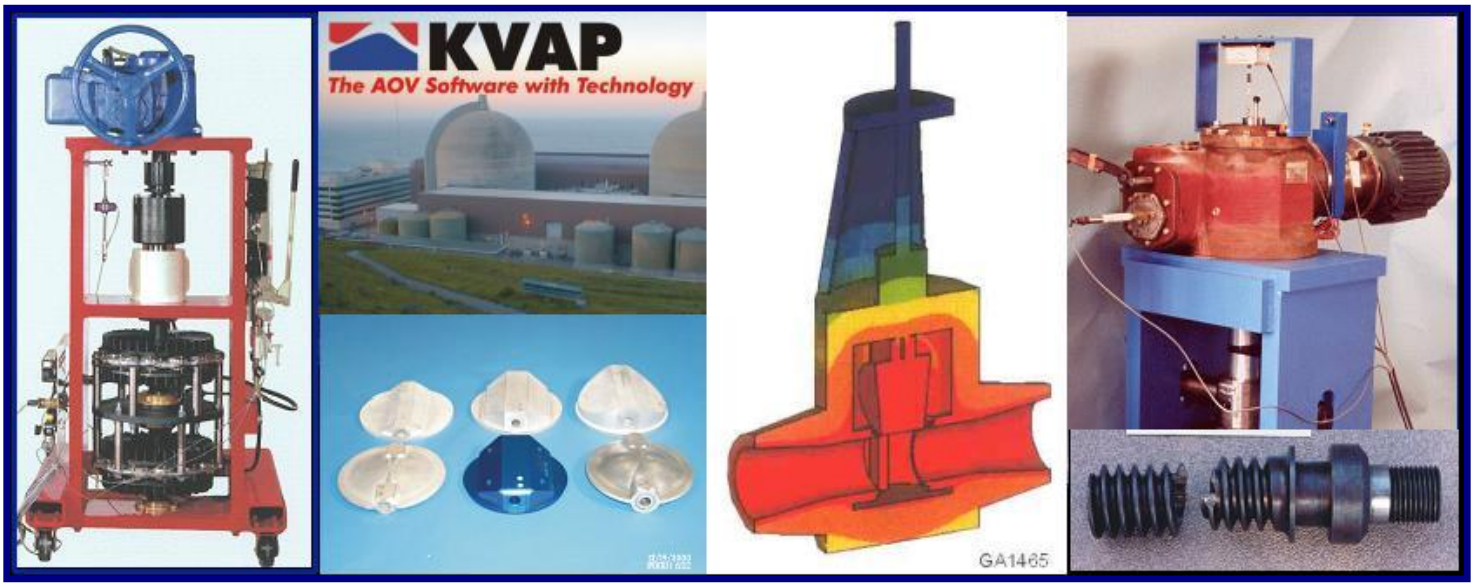
Kalsi Engineering, Inc.

Valves, Actuators, Seals & Mechanical Equipment Background



Kalsi Engineering, Inc.

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Sugar Land, Texas 77478

Kalsi Engineering, Inc. Valves, Actuators, Seals & Mechanical Equipment Background & Experience

Kalsi Engineering, Inc., a high technology firm, was founded in 1978 to provide consulting engineering services in the areas of research and development, design, analysis, and testing of mechanical equipment and structures. Our organization is recognized worldwide for technical excellence and development of innovative products. Our staff has an outstanding background and record of accomplishments in developing practical and cost effective solutions to mechanical engineering problems in a wide range of applications in the power generation, oil field, petrochemical, aerospace, defense, manufacturing, and mining industries.

The company provides advanced mechanical product design, analysis, testing, development, troubleshooting/root cause investigation, and field problem solving consulting services to the oil field, petrochemical, power generation (fossil and nuclear), aerospace, and offshore industries. Over the past 30 years KEI staff has managed many projects involving valves (gate, globe, butterfly, safety/relief, check, and ball valves), seals, pressure vessels, flanges, clamps, pumps, bearings, down-hole tools, turbines and drill string components. It has performed ASME Section VIII and Section III stress analyses: vibration (including self-excited and fluid/structure interaction), impact/shock, fatigue/wear prediction, and seismic analysis of pressure vessels, valves, and other piping components. Experience includes design, development, troubleshooting, and improvements in static and dynamic seals for harsh operating conditions (including mechanical face seals, lip seals, packings, and other unique designs). KEI staff has conducted many failure analysis investigations, made design modifications, developed predictive degradation techniques, and contributed significantly to the development of industry guideline documents for the application and use of valves.

KEI staff members have also served as principal investigators in many valve, seal and other mechanical equipment research and development projects for Electric Power Research Institute (EPRI) as well as the U.S. Small Business Innovation Research (SBIR) Phase I & II projects awarded by NRC, DOD, DOE and NASA. The proprietary, innovative technologies relating to hydrodynamically lubricated rotary shaft seals, bearings and valves developed by KEI have resulted in a number of commercial products. The company possesses over 40 patents and has authored or co-authored many technical papers, industry guides and other documents.

Design, analysis, testing, model development, application, and problem solving are areas of special competence at Kalsi Engineering. For example, our personnel have in-depth knowledge, extensive experience, and an established track record of supporting all US nuclear power utilities, as well as, electric power plants in Canada, England, France, Japan, Korea, Taiwan, Mexico, Sweden, and Switzerland. Kalsi Engineering has contributed 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 30 years is unique in the industry.

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.

Flow Loop

Testing Laboratory

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 30 years of experience directly related to solving problems with all types of valves, seals and mechanical equipment. The average tenure of our senior staff is 25 years. Their continuity and depth of experience makes them immediately productive on your project.
- ***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 made by all the major manufacturers and mechanical equipment. 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 performance. Kalsi Engineering can provide complete design modification support to solve equipment problems.
- ***Special Valve Test Facilities and Flow Loops***. Kalsi Engineering has a variety of unique test fixtures and flow loops to perform laboratory tests on mechanical equipment. For example, 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 2700 gpm is available at KEI test facilities.
- ***Development of Innovations Related to Valves, Seals & Mechanical Equipment***. Over 40 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 commercially used 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, chemical, oil and gas, nuclear, aerospace and manufacturing plants.
- ***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.

- ***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). These models are also being used for AOV evaluations as described in the EPRI AOV Evaluation Guide (TR-107322), which is endorsed by JOG AOV. 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 plants (over 75 units) in performing design basis calculations and reviews of MOV, AOV, and check valves, and providing analyses/recommendations for margin improvements related to NRC IE Bulletin 85-03, NRC GL 89-10, NRC GL 95-07, NRC GL96-05, NRC RIS 2000-3; INPO SOER 86-03, JOG AOV program, JOG MOV PV program. Some of these projects have employed advanced analytical methods (e.g., CFD and FEA or use of KEI software such as KVAP, CVAP, LiFE, etc) 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 numerous critical industry-wide programs and individual utility

issues. Kalsi Engineering has successfully supported numerous utilities in NRC closures, inspections, and enforcement conferences.

- ***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 and 95-07 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

Table 2: Significant Projects Performed by Kalsi Engineering, Inc. for EPRI

EPRI Report Title	Date	Report No.	KEI Principal Investigators
Gate Valve Model Report	October 1994	TR-103229	Wang, Kalsi
Butterfly Valve Model Description Report	December 1994	TR-103224	Eldiwany, Kalsi
Stem Thrust Prediction Method for Westinghouse Flexible Wedge Gate Valves	November 1995	TR-103233	Wang, Kalsi
Stem Thrust Prediction Method for W-K-M Parallel Expanding Gate Valves	May 1995	TR-103236	Eldiwany, Alvarez
Gate Valve Design Effects Testing Results	July 1994	TR-103255	Alvarez, Kalsi
Butterfly Valve Design, Elbow, and Scaling Effects Test Report	May 1994	TR-103257	Sharma, Kalsi
Motor-Operated Valve Margin Improvement Guide	February 1992	TR-100449	Alvarez, Kalsi
Application Guide for Motor-Operated Gate and Globe Valves in Nuclear Power Plants, Rev. 2	August 2007	1015396 Volume 1	Kalsi, Wang, Alvarez, Eldiwany
Application Guide for Motor-Operated Butterfly Valves in Nuclear Power Plants, Rev. 2	August 2007	1015396 Volume 2	Eldiwany, Kalsi
Assessment and Recommendations for Using EPRI MOV PPM Butterfly Model for Applications with Variable Actuator Output Torque Capability	February 2004	TR-1009227	Sicking, Eldiwany
Guide for the Application, Use, and Maintenance of Valves in Power Plants	September 1999	TR-105852-V1	Eldiwany, Alvarez
Guide for the Application and Use of Valves in Power Plant Systems	September 1990	NP-6516, Rev 0	Kalsi, Alvarez
Application Guide for Check Valves in Nuclear Power Plants	June 1993	NP-5479, Revs 0 and 1	Kalsi, Wang, Sharma
U.S. Nuclear Industry Approaches to Address Gate Valve Pressure Locking, Thermal Binding, and Related Issues	November 1999	TR-114051	Eldiwany, Kalsi
Gate Valve Thermal Binding Unwedging Thrust Methodology	October 2001	1006676 E210203	Kalsi, Wang, Alvarez, Somogyi
Non-Metallic Bearing Friction Test Program for Quarter-Turn Valves	October 2002	TR-113561	Alvarez, Sicking
Limitorque Actuator Fatigue Life Extension	December 2008	1016701	Estep, Alvarez, Kalsi
Air-Operated Valve Evaluation Guide: Revision 1	August 2011	1022646	Eldiwany, Leutwyler, Alvarez, Kalsi
Turbine Valve Condition Monitoring	June 2015	3002006235	Estep, Beasley, Walker
Application Guide for Air-Operated Valves Rev. 2	2016	3002008056	Beasley, Alvarez, Z. Leutwyler, Kalsi, Eldiwany, E. Leutwyler,
Evaluation Guide for Valve Thrust & Torque Requirements	2016	3002008055	Beasley, Kalsi, Alvarez, Estep, Eldiwany, Leutwyler
Balanced & Unbalanced Globe Valve Methodology Including a Validated Approach for Balance Disc Valves	2016	3002009050	Beasley, Mistry, Z. Leutwyler, E. Leutwyler, Kalsi

- ***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.

- ***Plant Evaluations of MOV Actuators.*** Kalsi Engineering, Inc. has over 15 years of actuator analysis and testing experience in performing *plant specific* evaluations of many different types of Limitorque actuators that have been subjected to over-load conditions due to incorrect setting/failure of torque switch trip for many US nuclear power plants. These evaluations addressed situations in which the over-loads were *significantly higher than those permitted by the generic recommendations* from the Limitorque Actuator Rating Increase Program. The plant specific evaluations also included the impact of inadvertently substituting lower strength materials on structural strength and fatigue life.

- ***Limitorque Actuator Rating Increase Program and LTAFLA Software***. Kalsi Engineering conducted a comprehensive four year, multi-utility-sponsored Limitorque Actuator Rating Increase Program, which has been *recognized as one of the most valuable and cost-effective programs* by all participating utilities. The program results were presented to and accepted by NRC. The program results permitted the utilities to perform Limitorque actuator evaluations, and based on the conclusions, allowed the utilities to safely use the actuators at thrust and torque ratings well above Limitorque's standard published ratings in most MOV applications. Under Phase II LTAFLA (Limitorque Actuator Fatigue Life Analysis) software was developed and validated to determine allowable cycles in operation under over-torque conditions. This project entailed performing life cycle testing of several sizes of Limitorque SMB, SB, and H0BC actuators. The test matrix included several tests in which components were taken to failure, as well as tests in which testing was suspended after reaching the ASME margin criteria required above allowable cycles. Testing was continuously monitored, and detailed NDE inspections were performed on a periodic basis to identify any impending failure (crack initiation), premature wear, and components that might require periodic maintenance/replacement.

- ***MOV Actuator Test Stand***. Kalsi Engineering developed an actuator test stand to permit testing of MOV actuators off-line to determine the actuator health before and after maintenance, to preset actuator torque switches without exposing the actuator or valve to unexpected levels of load, to determine actuator efficiency, and to develop electric motor torque signatures throughout the motor performance curve. The actuator test stand allows independent application of thrust and torque to accurately determine the effect of thrust on torque switch settings. The test stand has been sold to several utilities in the United States, Canada, and Korea.

  The test stand is capable of testing Limitorque SMB/SB/SBD, SMC, and HBC actuators and equivalent actuators made by Rotork, EIM, Hopkinson, Jucomatic, Master Gear, and other manufacturers. The test stand is capable of developing a reaction torque of 3,000 ft-lb and applying 75,000 pound of tension and compression stem load. An optional motor dynamometer allows measuring electric motor torque and speed of Limitorque actuators.

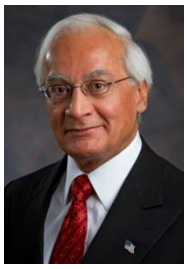
- ***MOV, AOV, and Check Valve Training Seminars for Utilities and NMAC.*** Kalsi Engineering has presented numerous seminars to provide basic and advanced MOV, AOV, and check valve training to utilities and the EPRI/NMAC organization. Seminars can be custom tailored and scheduled to meet the individual 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.
- ***Extensive Experience in 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
  - Top entry ball valves for high pressure (5,000 psi) gathering manifolds in oil and gas production
  - Rectangular body gate valves of fabricated design for high temperature cyclic service in petrochemical plant applications
  - High performance, fire-safe butterfly valves for power generation, petrochemical, chemical 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.

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 35 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 30 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. Neal Estep holds a B.S. and M.S. in mechanical engineering and is a licensed PE. He is a Vice President and Principal Consultant 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 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. P. D. Alvarez holds a Bachelor Degree in Mechanical Technology. He is a Vice President and Principal Consultant at Kalsi Engineering, and has over 35 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 DP 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.

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 Senior Consultant with over 25 years of experience in the commercial nuclear power industry with a focus on valves and other mechanical equipment. Mr. Beasley has served on multiple industry committees such as the AOV-JOG core team and the AOV User's Group steering committee. He 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 Senior Specialist 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.

Dr. Bahir Eldiwany holds a B.S., M.S., and Ph.D. degrees in mechanical engineering. He is a Senior Specialist with over 30 years of experience 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.

Mr. Zachary Leutwyler is a senior specialist at Kalsi Engineering, Inc. with more than 14 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 Senior Consultant with over 20 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 in the use of Kalsi Engineering software such as KVAP, CVAP, LiFE, and COMMAND. He has also led industry testing initiatives to quantify internal degradation of check valves using non-intrusive diagnostics. 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. Aaron Richie holds a B.S. degree in mechanical engineering. He is a consulting engineer \ with more than 16 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 also supports the development, maintenance and enhancement of the Kalsi Valve and Actuator Program (KVAP) software.

Mr. Nimish Jagtap has over 12 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, hyperelastic 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 specialist at Kalsi Engineering, Inc. holds a B.S. and M.S. in mechanical engineering. Mr. Mistry has more than 7 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 Leytwyler is a Consultant at Kalsi Engineering and has over 6 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.

Recently, Mr. Leutwyler and has been involved in developing test procedure and performing tests to support the development and validation of the refined side load model for balanced globe valves (Revision 2 of the EPRI AOV Guide).

Specialized Services/Products for Nuclear Power Plants

NAME	DESCRIPTION & BENEFITS
ENGINEERING SERVICES for all Valves & Actuators	• Determining Failure root cause and solving operability problems • Bolted joint evaluation • Design modifications to improve valve/actuator reliability & increase plant availability • Independent Third Party Reviews of Valve & Actuator Repair/Modifications and in-plant evaluations • Pre-outage engineering evaluations to define outage scope • Support the resolution of emergent valve and actuator problems on outage critical path • Self assessment and development of valve programs • Valve & actuator evaluations to support Power Uprate • Valve & actuator evaluations to support Life Extension • 10CFR50 Appendix B Flow loop/Laboratory testing to develop valve and actuator specific data • Comprehensive valve & actuator training seminars • Technical support, including customized products to suit unique requirements: CVAP, KVAP, LTAFLA, MOV Actuator Test Stand, KPLTB, etc. • AOV/MOV design basis calculations, reviews and testing to support NRC GL 89-10, 95-07, 96-05, & 96-06 including compiling vendor data, updating calculations, reconciling field test data &set-point information, resolution of low/negative margin & instability issues, application of pressure locking & thermal binding methodologies, etc. • MOV JOG Periodic Verification Program Implementation using industry best practices and all available data • Implementation of INPO SOER 86-03 check valve program, Check valve equipment reliability improvement and ASME OM-22 condition monitoring programs ***Benefits*** • Ready access to expertise for resolving emergent problems, bridging resource gaps in meeting scheduler commitments • Implement technical initiatives, training/refresher programs

KVAP Software for AOVs & MOVs	A widely accepted computer program for performing design basis margin calculations for all common types of valves and actuators used in AOV & MOV applications. *The **KVAP** database and its validated models have demonstrated substantial cost savings at many of the over thirty plants that actively use this software.* **Features** • The only software in the industry that includes a number of new validated valve models that enable *reliable* margin calculations not previously possible • KVAP includes 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. (other industry softwares lack this features and rely on unvalidated, best available information) • The user-friendly graphic interface eliminates mistakes and errors commonly made during calculations, enabling efficient evaluations without requiring a "specialist" **Benefits** • Acceptable *alternative to expensive in-situ dynamic DP testing* for demonstrating valve operability, saving thousands of dollars per valve. • New validated models *provide a substantial increase in AOV/MOV margin thus eliminating unnecessary equipment modifications (typically in excess of $500,000) and extend static periodic test intervals* • Enables doing calculations correctly the first time by overcoming the limitations of earlier models developed by EPRI as identified in EPRI MOV PPM Software Information Notice 2002-1, EPRI PPM Software Error Notice 2003-1, 2003-2 *etc.* • Mature Comprehensive Program regularly updated to incorporate industry emergent issues based on feedback from over 36 KVAP users

MOV Actuator Test Stand for Motor Actuators

A test bench to verify fitness for service following maintenance and accurately quantify MOV actuator output.

Features

Measures:

- Output torque both with and without stem thrust
- True reduced voltage capability
- Motor current & power
- Torque switch operation/settings
- Gear box efficiency, motor outputs under temperature effects
- Stall Capability

Detect post maintenance problems:

- Damaged thrust bearings
- Excessive bearing preload due to improper shim thickness or high preload on bolts
- Worm to worm shaft or Worm-to-worm gear misalignment
- Worm/worm gear excessive wear or damage
- Torque switch imbalance
- Excessive pre-load on housing cover bolts

Set-up actuator offline:

- Set torque switches for butterfly valves that close on torque. *(HBC/SMB is tested on the test stand))*
- Set torque switches to protect MOVs that operate on limits
- Develop spring pack displacement versus stem torque curves. *Particularly important when it is not feasible to install stem torque/thrust sensors on valve*
- Select optimum spring pack for required torque control

Benefits

- Increase margin (10-40%) to expand set-up window, extend periodic verification static test frequencies, avoid unwarranted equipment modification. Additional capability over calculated or published values by precisely quantifying actuator output that eliminates the need for bounding and excessively conservative assumptions
- Guarantee fitness for service by detecting actuator degradation, mis-assembly and troubleshooting sources of actuator malfunction thus preventing faulty actuators from being installed
- Enhance the readiness of replacement actuators for outages by maintaining and certifying spare actuators in between outages. Save time on outage critical path and eliminate potentially expensive damage to the MOV
- Typical payback in one outage; 22 plants installed base in USA, Canada and S. Korea

CVAP Software for Check Valves	The only widely accepted computer program to quantify the rate of degradation of check valve internals used to analyze thousands of check valves in U.S. nuclear power plants, and called a "model" for the industry by INPO. Cvap is based on rigorous testing and analytical research performed at Kalsi Engineering and reported in NUREG/CR-5159 & /CR-5583. It incorporates the technical guidelines provided by EPRI NP-5479 *Application Guide for Check Valves.* **Features** • Capable of analyzing swing, tilt, double-disc, and lift check valves. • Quantifies hinge pin wear and disc stud fatigue, • Used to prioritize valve maintenance, diagnose problems, and implement condition monitoring programs **Benefits** • Identify problem check valve applications • Prioritize maintenance and inspection to reduce unnecessary inspection of properly functioning valves • Prepare baseline calculations for a check valve condition monitoring based maintenance program
LiFE Software for MOV Electric Actuators	Limitorque Actuator Fatigue Life Analysis software computes the expected fatigue life of thrust and torsional components of Limitorque actuators **Features** • For type SMB/SB/SBD and size range including (000), (00), (0), (1), and (2). • Based on first principles models which were validated against the results of extensive testing of SMB Limitorque actuators performed at Kalsi Engineering to quantify the load cycle limitations for SMB, SB, and SBD class of actuators that have been loaded *above* their published thrust and torque ratings. **Benefits** • Permits increased actuator torque switch trip setting in low margin valves – expand static periodic verification test intervals • Reliable prediction of fatigue life of torsional components of actuators loaded *above* their published torque ratings, thus preventing unscheduled plant shutdowns & actuator replacement

KPLTB Software for Gate Valves	Software to predict unwedging thrust for gate valves including the COMBINED effects of pressure locking, thermal binding & pressure induced binding. **Features** • The only *validated* methodology to include a detailed modeling of body flexibility, pressure and temperature changes from the time the valve was closed to when it is opened (and not just the initial and final conditions), and the release of strain energy trapped in the yoke and the associated disk pinching (this phenomenon has caused significantly high opening thrust requirements in *even pressure equalized flexible wedge and solid wedge gate valves*) • Based on coupled fluid flow, thermal, and structural analysis, and extensive testing. **Benefits** • Single calculation to address pressure locking, thermal binding and pressure induced binding using the most up-to-date industry information • Enables performing the entire calculation correctly and completely the first time; overcomes limitations/large uncertainties of other industry methodologies