From: Halter, Mandy
Sent: Monday, June 20, 2011 1:33 PM
To: 'pbode@entergy.com'
Subject: Part 21 - KASI MOV and AOV Software
Attachments: EN46955.pdf; KVAP-Software-for-AOV-&-MOV-design-basis-margin-calculations-for-JOG-Program-Implementation-GL-96-05-Periodic-Verification-margin-improvement.pdf

Paul,

Attached is the Part 21 that came out of Oconee (attached above EN 46955). The defect is related to errors in the Kalsi Engineering Valve and Actuator Program (KVAP) software that provide default flow and torque coefficients for ball and plug valves which can affect margin predictions.

Please confirm whether or not Indian Point has reviewed this issue for applicability.

Thanks and kind regards,

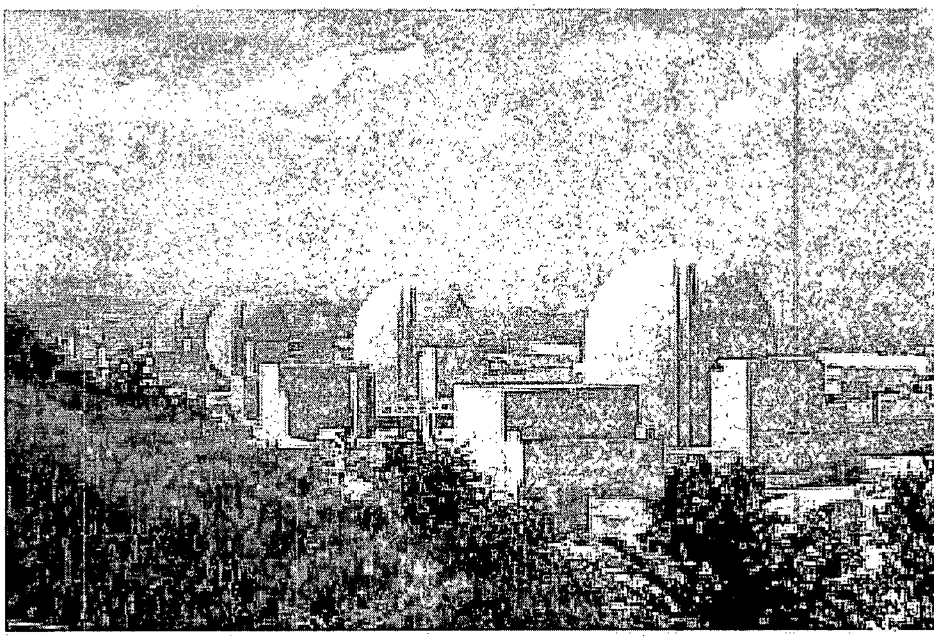
Mandy

Mandy Halter
U.S. Nuclear Regulatory Commission
Resident Inspector
Indian Point Energy Center - Unit 3
(914) 739-8565

A-26

KVAP

The Leading AOV/MOV Software...



...Serving the Energy Industries

Kalsi Engineering, Inc.
745 Park Two Drive
Sugar Land, TX 77478-2885
(281)240-6500
www.kalsi.com

Revision Date: December 17, 2007

Table of Contents

Introduction to **KVAP**
The AOV/MOV Software with Technology

KVAP, the Kalsi Valve & Actuator Program, is a state-of-the-art software for performing reliable design basis calculations for all common types of globe, gate, diaphragm, butterfly, ball, and plug valves.

The KVAP software represents a *significant advancement* over all other design basis calculation software packages (e.g. EPRI MOV PPM, ACE, AirBase, etc.) available in the industry for it incorporates *validated* models that the industry was lacking for many different types of valves commonly used in AOV/MOV applications (see Tables 1(A) through 1(D)). These validated models are the outcome of a very comprehensive flow loop testing program conducted by Kalsi Engineering, Inc., (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 below).

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 performed under the Kalsi Engineering, Inc., quality assurance program, which meets 10CFR50 Appendix B requirements.

KVAP Benefits

Key advantages offered by KVAP to it's over 50 current users are:

- 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
- 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 :

- 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, Stability and Continuity

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

Table 1(A)

Quarter-Turn Valves **Validated Methodologies/Software Available For AOVs & MOVs**

	Valve Types Prevalent in AOV Population	NRC/INEL Cont. Purge*	EPRI MOV PPM**	Ace, AirBase	KVAP
1	Symmetric Butterfly	None	✔	None	✔
2	Single-Offset Butterfly	✔	✔***	None	✔
3	Double-Offset Butterfly	None	None	None	✔
4	Segmented V-Ball	None	None	None	✔
5	Spherical Ball	None	None	None	✔
6	Eccentric Plug	None	None	None	✔
7	Tapered/Cylinder Plug	None	None	None	✔

* No software was provided by NRC/INEL

** No Compressible flow testing was performed by EPRI

*** EPRI Models found to be non-conservative for certain applications as described in NRC Part 21 and EPRI Error Notices (see previous page for a listing)

Table 1(B)

Linear Valves **Validated or First Principles Based Methodologies/Software Available for AOVs & MOVs**

	Valve Type	EPRI MOV PPM	Ace, AirBase	KVAP
1	Globe-Unbalanced	✔	✔	✔
2	Globe-Balanced, Cage	✔	✔	✔
3	Globe-Balanced, Double Disc	✔	✔	✔
4	Globe-Balanced, Pilot	None	✔	✔
5	Globe-3-way Converging, Single Disc	None	None	✔
6	Globe-3-way Converging, Double Disc	None	None	✔
7	Globe-3-way Diverging, Single Disc	None	✔	✔
8	Globe-3-way Diverging, Double Disc	None	✔	✔
9	Diaphragm	None	✔	✔
10	Gate-Solid or Flexible	✔	✔	✔

Table 1(C)

Linear and Quarter-Turn Actuator **Models/Software Available for AOVs & MOVs**

Actuator Type	EPRI MOV PPM	Ace, AirBase	KVAP
AOVs			
Cylinder	None	✔	✔
Diaphragm	None	✔	✔
Scotch Yoke	None	✔	✔
Rack & Pinion	None	✔	✔
Cylinder with Linkage (Type 1)	None	✔	✔
Cylinder with Linkage (Type 2)	None	None	✔
Diaphragm with Lever	None	✔	✔
MOVs			
Limitorque	None	✔	✔
Rotork	None	✔	✔
Other			
User Defined	None	✔	✔

Table 1(D)

Margin Evaluation **and** *AOV Set Point Control* **Features**

Feature	EPRI MOV PPM	Ace, AirBase	KVAP
Margin Evaluation	None	✔*	✔
AOV Setup Box for Set Point Control	None	None	✔

***For linear valves, mid stroke margins are not calculated in Ace or AirBase**

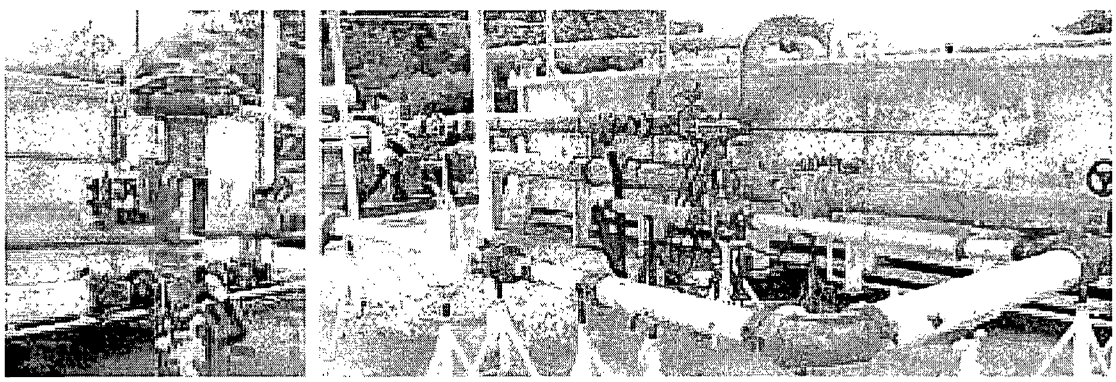
Background of Kalsi Engineering Flow Loop Testing and Validated Model Development Program for **KVAP**

As summarized in USNRC Regulatory Issue Summary 2000-03, problems with power-operated valves have resulted in an increased emphasis by USNRC on improving the performance reliability and predictability of AOVs. 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 AOV programs. Additionally, four utilities performed design basis calculations under EPRI's AOV pilot programs. This resulted in a calculation methodology for AOVs, which is documented in the EPRI AOV Evaluation Guide (TR107322).

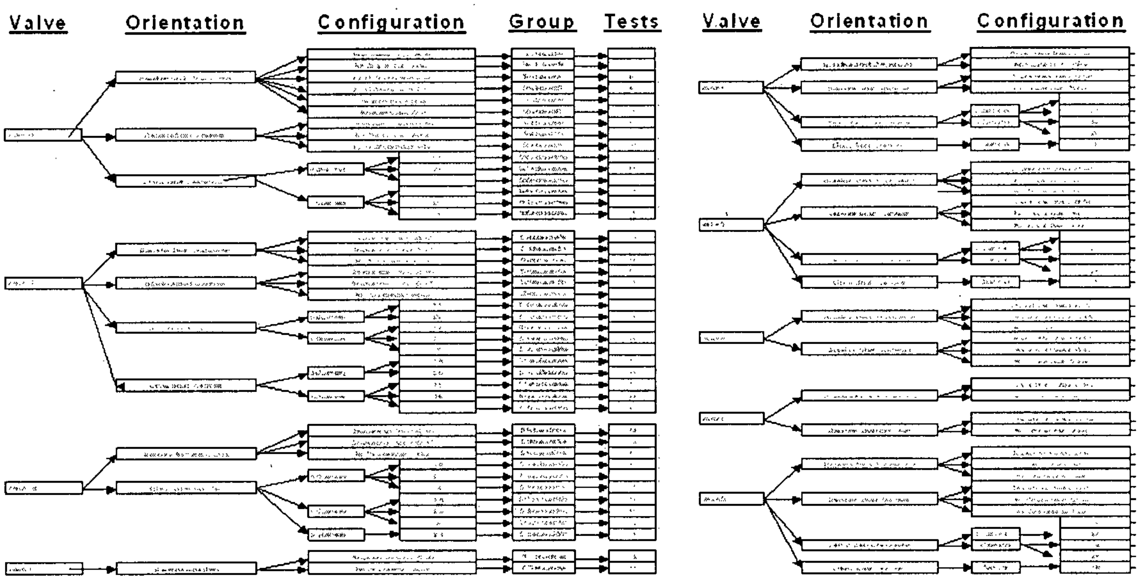
These EPRI AOV pilot plant programs, and the implementation of the AOV Evaluation Guide methodologies at other plants revealed three key problems:

- 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 AOV applications.

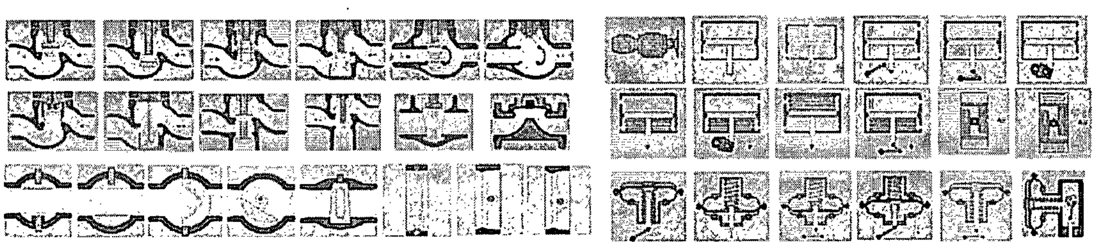


A comprehensive matrix of flow loop testing was performed to develop more accurate validated models for AOVs incorporated in KVAP.



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 AOV, MOV, HOV, SOV and check valves. Our specialists have more than 20 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 programs at more than 25 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
- 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
- Diaphragm

Quarter-Turn

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

Other

- User Defined

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*

Electric Motor

- Limitorque
- Rotork

Other

- User Defined
  - *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

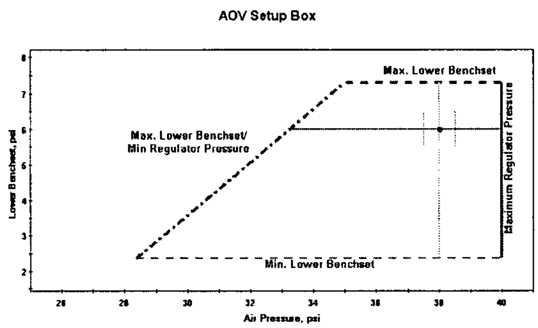
- Performs *reliable* POV design basis calculations, including minimum required thrust/torque, actuator capabilities and margin
- Eliminates the need for dynamic ΔP testing, saving tens of thousands of dollars per valve
- Provides models for double-offset butterfly, full ball, segmented ball, and plug 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.

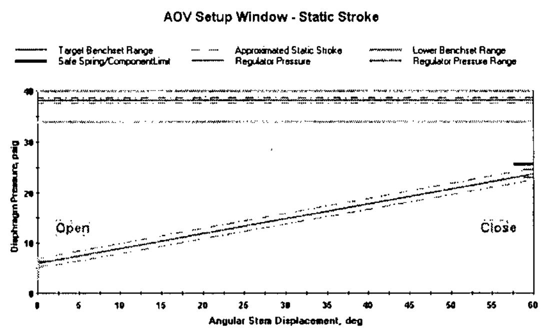
AOV Setup Box and Set Point Data Sheets for Field Implementation

The component level calculations provide an assessment of actuator margin based on valve requirements and actuator output. Changes in valve set points (e.g. regulator, air pressure and spring preload) and packing adjustments may affect the actuator output and invalidate values calculated prior to performing valve setup tests. Additionally, adjustments of the set points in one direction may affect the required set point in the opposite direction. To facilitate the addressing of these issues, a setup module has been incorporated into KVAP that graphically displays the required and allowable spring preload (i.e. minimum and maximum allowable lower bench set) as a function of regulated air pressure and regulator settings using two different approaches. This setup box also accounts for all AOV uncertainties in various parameters. The set point datasheet defines the setup parameters and allows adjustments to be made without revisiting the margin calculations. The following figure shows a typical AOV setup box and an alternative approach of displaying static thrust trace predicted by KVAP and the allowable bench set window.



Approach (A)

Setup Box Showing Allowable Spring Preload Range as a Function of Regulated Air Supply Pressure



Approach (B)

Setup Window for Allowable Lower Bench Set Range for a Given Regulated Air Supply Pressure Displayed on KVAP Static Thrust Stroke Predictions

Graphical Approaches in KVAP for Field Implementation of AOV Setup Parameters

MOV Actuator Module

The KVAP MOV Actuator Module is developed to calculate torque and thrust capabilities for motor operated valve actuators and quarter-turn units based on "Application Guide for Motor-Operated Valves in Nuclear Power Plants" prepared by Kalsi Engineering, Inc. It features a user-friendly graphical interface that reduces mistakes and errors commonly made during calculations, thus enabling a more efficient completion of evaluations. The module includes Limitorque SMB/SB/SBD actuators, Rotork Actuator, and quarter turn gear operators. This module can augment calculations performed during the implementation of the GL-96-05 MOV JOG Periodic Verification program.

The Limitorque actuator module enables the calculation of SMB/SB/SBD for:

- Pullout torque/thrust,
- Stall torque/thrust,
- Running torque/thrust and
- Stem speed

Inputs include: the overall gear ratio, stem thread characteristics (as applicable), application factors, efficiency, reduced voltage, and temperature effects (as applicable). The model comprises equations, and built-in manufacturers' default values for actuator efficiency, application factors, motor ratings, and temperature effects. The model also provides inputs for using enhanced electric motor models such as ComEd.

The Rotork actuator module uses torque and thrust output capability values published in the Rotork catalog for "A" type actuators. The user selects the gearbox size and stem nut RPM, and enters stem diameter, stem lead, stem pitch, and coefficient of friction between the stem and stem nut. The model selects the corresponding values of torque rating and thrust rating and calculates the thrust output. The value for torque output is the same as the torque rating. The values returned are applicable to type "A" 60 Hz 3 phase Rotork actuators.

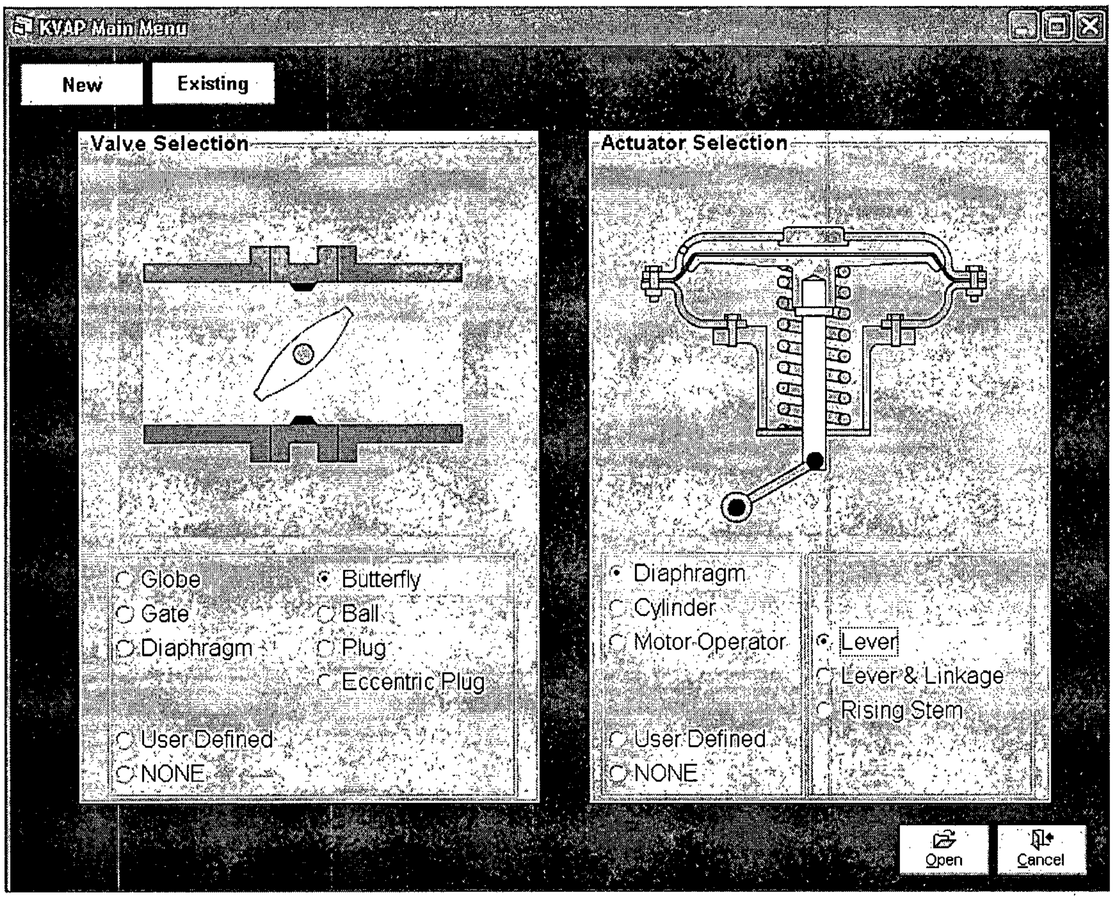
The quarter turn gear operator can be coupled to Limitorque or Rotork actuators. The inputs allow for any generic actuator definition which defines the actuator by gear ratio and efficiency.

Typical **KVAP** Screens

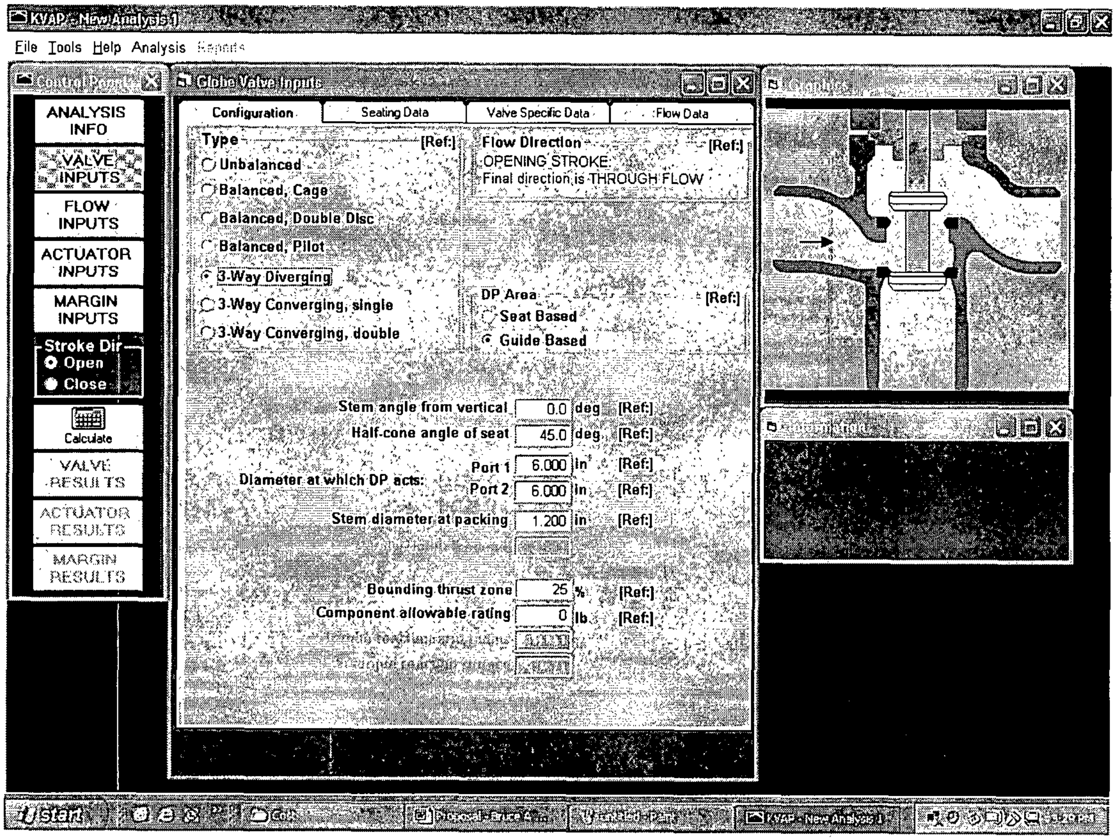
The KVAP software input and output screens are heavily supported by graphics that illustrate critical features and dimensions of the valve being analyzed, valve orientation, flow direction, elbow orientation, required valve thrust/torque throughout the stroke, minimum and maximum actuator capability 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:

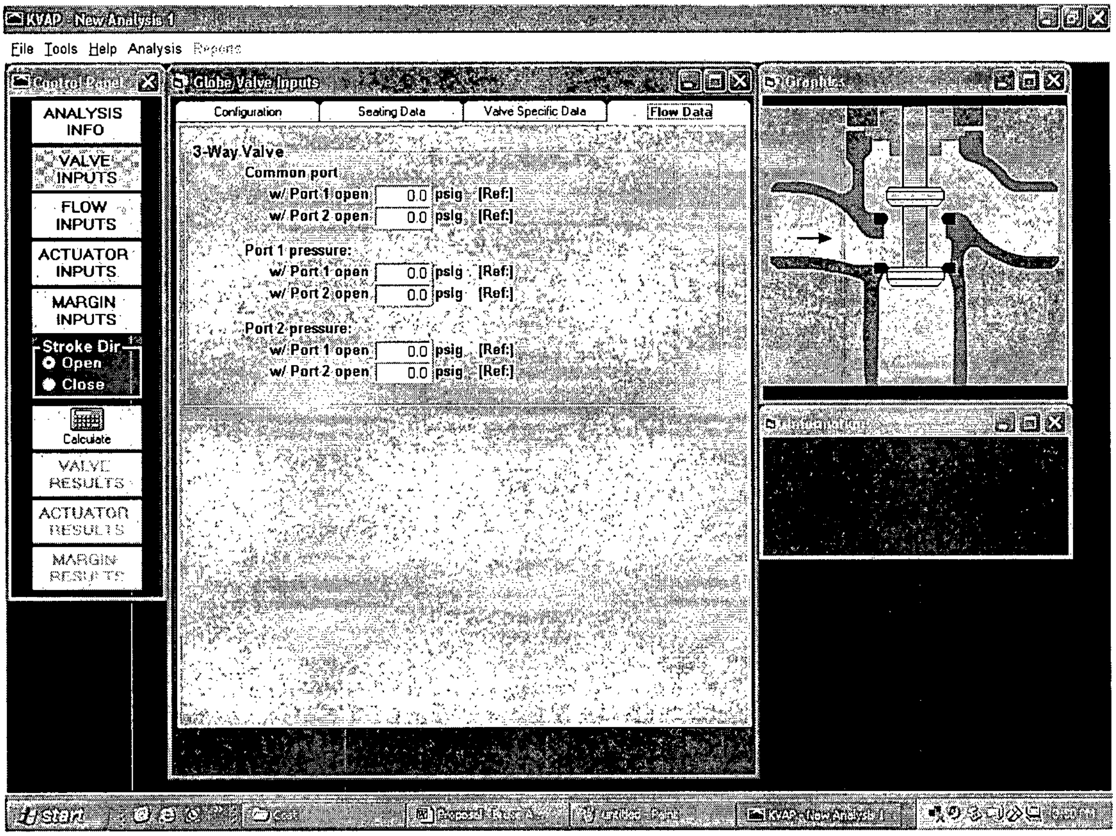
KVAP Main Menu



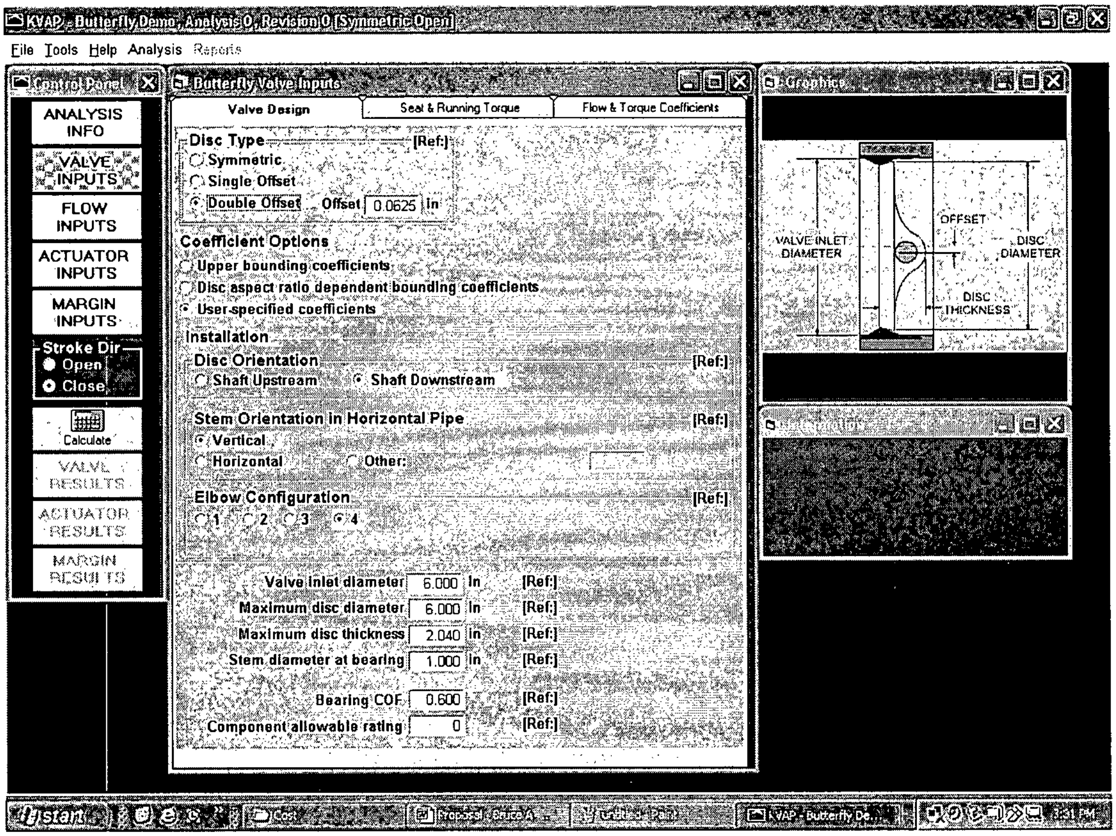
Globe Valve Configuration



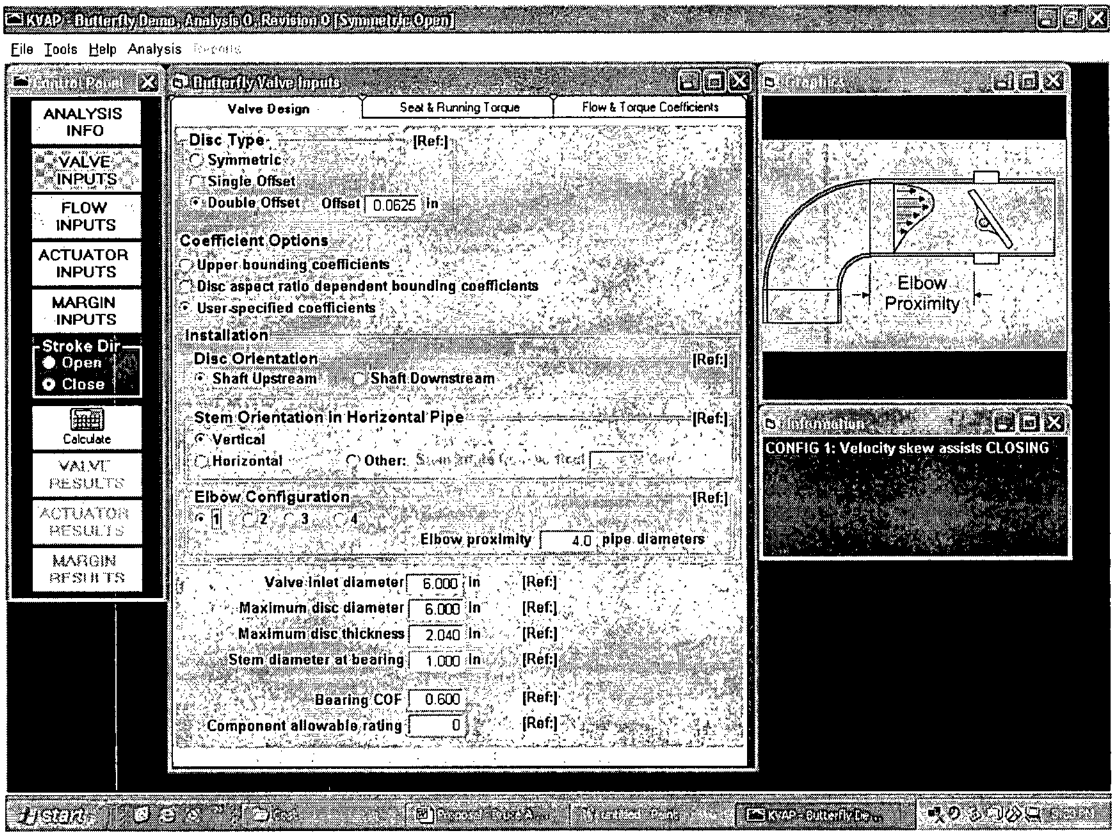
Flow Inputs for Globe Valve



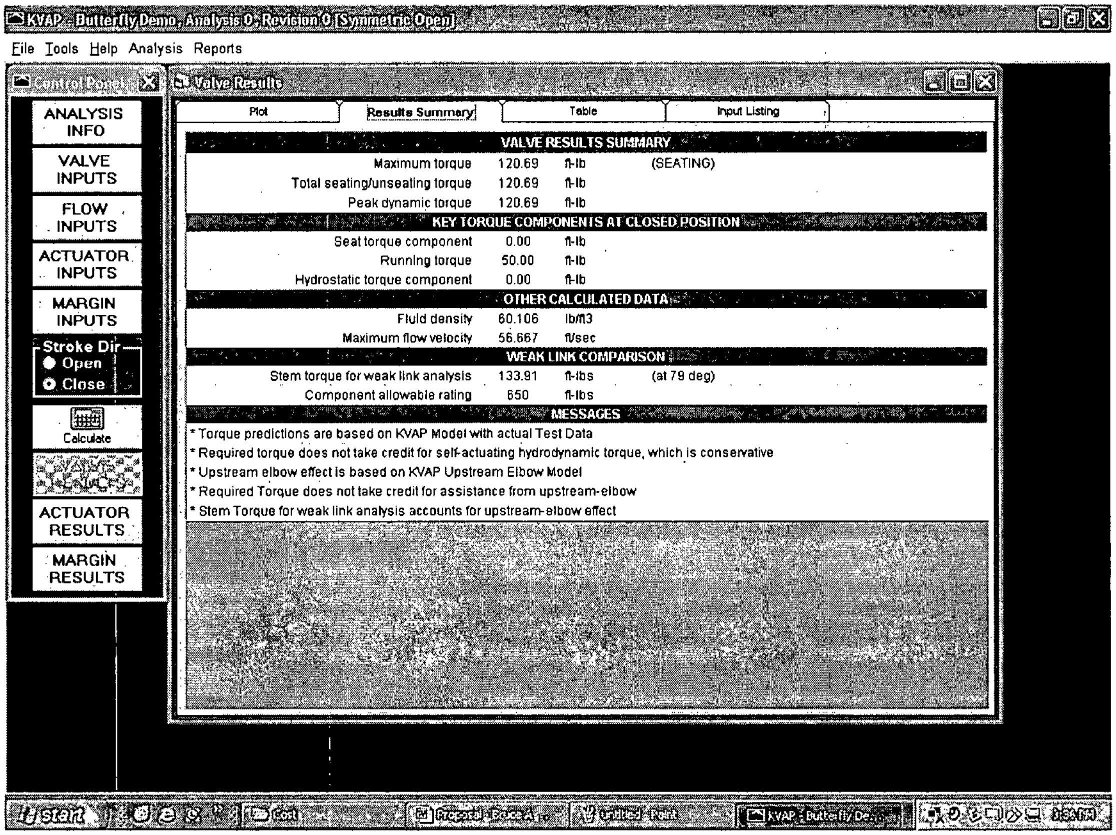
Valve Design



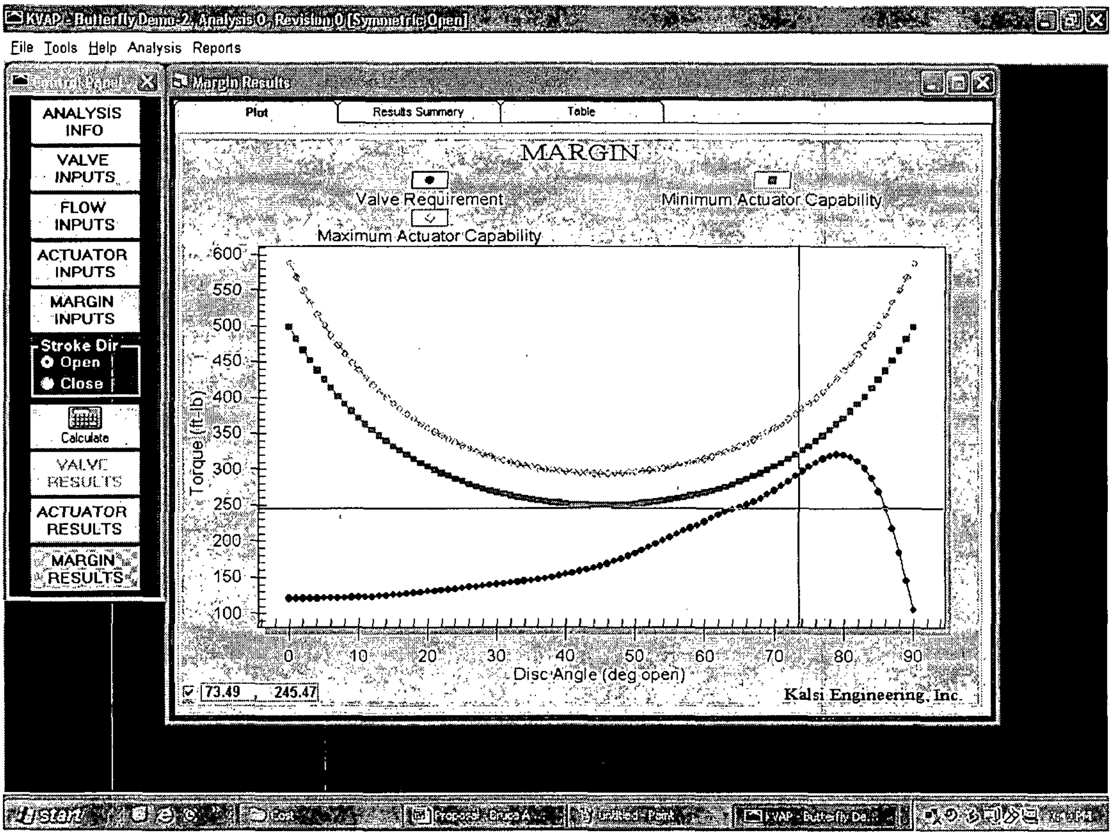
Valve Installation



Valve Results



Margin Plot



KVAP - Butterfly Demo-2, Analysis 0, Revision 0 [Symmetric Open]
File Tools Help Analysis Reports
ANALYSIS INFO
VALVE INPUTS
FLOW INPUTS
ACTUATOR INPUTS
MARGIN INPUTS
Stroke Dir
Open
Close
Calculate
VALVE RESULTS
ACTUATOR RESULTS
MARGIN RESULTS
Margin Results
Plot
Results Summary
Table
MARGIN
Valve Requirement
Minimum Actuator Capability
Maximum Actuator Capability
Torque (ft-lb)
Disc Angle (deg open)
73.49 , 245.47
Kalsi Engineering, Inc.
start

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 AOV, MOV, and check valve issues for nuclear power utilities over the last 25 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 at the same facility in the Houston metropolitan area. This environment facilitates the development of the most optimum approach based on the appropriate combination of analysis and testing.

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

- ***Personnel with Strong Technical Background, Experience, and Continuity.*** Our key personnel have more than 25 years of experience directly related to solving problems with all types of valves, and the average tenure of our senior staff is 19 years. Their continuity and depth of experience makes them immediately productive on your project.

- ***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 2).

  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.

- ***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, 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.
- ***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.

Table 2: Kalsi Engineering EPRI Projects		
EPRI Report Title	**Report No.**	**Kalsi Engineering Principal Investigators**
Gate Valve Model Report	TR-103229	Wang, Kalsi
Butterfly Valve Model Description Report	TR-103224	Eldiwany, Kalsi
Stem Thrust Prediction Method for Westinghouse Flexible Wedge Gate Valves	TR-103233	Wang, Kalsi
Stem Thrust Prediction Method for W-K-M Parallel Expanding Gate Valves	TR-103236	Eldiwany, Alvarez
Gate Valve Design Effects Testing Results	TR-103255	Alvarez, Kalsi
Butterfly Valve Design, Elbow, and Scaling Effects Test Report	TR-103257	Sharma, Kalsi
Motor-Operated Valve Margin Improvement Guide	TR-100449	Alvarez, Kalsi
Application Guide for Motor-Operated Gate and Globe Valves in Nuclear Power Plants, Rev. 2	1015396 Volume 1	Kalsi, Wang, Alvarez, Eldiwany
Application Guide for Motor-Operated Butterfly Valves in Nuclear Power Plants, Rev. 2	1015396 Volume 2	Eldiwany, Kalsi
Guide for the Application, Use, and Maintenance of Valves in Power Plants	TR-105852-V1	Eldiwany, Alvarez
Guide for the Application and Use of Valves in Power Plant Systems	NP-6516, Rev 0	Kalsi, Alvarez
Application Guide for Check Valves in Nuclear Power Plants	NP-5479, Rev 0 and Rev. 1	Kalsi, Wang, Sharma
U.S. Nuclear Industry Approaches to Address Gate Valve Pressure Locking, Thermal Binding, and Related Issues	TR-114051	Eldiwany, Kalsi
Gate Valve Thermal Binding Unwedging Thrust Methodology	E210203 Volumes 1-4	Kalsi, Wang, Alvarez, Somogyi
Non-Metallic Bearing Friction Test Program for Quarter-Turn Valves	1003151, 1007285, 1007286, 1007287 1007288	Alvarez, Sicking
Limitorque Actuator Fatigue Life Extension	1013464	Estep, Alvarez, Kalsi

Table Updated on August 21, 2007

- ***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 (see Attachment 2 papers).
- ***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 LTAFLA 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 Gate Valve Unwedging Thrust, including Pressure Locking and Pressure-Induced Binding.*** 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.*** Under the sponsorship of EPRI, Kalsi Engineering has developed a comprehensive, first-principles model for thermal binding of gate valves. Under Phase I, the first principles model was released in March 1998 as EPRI Report No. GC-110301. Phase II is in progress to validate the methodology by flow loop testing under a variety of thermal binding scenarios.

- ***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 3,000 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 six 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 20 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 30 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 25 patents, eight of which pertain to valve design improvements, and has published more than 60 technical papers related to valves. 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 25 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 more than 40 nuclear power plants as well as all major valve manufacturers in resolving valve issues for gate, check, safety relief, plug, control, butterfly, and ball valves. Dr. Kalsi has worked extensively in all aspects of valves: 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 best technical approach to meet the project objectives at a minimum cost.

Mr. P. D. Alvarez holds a Bachelor Degree in Mechanical Technology. He is a vice president and principal consultant at Kalsi Engineering, and has over 31 years of experience in performing valve calculations, design basis reviews, operability evaluations, and providing recommendations to solve valve problems. Prior to joining Kalsi Engineering, he worked at a major valve manufacturing company. He has performed extensive work in the design, analysis, and testing, of valves of all types. He currently holds six patents, five pertaining to valve improvements.

He was the project leader responsible for developing a very sophisticated Gate Valve Design Effects Test Fixture under the EPRI MOV Performance Prediction Program. Mr. Alvarez conducted an extensive matrix of tests to evaluate the effect of variations in design features present in different manufacturer's valves on the performance under a range of □P and flow conditions. He was the lead engineer in the Limitorque Actuator Thrust Rating Increase study performed by Kalsi Engineering for a consortium of nuclear utilities. He was also a principal contributor to the development of the GE Improved Gate Valve. He was responsible for overall project coordination of the Kalsi Valve Analysis Program (KVAP) and development of validated models for POV quarter-turn valves at Kalsi Engineering.

Mr. Alvarez was a principal contributor to the preparation of *Application Guidelines for Valves in Nuclear Power Plants* that was published in 1990 and updated in 1998 under EPRI sponsorship. He has worked on several projects relating to MOV actuator sizing and thrust requirements over a range of operating conditions for ten major utilities; analyzed operability problems in different types of valves in power plants, pipelines, petrochemical, and oil field applications; and developed modifications to overcome operability problems. He has performed stress analyses to determine maximum stresses at critical areas of the drive train from the actuator to the final inner valve element and identified problem areas to allow the correct settings for limit switches. He has designed several test fixtures and performed instrumented tests on valves under conditions simulating various combinations of piping loads, flows, pressures, and temperatures. Mr. Alvarez was project leader in performing MOV design basis reviews related to torque/thrust requirements, determination, and improvements. He was the principal investigator for the EPRI MOV Margin Improvement Guide and Gate Valve Design Effects Testing.

Dr. Bahir Eldiwany holds a B.S., M.S., and Ph.D. degrees in mechanical engineering. He is a senior consultant with 20 years of experience with Kalsi Engineering in mechanical equipment design and analysis, including MOVs, AOVs, and check valves. His analysis experience includes first principles model development, design basis reviews, and recommending solutions for valve problems. He has performed analyses to determine operating thrust/torque requirements and stresses in various types of gate valves, butterfly valves, and globe valves and has developed many in-house and commercial software packages to perform valve calculations. Dr. Eldiwany has performed root cause investigations of valve failures and has been instrumental in proposing design modifications and solutions for MOV, AOV, and check valve problems. Dr. Eldiwany was the principal investigator in developing the Butterfly Valve Model and the W-K-M Parallel Expanding Gate Valve Model of the EPRI MOV PPM. He also developed the Butterfly MOV Guide for EPRI/NMAC. Recently he was the lead engineer for developing the quarter-turn butterfly, ball, and plug valve models for the Kalsi Valve and Actuator analysis Program (KVAP) to more accurately predict torque requirements.

Dr. J. K. Wang holds B.S., M.S. and Ph.D. degrees in mechanical engineering. He has been a vice president and principal consultant at Kalsi Engineering for 25 years, and has 28 years of experience in performing valve calculations, model development, component level design basis reviews, operability evaluations, and providing recommendations to solve valve problems for more than 35 nuclear power plants. Prior to joining Kalsi Engineering, he worked at a major valve manufacturing company. His background includes detailed analysis, design, and testing of valve body structures and internal components such as seats, gates, stems, and packing to accommodate external piping loads, pressures, and temperatures to ensure valve operability and structural integrity. Dr. Wang was the principal investigator in developing the *Flexible and Solid Gate Valve Model* and Westinghouse *Gate Valve Model* of the EPRI MOV Performance Prediction Program. He was also the principal investigator for the development of Kalsi Engineering's Generalized Pressure Locking Methodology and EPRI's Gate Valve Thermal Binding Methodology. He was the lead engineer for developing the first principles model for gate valves, globe valves, diaphragm valves, and all linear and quarter-turn actuators used in the Kalsi Valve and Actuator Program (KVAP) software.

Mr. Neal Estep holds a B.S. and M.S. in mechanical engineering and is a licensed PE. He is a Senior Specialist and Project Manager with over 25 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 also 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 also 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 also 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. Steven Averitt holds a B.S. degree in mechanical engineering. He is a consulting engineer \ with more than nine years of experience in analysis, modeling, and capability evaluations of MOVs, AOVs, and check valves. Mr. Averitt has supported project leaders by reducing data obtained from analysis and testing, and by evaluating MOVs in safety and non-safety nuclear power plant applications using in-situ test data. He has been responsible for developing a user-friendly input interface for the Kalsi Engineering model used to analyze gate valves in support of NRC GL89-10 programs. He was responsible for the development of valve body and disc stiffness models used in the enhanced pressure locking and thermal binding methodologies developed by Kalsi Engineering. He is the software lead engineer for the development, maintenance and enhancements of Kalsi Engineering's KVAP software.

Mr. Ryan Sicking holds a B.S. degree in mechanical engineering. He is a consulting engineer with nine years of experience in analysis, design, testing, and capability evaluations of MOVs, AOVs, and check valves. Mr. Sicking has been a project leader on numerous high-volume AOV, MOV, and check valve evaluations, and is knowledgeable and fluent in the use of Kalsi Engineering software such as KVAP, CVAP, LiFE, and KEI's pressure locking and thermal binding software. He has also assisted in developing the user-friendly input interfaces for many of the Kalsi Engineering software models. Mr. Sicking is the principal engineer responsible for actuator test stands used in performing quality control testing at nuclear power plants and at Limitorque Corporation. He has also supported several cases in expert witness litigation related to valve incidents

Mr. Zachary Leutwyler 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 includes 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 graduate course work emphasized studies in computational, thermal, and fluid sciences. 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 has been a part the Kalsi Engineering research and development team for several years (both working directly and in partnership with the University of Houston). He has had a significant role in the KEI AOV quarter-turn valve test program (including incompressible and compressible fluid media), computational modeling and methodology development and application. Mr. Leutwyler also has had an active role in developing the Kalsi Valve and Actuator Analysis Program (KVAP) software. Prior to joining Kalsi Engineering, Mr. Leutwyler worked for a major valve manufacture and has a fundamental understanding of valve and actuator assembly, positioner calibration and seat-leak, hydrostatic, and valve diagnostic testing. His valve experience also includes pneumatic, I/P, and digital positioners.

Mr. Aaron Richie holds a B.S. degree in mechanical engineering. He is a consulting engineer \ with more than five years of experience in analysis, modeling, and capability evaluations of MOVs, AOVs, and check valves. 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 supports Steven Averitt in the development, maintenance and enhancement of the Kalsi Valve and Actuator Program (KVAP) software.

KVAP References and Other Significant Documents Developed by Kalsi Engineering, Inc.

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 Version 1.2: 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 Version 2.0: 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 Version 2.0: Software Design Specification - Default Flow and Torque Coefficients Module for Butterfly.*
15. KEI Document No. 2094C, Attachment 12: *KVAP Software Version 2.0: Software Design Specification – Motor Operator.*
16. KEI Document No. 2095C: *KVAP Software Version 2.0: Program Code Listing:*
17. KEI Document No. 2096C: *KVAP Software Version 2.0: Verfication and Validation Plan.*

18. KEI Document No. 2097C: *KVAP Software Version 1.2: 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 Version 2.0*: *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).

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EPRI/NMAC Guides developed by Kalsi Engineering, Inc.

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71. 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.

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80. EPRI MOV Performance Prediction Program: Stem Thrust Prediction Method for Westinghouse Flexible Wedge Gate Valves, Electric Power Research Institute, EPRI TR-103233.

81. EPRI MOV Performance Prediction Program: Stem Thrust Prediction Method for W-K-M Parallel Expanding Gate Valves, Electric Power Research Institute, EPRI TR-103236.

82. 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 November 2000

Initial Modules

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

KVAP 1.1 Released March 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 February 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 January 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 May 2004

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 August 2004

Corrected problem identified in Error Report 2004-2

KVAP 2.2 Released October 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 to be released in 2008

JOG MOV PV predictions

SQL server database

Force equations in reports

Packing friction force calculator

Parallel slide gate valve model

Butterfly valve disc weight equations

Data import & export features

SI units

MOV setup window to account for margin and uncertainty values

Autotork and AUMA actuator capability tables

Spring characteristics for bellows sealed valves

Nested spring equations for air operators

Potential Enhancements for Future Revisions

PPM equivalent predictions

Westinghouse valve model

Split wedge gate valve model

Anchor-Darling double disc gate valve model

Comprehensive KVAP Training Seminar Outline

1. **Thrust Requirements for Globe Valves**
   - Required Stem Thrust for Globe valves
   - Model Applicability and Limitations
   - Approach
   - Assumptions
   - Required Thrust for Unbalanced Disc Globe Valves
   - Required Thrust for Balanced Disc Globe Valves
   - Required Thrust for Other Types of Globe Valves
   - Criteria for Determining whether a Globe Valve is Seat Based or Guide Based
2. **Evaluation of Air Operators**
   - Scope
   - Model Description
   - Assumptions
   - Rising Stem Actuators
     - — Double-Acting Air Cylinder, Single Ended
     - — Double-Acting Air Cylinder, Double Ended
     - — Double-Acting Air Cylinder, Direct Acting (Spring to Retract)
     - — Double-Acting Air Cylinder, Reverse Acting (Spring to Extend)
     - — Direct-Acting Diaphragm (Spring to Retract)
     - — Reverse-Acting Diaphragm (Spring to Extend)
     - — Direct-Acting Diaphragm with Mechanical Advantage
     - — Reverse-Acting Diaphragm with Mechanical Advantage
   - Quarter-Turn Stem Actuators
     - — Scotch Yoke, Double-Acting Air Cylinder
     - — Scotch Yoke, Single-Acting Air Cylinder with Spring to Retract
     - — Rotary Diaphragm Actuator
     - — Rack and Pinion, Double-Acting Air Cylinder
     - — Rack and Pinion, Single-Acting Air Cylinder with Spring Return
     - — Double-Acting Air Cylinder with Linkage
     - — Single-Acting Air Cylinder with Spring Return and Linkage
3. **Torque Requirements for Butterfly Valves: KVAP-Improved Models**
   - Torque Requirements for Butterfly Valves
     - — References
     - — Butterfly Valve Design
     - — KVAP Butterfly Valve Model
   - Model Applicability and Limitations
   - Assumptions
   - Effect of Flow Disturbances on Hydrodynamic Torque (Upstream Elbow Model)
   - Maximum Transmitted Torque, T_{TR}
   - KVAP Butterfly Model Validation

4. **Torque Requirements for Ball/Plug Valves KVAP Improved Models**
   - Ball/Plug Valve Model
   - Assumptions
   - Required Actuation Torque
5. **Thrust Requirements for Solid and Flexible Wedge Gate Valves**
   - Scope
   - Model Applicability and Limitations
   - Assumptions
   - Application of Thrust Equations for Steam Flow Conditions
   - Opening Stroke Equations
   - Closing Stroke Equations
   - Force Component Calculations
   - Bounding Friction Coefficients
   - Obtaining Disc-to-Seat Friction Coefficient through In-Situ Testing
   - Relationship between Valve Factor and Coefficient of Friction for Gate Valves
     - Exact Relationship between the Valve Factor and the Disc-to-Seat Coefficient of Friction
6. **Thrust Requirements for Diaphragm Valves**
   - Required Stem Thrust
   - Definitions and Units
   - Assumptions
   - Opening Stroke Equations
   - Closing Stroke Equations
   - Force Component Calculations
7. **Case Studies – Plant Examples Provided by Students**

OPTIONAL TOPICS

8. **Overview of AOV Problems, Testing Control, & Accessories**
   - Major Causes of AOV Failure
   - Corrective Actions
   - Overview of AOV Diagnostic Devices
   - Bench Set Point Control
   - Functions of AOV Accessories
9. **Margins**
   - Margin Definitions
   - Uncertainties
   - Degradation
   - Margin Improvement