, Kalsi *AOV/MOV Compressible Flow Testing Report*.

53. KEI Document No. 2222C, Attachment 1: Ball Valve: Full Ball, Trunnion Mounted 6" Valve (Assembly 1).

54. KEI Document No. 2222C, Attachment 2: Jamesbury 6" Butterfly Valve Double Disc (Assembly 3).

55. KEI Document No. 2222C, Attachment 3: Kalsi Butterfly Valve Test Fixture with Single Offset Disc 0.15 Aspect Ratio (Assembly 5).

56. KEI Document No. 2222C, Attachment 4: Kalsi Butterfly Valve Test Fixture with Single Offset Disc 0.25 Aspect Ratio (Assembly 6).

57. KEI Document No. 2222C, Attachment 5: Kalsi Butterfly Valve Double Offset Disc with 0.25 Aspect Ratio (Assembly 8).

58. KEI Document No. 2222C, Attachment 6: Jamesbury 6" Valve Double Offset with Steamline Disc (Assembly 11).

59. KEI Document No. 2222C, Attachment 7: 6" Model of a 48" Henry Pratt Butterfly Valve (Assembly 16).

60. KEI Document No. 2222C, Attachment 8: 6" Scale Model of an 18" Jamesbury Butterfly Valve (Assembly 18).

61. KEI Document No. 2222C, Attachment 9: Kalsi Butterfly Valve Test Fixture Symmetric Disc with 0.25 Aspect Ratio (Assembly 19).

62. M. S. Kalsi, B. H. Eldiwany, V. Sharma, D. Somogyi. "Dynamic Torque Models for Quarter-Turn Air-Operated Valves," **Proceedings of the Sixth NRC/ASME Symposium on Valve & Pump Testing**, NUREG/CP-0152, Vol. 3, July 2000.

63. M. S. Kalsi, Bahir Eldiwany, Vinod Sharma, Ryan Sicking, "Flow Loop Testing to Validate Improved Models for Single, Double & Triple Offset Disk Butterfly Valves," **Abstract for EPRI/NMAC Eighth Valve Technology Symposium,** August 2001.

64. J. K. Wang, Desi Somogyi, P. Daniel Alvarez, M. S. Kalsi, John Hosler (EPRI), "Flow Loop Testing and Validation of Thermal Binding Model for Wedge Gate Valves," **Proceedings of the EPRI/NMAC Eighth Valve Technology Symposium,** August 2001.

65. M. S. Kalsi, B. E. Eldiwany, V. Sharma, "Butterfly Valve Model Improvements Based on Compressible Flow Testing Benefit Industry AOV Programs, **Proceedings of the Seventh NRC/ASME Symposium on Valve and Pump Testing,** July 2002.

66. M. S. Kalsi, B. Eldiwany, "Plant Experience Based Upon Application of New Validated Models for Air-Operated Valves, **Proceedings of the 9th EPRI Valve Technology Symposium,** August 2003.

67. M. S. Kalsi, B. Eldiwany, Vinod Sharma, Aaron Richie, "Effect of Butterfly Valve Disc Shape Variations on Torque Requirements for Power Plant Applications, **Proceedings of the Eighth NRC/ASME Symposium on Valve and Pump Testing,** July 2004.

68. KEI Document No. 2099C, **KVAP User's Manual**.

EPRI MOV Performance Prediction Program &
EPRI/NMAC Guides developed by Kalsi Engineering, Inc.

69. EPRI MOV Performance Prediction Program: Guide for the Application and Use of Valves in Power Plant Systems, Electric Power Research Institute, EPRI NP-6516, Rev. 0.

70. EPRI MOV Performance Prediction Program: Guide for the Application, Use, and Maintenance of Valves in Power Plants, Electric Power Research Institute, EPRI TR-105852-V1.

71. EPRI MOV Performance Prediction Program: Butterfly Valve Model Description Report, Electric Power Research Institute, EPRI TR-103224.

72. EPRI MOV Performance Prediction Program: Butterfly Valve Design, Elbow, and Scaling Effects Test Report, Electric Power Research Institute, EPRI TR-103257.

73. EPRI MOV Performance Prediction Program: Application Guide for Motor-Operated Butterfly Valves in Nuclear Power Plants, Electric Power Research Institute, EPRI NP-7501.

74. EPRI MOV Performance Prediction Program: Application Guide for Motor-Operated Butterfly Valves in Nuclear Power Plants, Rev. 1, Electric Power Research Institute, EPRI TR-106563 V2.

75. EPRI MOV Performance Prediction Program: Application Guide for Motor-Operated Gate and Globe Valves in Nuclear Power Plants, Rev. 1, Electric Power Research Institute, EPRI TR-106563 V1.

76. EPRI MOV Performance Prediction Program: Gate Valve Model Report, Electric Power Research Institute, EPRI TR-103229.

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81. EPRI MOV Performance Prediction Program: Motor-Operated Valve Margin Improvement Guide, Electric Power Research Institute, EPRI TR-100449.

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KVAP Development/Enhancement

KVAP is actively being developed and technically enhanced to ensure that the software is up-to-date and is responsive to emergent industry issues. The following summary illustrates the upgrades performed on KVAP since its release in November 2000. The software has since been revised to incorporate new features, address error reports, and fix non-technical format problems. Subscribers to the software annual maintenance receive free upgrades and electronic database migration services.

KVAP 1.0 Released in 2000

Initial Modules

- Globe
- Butterfly
- Gate
- Air operators
- Margin
- Flow
- Default butterfly coefficients
- User interface

KVAP 1.1 Released in 2001

Corrected problems identified in Error Reports:

- 2000-1 through 2000-22, except 2000-18
- Revised code to address 12 formatting/enhancement type non-technical issues

KVAP 1.2 Released in 2002

New features:

- Ball and plug valves module
- Default incompressible flow coefficients for full spherical ball and segmented ball
- Rotary diaphragm with linkage
- Reverse acting piston actuator
- "Other" actuator for defining out of scope actuators

Correct problem identified in Error Report 2000-18, and 2001-1

Added saturation temperature information calculation for steam and water

Added safe spring load data field

Revised code to address 19 formatting/enhancement type non-technical issues

KVAP 1.3 Released in 2003

Correct problem identified in Error Reports 2002-2,
2002-4, 2002-6, 2002-7,

Revised code to address 42 formatting/enhancement type non-technical issues

KVAP 2.0 Released in 2004

Added MOV Module

Significantly upgraded KVAP capabilities to analyze quarter-turn valves in compressible flow application including at low-pressure coefficients for butterfly valves. This effort was supported by an additional 1100 compressible flow tests on 9 different valve designs tested in 84 configurations. (KVAP 1.3 models were based on over 1250 incompressible flow tests on 15 valves designs in 71 configurations). New features included:

Additional incompressible flow torque coefficients for cylindrical and tapered plug valves and Camflex valves

Default compressible flow coefficients for ball, plug, and eccentric plug valves

Butterfly valve compressible flow coefficient for very low pressures and vacuum

Optional bounding torque coefficients for butterfly valves
Added Reverse acting pilot balanced valve
Added Three way converging globe valve
"User" valve to permit manually defining thrust/torque valve requirements
Torque predictions for 1/4 turn valves under incompressible blowdown conditions
Ability to analyze valve and actuator, valve only, or actuator only
Ability to change actuator type after beginning analysis
Ability to define piston actuator using area or diameters
Customization of AOV categories
Component thrust/torque rating input
Ability to selectively calculate and plot margin calculations
New input screen for defining margin calculation options
Added valve thrust plot capability to all linear valves
New optional MOV actuator sizing module for Limitorque and Rotork actuators
Numerous new illustrations
Expanded numerous help menu definitions

Corrected problem identified in Error Reports 2001-1, 2002-1, 2002-2, 2003-1 through 2003-7r1, and K2004-1

Redesigned input screens for added flexibility and user-friendliness

Redesigned reports for added flexibility and user-friendliness

Redesigned report header wizard

Query feature for sorting the database

KVAP 2.1 Released in 2004

Corrected problem identified in Error Report 2004-2

KVAP 2.2 Released in 2005

Add AOV setup parameter window and set-up datasheet

Provide user with options for addressing uncertainties

Add open and close stroke in same analysis

Provide alternate "valve factor" input for gate valves in addition to coefficient of friction

Refined pilot globe valve seating-thrust calculations

Enhanced effective diaphragm area model

Refined Sigma-F methodology

Improved application of benchset parameters

Included additional combinations of actuator and linkage types

KVAP 3.0 Released in 2009

JOG MOV PV-based predictions

SQL server and Access database options

Packing friction force calculator

Parallel slide gate valve model

Butterfly valve disc weight equations

Data import & export features

SI units

Force equations provided

MOV setup window to account for margin and uncertainty values

MOV sizing module for Limitorque, Rotork, Autotork, Auma and user defined actuators

Spring characteristics for bellows sealed valves

Nested spring equations for air operators

An enhanced AOV set-up control module with a test data import feature

KVAP 3.1 Released in 2010

Rising & Rotating Stem Globe Valves

Globe Valve Enhancements for Refined Mid-Stroke Predictions

MOV Setup Window & Measurement Uncertainty Enhancements

KVAP Version 4.0 Released in 2016

Utilization of .NET architecture that is natively compatible with 32 bit/64 bit Windows 7, Windows 8, and other future Microsoft operating systems

Evaluation of AOV/MOV functional margin from test data in accordance with ASME OM Code Mandatory Appendices III and IV

Enhanced AOV uncertainty calculations with instrument catalogs to address measurement uncertainties

Expanded efficiency & effective diaphragm area interpolation over the full stroke for quarter-turn actuators

Enhanced layout and ability to work with multiple analysis at the same time

Improved unwedging methodology for gate valves

MOV Degraded voltage calculation using Motor Control Center (MCC) voltage and up to 3 cable lengths at different temperatures.

Inertia factor effects on MOV actuator set-up window

Pivot Cylinder Air Actuator

KVAP Version 4.1 Released in 2016

Enhanced gate valve module to determine required thrust and status of predictability for high flow applications with standard wedge gate valves and with Westinghouse gate valves (for EPRI Licensed Users Only)

KVAP 4.2 Enhancements Released in 2019

DC Motor Methodology for linear and quarter-turn valves

- Uses valve load profiles from KVAP or external data
- Allows quarter-turn valve modeling not found in other tools

EPRI Balanced Globe Valve Side Load Methodology based on EPRI 3002009050.

MOV stem nut wear model

Additional fields for ASME Appendix III implementation

Enhanced eccentric plug valve model

KVAP 4.3 Enhancements Released in 2021

Calculation workflow routing

Windows authentication login

Electronic signatures

Calculation change tracking by user

Compare differences between analyses

Archive analysis and report feature

Software self-verification