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Nuclear Industry Valve Problems

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Abstract

On 20 and 21 May, 1980 a workshop on nuclear industry valve problems was held at the Electric Power Research Institute (EPRI) offices in Washington, D.C. Representatives from 29 nuclear industry organizations (11 valve manufacturers, 4 nuclear steam supply system vendors, 5 utilities, 3 national laboratories, 2 architect/engineering firms, the Department of Energy (DOE), EPRI, and 2 others) attended the workshop which was organized by Sandia National Laboratories and sponsored by EPRI and DOE. Working sessions on key valves and on valve stem and seat leakage developed the following recommendations: 1) establish a small permanent expert staff to collect, analyze, and disseminate information about nuclear valve problems; 2) perform generic "key" valve programs for pressurized water reactors and for boiling water reactors, and several plant specific "key" valve programs, the latter to demonstrate the cost-effectiveness of such studies; 3) confirm the identity of, define, and initiate needed longer term research and development programs dealing with seat and stem leakage; and 4) establish an industry working group to review and advise on these efforts.

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Introduction

Is There a Problem? The substantial impact of valve failures and valve maintenance upon the safety and availability of Light Water Reactors (LWRs) was evident well before the accident at Three Mile Island (TMI). For example, thru 1978 the NRC's Licensee Event Report (LER) file contains almost 25,000 entries. Over 5,000 of these entries (20%) describe events which involved valves [1]. More than one third of the LERs that ended with a reactor shutdown involved valves. EPRI studies of valve problems [2] and of major outage trends [3] found that on a yearly basis, 30 percent of all maintenance time (up to 50% at some reactors) is devoted to valve problems; that valve maintenance during major outages (downtime 100 hr) averages 8 percent of total downtime (up to 80% during some outages); and that for typical plants, 13 percent of total in-plant radiation exposures is incurred during valve maintenance (up to 67% at some plants).

Studies of component failures by Science Applications, Inc. [4], Combustion Engineering [5], and General Electric [6] suggest that, for both BWRs and PWRs, valve problems cause at least one scram per year of plant operation and account for roughly three days of downtime per year at a typical plant. The Limiting Factor Analysis studies performed for EPRI found that valves are the cause of 12%

of total unavailability at BWRs [7], of 21% and 23%, respectively, of lost electric generating capacity at Turkey Point, Unit 3 [8], and Maine Yankee [9], and of 16% of total man hours devoted to maintenance at Oconee, Unit 1 [10].

At TMI, three problems involving valves contributed to the accident sequence. The initial feedwater transient appears to have been caused by the malfunction of an air operated valve due to moisture in a compressed air line; the auxilliary feedwater system was inoperable because it was locked out by mispositioned valves; and failure of the pressurizer relief valve to reseat helped to convert a transient event into a small break LOCA. Clearly, there is a problem!

A Little History. During the last 10 years, valve problems have been addressed by a variety of studies, meetings, and standards programs. Nuclear industry valve problems have been delineated in reports written by MPR Associates, Inc. [2], by Teledyne Engineering Services [11], and by Burns and Roe, Inc. [12]. The Department of Energy, its predecessors, and EPRI have sponsored a number of meetings in an effort to initiate a concerted industry-wide attack on valve problems.

Date	Title	Sponsor
Nov 72	Valve Operability and Integrity	AEC
Sept 75	LWR PLant and Valve Operator Design, Development and Testing Requirements	ERDA

Oct	75	GE Proposed Valve Development Program	GE/ERDA
May	80	Nuclear Industry Valve Problems Workshop	EPRI/DOE

Numerous standards writing programs have led to the adoption of at least 33 valve standards (6 ANSI, 7 RTD, 17 MSS, 1 ASME, 3 NRC). In addition, several major standards writing efforts which concern valves are underway. But, despite all of these efforts, valve problems persist.

Findings of Previous Studies. The principal findings of the EPRI sponsored MPR, Inc., "Assessment of Industry Valve Problems" were as follows:

- Turbine and turbine control, main steam isolation, feedwater control, pressurizer spray, and safety relief valves have caused repetitive shutdowns at LWRs. Most shutdowns have been of short duration but some have lasted up to 25 days.
- The maintenance burden attributable to valves is substantial. At most plants a minimum of 20% of all maintenance time is devoted to valves. Most maintenance involves repacking of stem seals, cleaning or relapping of seating surfaces, and adjustment of valve operators.

- Many valve problems are caused by misapplication of valves or by a lack of information necessary to properly maintain valves.

- Lack of compatibility between valves and their operators and control circuitry, and stem and seat leakage are generic problems.

- Valve problems are usually resolved on a case-by-case basis without industry-wide dissemination of solutions. Despite repetitive solution of the same problem, root causes frequently remain poorly defined.

During fiscal 1979, Teledyne Engineering Services and Burns and Roe, Inc., performed studies of LWR valve problems for the DOE under contract to Sandia National Laboratories. The principal findings of the Teledyne study were:

- Root causes of valve failures usually cannot be identified from current component failure data banks such as the LERs or NPRDS. An engineering evaluation center for the collection, analysis, and dissemination of valve failure data would significantly speed the resolution of valve problems.

- Excessive stem leakage due to improper packing installation or packing wear is a generic problem which can be addressed by the use of improved lubricants, packing materials and material combinations, and stuffing box designs.

- Stringent in-plant technical specification tests impose seat leak rate requirements on many nuclear valves that are difficult to meet without constant examination and reworking of valve seats. Better methods for achieving seat tightness for main steam isolation, feedwater check, and containment isolation valves are needed. Also needed are improved test procedures for detecting seat leakage, and seat maintenance procedures which minimize radiation exposures.

- Oversized actuators and misadjusted limit switches are the predominant cause of numerous structural failures of valve yoke legs and valve stems. Wide variance in operating voltage requires actuators to be sized to provide sufficient stem thrust at minimum voltage, which can produce excessive stem thrust at maximum voltage. Better specification of valve/operator/controller combinations and minimization of the varience in operating voltage can significantly decrease these problems.

- o A large scale valve test facility is needed to permit full scale testing of valves over the full range of expected operational and transient conditions.

The principal conclusions of the Burns and Roe study were:

- o Valve stem leakage frequently causes technical specifications to be exceeded thereby forcing plant shutdowns.
- o Failures of pilot operated main steam relief valves are the single greatest cause of shutdowns at BWRs. Pilot valve leakage due to dirt, debris, moisture, or vibration is the principal root cause.
- o The capabilities of spring loaded safety relief valves to perform satisfactorily during two phase flow conditions are largely unknown.
- o Excessive leakage and poor main valve control system performance are the principal causes of main steam isolation valve failures.
- o Valve seat and/or plug degradation, stem packing leaks, poor design, and improper material selection are the principal causes of problems with feedwater regulator valves.

- Pressurizer spray valves have failed frequently due to stem leakage.

- Presence of foreign matter not compatible with the operating environment, improper selection, and improper sizing are the major causes of solenoid valve failures.

- Inadequate attention is given to the specification, selection, and testing of valves to ensure their performance in the intended service.

- Valves important to safety and plant availability should be certified as suitable for the intended service either by their operating histories or by testing (the necessary testing may require the construction of a national valve test facility).

- The root cause of the failure of many motor operated isolation valves is the inability of the valve structure to handle the motor stall torque, which is often 4 or 5 times the operating torque.

The appendix of this report contains summaries of the valve problem studies performed by MPR, Inc., Teledyne Engineering Services, and Burns and Roe, Inc.

Current EPRI Programs. Working through their existing task force organization, established by participating

electric utilities, EPRI is currently sponsoring programs which address several of the major valve problems that are identified in the MPR Associates, Teledyne Engineering Services, and Burns and Roe reports. These are:

- o *Improved Packing Systems for Valve Stem Seals*
- o BWR Main Steam Isolation Valve Stem Seal and Seat Maintenance
- o Performance Testing of Safety and Power Operated Relief Valves under Steam, Water, and Mixed Media Flow Conditions

Brief outlines of these programs are presented in the appendix.

Other Programs: The Burns and Roe report identifies failures of pilot operated main steam safety/relief valves, caused principally by pilot valve leakage, as the single greatest cause of shutdowns at BWRs. A cooperative program conducted by the General Electric Co. and by Target Rock Corp. has developed a self-actuated, pilot-operated, safety/relief valve, which is not sensitive to pilot valve leakage.

EPRI/DOE Nuclear Industry Valve Problems Workshop. On 20 and 21 May 1980, EPRI and the DOE sponsored a valve problems workshop at which the current status of EPRI valve programs was summarized and the results of the Teledyne and Burns and Roe valve failure studies were presented. Representatives from 11 valve manufacturers,

4 nuclear steam supply system vendors, 5 utilities, 3 national laboratories, and 2 architect/engineering firms attended the workshop, which was held at EPRI's offices in Washington, D.C. A list of the workshop attendees and the workshop agenda are presented in the appendix. Working group recommendations are presented in the next section.

Recommendations

Following the summaries of EPRI valve programs and of the studies performed by Teledyne Engineering Services, and by Burns and Roe, Inc., two working sessions, one on "key" valves and the other on stem and seat leakage, were held in order to develop programmatic recommendations. Although the two working sessions formally addressed different topics, together their separate recommendations constitute a coherent approach to valve problems. Therefore, the recommendations of the two working sessions are not presented separately.

Overview. In broad outline the working sessions recommended (1) that a small permanent staff of experts should be established to collect, analyze, and disseminate information about valve problems and their solutions; (2) that generic "key" valve programs should be performed for pressurized water reactors and for boiling water reactors;

(3) that several plant specific "key" valve improvement programs needed to be performed and/or documented in order to demonstrate their cost effectiveness; (4) that needed longer term research and development programs, addressing seat and stem leakage problems, need to be identified and sufficiently defined to permit their initiation via subcontracts; and (5) that an industry working group should be constituted to review and advise on these efforts.

Evaluation Staff. Intermittent analysis of valve problems was emphatically stated to be ineffective. Instead, establishment of a valve problem evaluation center with a small, expert, permanent staff was strongly recommended. By review of nuclear industry data banks (e.g., LERs, NPRDS), the staff would identify recurrent valve problems. Problem root causes and potential solutions would be developed by analysis of additional pertinent information (e.g., design, installation, maintenance, and test data) and by discussions (telephone surveys, site visits) with vendor and utility personnel. Problem descriptions and recommended solutions would be routinely disseminated to utilities, valve manufacturers, NSSS vendors, architect-engineering firms, and technical society code committees. Other products of this analysis process would include: (1) development of a library of information on valve problems (e.g., data bank of valve

performance statistics, bibliography of reports and publications, collection of video taped demonstrations); (2) organization and presentation (by staff or utility or vendor personnel) of valve problem seminars which cover proper valve selection, maintenance, and test procedures; (3) identification of needed seat and stem leakage R & D programs; and (4) performance of generic key valve studies for PWRs and BWRs. Several questions concerning the evaluation staff need to be addressed: (1) What industry organization (the following organizations were suggested by workshop participants - AIF, ASME, DOE, Edison Electric Institute, EPRI, INPO, NSAC, Valve Manufacturers Assoc.) should be the permanent sponsor for the staff? (2) Where should the staff be located and housed? (3) How large should the staff be, how should it be selected, what expertise should it have?

Key Valve Programs. "Key" valves are those valves which perform valve functions which have a significant impact on safety or availability (this definition must be expanded and refined). Of the approximately 10,000 valves in a typical LWR, only about 500 will perform "key" functions (11). Both generic and demonstration key valve programs were recommended.

Generic Key Valve Programs. A generic key valve program for PWRs or BWRs would start by reviewing the

valve functions performed at a representative set of PWRs or BWRs. Once the list of key valve functions had been constructed, the functions and the environments (both normal and transient), in which these functions will or might have to be performed, would be precisely defined. Then, to provide guidance for the selection of key valves, recommended performance criteria would be developed for each key valve service. A survey of valves in service or available for each service would identify those commercially available valves, which have satisfactorily performed, or seem upon analysis and/or testing likely to satisfactorily perform, each key service.

In order to facilitate attaining optimum valve performance, for each comercially available valve suitable for a given service, descriptions (possibly procedures manuals) of how best to install, operate, maintain, and test the specific valve would be developed in conjuction with the manufacturer of the valve and its utility users. Where necessary, the need for specialized maintenance tools would be identified and appropriate tools would be designed and fabricated. Where suitability for a specific valve function can only be adequately determined by testing, test protocols would be drafted. If appropriate test facilities were found to be lacking, then the capabilities of and a preliminary conceptual design for a valve test facility could be developed.

The following questions about generic key valve programs should be resolved. First, given that several utilities and each of the Limiting Factor Analysis studies for Maine Yankee, Turkey Point, Oconee, and Peach Bottom have already completed key valve studies, is the needed information about key valves already available and therefore, are generic key valve studies really needed? Second, even assuming that generic key valve studies would be of benefit, wouldn't the limited funds available be better spent on those valve research and development efforts already known to be needed?

Key Valve Demonstration Programs. A number of utilities have already completed or are now conducting "key" valve improvement programs. These programs survey the valve population of a specific plant, identify those valves that perform key functions, and develop that information, which is required to insure that key valves perform optimally. Because plant specific key valve programs are costly and time-consuming, their cost-effectiveness needs to be demonstrated and documented in order to provide to the management of other utilities that information which can justify the initiation of such programs. A determination of which utilities have already completed or are currently performing plant specific key valve programs should be made, in order to identify candidate programs for documentation.

Stem and Seat Leakage. Much information about seat leakage (selection criteria, seat materials and designs, valve orientation, maintenance procedures) and stem packing leakage (material selection criteria, installation procedures, maintenance practices) already exists throughout the nuclear valve community. For example, TVA, Westinghouse, Fisher Controls, Commonwealth Edison, and Chesterton have offered to make available in-house information about various stem leakage problems; and TVA, Commonwealth Edison, and General Electric have offered to make available in-house information about various seat leakage problems. This information and information available from other companies should be collected, evaluated, and distributed (bulletins, reports, seminars) before new R & D programs are initiated. By review of LERs, discussions with utility and vendor personnel, and collection and evaluation of information already available within the nuclear valve community but not yet widely disseminated, those R & D programs needed to resolve presently unsolved seat and stem leakage problems will be identified and defined.

Stem packing problems which may warrent R & D efforts include (1) development of parametric data, (2) studies of physical and chemical behavior of packing materials and material combinations, (3) development of improved packing installation procedures (torquing, clearances,

material finishes), and (4) design and fabrication of improved packing tools. Long term seat leakage R & D efforts should consider (1) development of detailed specification and selection criteria, and (2) conduct of maintenance seminars. Once these programs (or others identified later) have been adequately defined, they can be submitted to the DOE, EPRI, or other members of the nuclear community for consideration for funding. Cost-sharing seems appropriate for R & D programs that will develop commercial products.

Industry Oversight Working Group. Given the complexity of nuclear valve problems and the large number of organizations affected by the problems and having knowledge and experience important to their solution, the formation of an industry oversight working group to guide, coordinate, and review the programs outlined above was strongly recommended. Discussion suggested that membership on the working group should be open to all organizations of the nuclear valve community. Since this is likely to produce a large formal membership roster, a smaller steering group, whose members serve several year overlapping terms (to provide continuity), may also be needed. It seems advisable to informally constitute the working group in the very near future and to initially charge the group (1) with

leading the search for a permanent sponsor for the valve problem analysis staff and (2) with conducting a survey of the nuclear valve community to identify available information on valve problems, the nature of the problem for which information is available, and the terms (if any) under which the information will be provided.

References

[1] W. H. Schmidt, LWR Nuclear Power Plant Component Failures, SAND80-1884, Sandia National Laboratories, Albuquerque, NM, October 1980.

[2] "Assessment of Industry Valve Problems", EPRI NP-241, M. H. Kirkpatrick, MPR Associates, Inc., Washington, DC, November 1976.

[3] "Major Outage Trends in Light Water Reactors", EPRI NP-755, E. T. Burns, Science Applications, Inc., Palo Alto, CA, April 1978.

[4] a) "Component Failures That Lead to Reactor Scrams", ALO-78, SAI-154-79-PA, E. T. Burns, R. J. Wilson, and E. Y. Lim, Science Applications, Inc., Palo Alto, CA, April 1980; b) "Component Failures That Lead to Manual Shutdowns", ALO-79, SAI-180-80-PA, E. T. Burns and W. L. Ferrel, Science Applications, Inc., Palo Alto, CA, December 1979.

[5] "Component Failures at Pressurized Water Reactors, Final Report", M. F. Reisinger, Program Manager, Combustion Engineering, Inc., Windsor, CT, Sandia Laboratories Contract No. 13-6442, to be published.

[6] "Analysis of Scrams and Forced Outages at Boiling Water Reactors", NEDG-25202, R. T. Earle, W. P. Sullivan, K. R. Miller, and W. J. Schwegman, General Electric Co., San Jose, CA, May 1980.

[7] "Limiting Factor Analysis of High Availability Nuclear Plants (Boiling Water Reactors)", EPRI NP-1136, General Electric Co., Bechtel National, Inc., Philadelphia Electric Company, August 1979.

[8] "Limiting Factor Analysis of High Availability Nuclear Plants", EPRI NP-1139, Combustion Engineering, Inc., Windsor, CT, August 1979.

[9] "Limiting Factor Analysis of C-E Nuclear Plants", EPRI NP-1137, Combustion Engineering, Inc., Windsor, CT, August 1979.

[10] "Limiting Factor Analysis of High-Availability Nuclear Plants, EPRI NP-1138, Babcock & Wilcox, Duke Power Co., September 1979.

[11] "Pilot Program to Identify Valve Failures Which Impact the Safety and Operation of Light Water Nuclear Power Plants", ALO-75, J. C. Tscoyeanes and P. P. Raju, Teledyne Engineering Services, Waltham, MA, April 1980.

[12] "Study of Valve Failure Problems in LWR Power Plants", ALO-73, J. W. Riddington and R. J. Reyer, Burns and Roe, Inc., Oradell, NJ, April 1980.

Appendix

ASSESSMENT OF INDUSTRY VALVE PROBLEMS

"This section is a summary of EPRI Report NP-241, Assessment of Industry Valve Problems, November 1976. Reprinted with permission of the Electric Power Research Institute".

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OUTLINE OF PRESENTATION
TO
EEI PRIME MOVERS COMMITTEE
SEPTEMBER 26, 1977
KANSAS CITY, MISSOURI

PROJECT OBJECTIVES

SPECIFIC PROBLEM AREAS

FORCED OUTAGES ATTRIBUTABLE TO VALVES, VALVE OPERATORS, AND ASSOCIATED CONTROL CIRCUITS

MAINTENANCE BURDEN ATTRIBUTABLE TO VALVES, VALVE OPERATORS, AND ASSOCIATED CONTROL CIRCUITS

EXPERIENCE OF UTILITY STAFFS CONTACTED

GENERIC TECHNICAL PROBLEMS

COMPATIBILITY OF VALVE AND MOTOR OPERATOR

STEM SEAL LEAKAGE

LEAKAGE AT BODY-TO-BONNET JOINTS

LEAKAGE ACROSS VALVE SEATS

MISAPPLICATION OF VALVE TYPES OR DESIGNS

CONCLUSIONS AND RECOMMENDATIONS

QUESTIONS FROM THE AUDIENCE

DEFINITIONS

INDUSTRY AS USED HEREIN MEANS UTILITY INDUSTRY NOT THE VALVE SUPPLIER INDUSTRY.

KEY VALVE IS A VALVE IN AN APPLICATION WHERE A MALFUNCTION OR PROBLEM CAN CAUSE A FORCED OUTAGE OR POWER REDUCTION.

UMBRELLA EFFECT - REPAIRS OR OTHER MAINTENANCE ON VALVES OR VALVE OPERATORS DONE DURING A FORCED OUTAGE ATTRIBUTED TO OTHER EQUIPMENTS. THUS THE AMOUNT OF VALVE MAINTENANCE CONSIDERED URGENT BY THE STATION STAFF DOES NOT SHOW UP IN THE FORCED OUTAGE DATA IN PROPORTION TO THE ACTUAL SITUATION.

INFORMATION

Hard or Microfiche copies of EPRI Report NP-241, Assessment of Industry Valve Problems can be obtained from

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

Request Report PB-261[illegible]

ASSESSMENT OF INDUSTRY VALVE PROBLEMS

PROJECT OBJECTIVES

THE OBJECTIVES OF THIS PROJECT WERE TO:

1. IDENTIFY SPECIFIC TECHNICAL ASPECTS AND DETAILS OF PROBLEMS ARISING FROM THE PERFORMANCE, APPLICATION, DESIGN, OPERATION, MAINTENANCE, OR IN-PLANT TESTING OF VALVES, ASSOCIATED OPERATORS AND CONTROLS CURRENTLY INSTALLED IN COMMERCIALLY OPERATING NUCLEAR GENERATING STATIONS,

2. SYSTEMATICALLY PERFORM AN ENGINEERING REVIEW OF THE TECHNICAL ASPECTS AND DETAILS IDENTIFIED AS PROBLEMS,

3. RECOMMEND OR OUTLINE COURSES OF ACTION WHERE POSSIBLE FOR EACH PROBLEM IDENTIFIED, AND

4. GENERALIZE WHERE POSSIBLE THE APPROACHES FOUND USEFUL IN A PILOT PROGRAM FOR FUTURE USE IN THE ELECTRIC POWER INDUSTRY.

SOURCES OF INFORMATION

LISTED BELOW ARE THE PRINCIPAL SOURCES OF INFORMATION USED DURING THIS PROJECT.

EDISON ELECTRIC INSTITUTE (EEI)
EQUIPMENT AVAILABILITY DATA

NUCLEAR PLANT RELIABILITY DATA SYSTEM (NPRDS)

LICENSEE EVENT REPORTS TO NRC

OPERATING UNITS STATUS REPORTS -- NUREG -- 0020 MONTHLY

SEMI-ANNUAL REPORTS OF OPERATIONS AND MAINTENANCE (NOW ANNUAL REPORTS) TO NRC

VISITS TO STATIONS AND UTILITY STAFFS INCLUDED:
DISCUSSIONS
MAINTENANCE RECORDS
MODIFICATION RECORDS

CONCLUSIONS FROM FORCED OUTAGE DATA

1. FORCED OUTAGE RATE FOR ALL VALVES CONSIDERED AS ONE POPULATION IS NOT HIGH.

   ONLY 5 TO 10% OF ALL VALVES AT A STATION ARE LOCATED SUCH THAT THEIR FAILURE CAUSES A FORCED OUTAGE.

2. FORCED OUTAGES ATTRIBUTED TO VALVES, VALVE OPERATORS AND ASSOCIATED CONTROL CIRCUITS ARE UNDER-REPORTED BECAUSE OF THE "UMBRELLA" EFFECT.

3. FAILURES OF A FEW LARGE VALVES HAVE RESULTED IN LONG DURATION OUTAGES (LONGEST IDENTIFIED WAS 25 DAYS).

4. FAILURES OF A FEW SMALL VALVES BECAUSE OF THEIR APPLICATION AS "FIRST-OFF" OR ISOLATION VALVES HAVE CAUSED SHORT DURATION FORCED OUTAGES.

5. REPETITIVE SHUTDOWNS WERE CAUSED BY VALVES IN THE FOLLOWING APPLICATIONS:

PWRs	BWRs
TURBINE AND TURBINE CONTROLS	TURBINE AND TURBINE CONTROLS
MAIN STEAM ISOLATION	MAIN STEAM ISOLATION
FEEDWATER CONTROL	RELIEF VALVES
PRESSURIZER SPRAY	

APPROXIMATELY 1/6 OF SHUTDOWNS WERE CAUSED BY TURBINE AND TURBINE CONTROL VALVES, SLIGHTLY LESS THAN 1/6 WERE CAUSED BY MAIN STEAM ISOLATION VALVES.

CONCLUSIONS FROM FORCED OUTAGE DATA (Continued)

6. CAUSES OF VALVE PROBLEMS WHICH RESULT IN A FORCED OUTAGE ARE NOT REPORTED FOR 40 TO 50% OF ALL SUCH EVENTS.

7. NO MAJOR DIFFERENCE BETWEEN PWRs AND BWRs WAS EVIDENT.

8. 1/3 OF SHUTDOWNS ARE FROM VALVES IN BOP APPLICATIONS AND 2/3 ARE IN NSSS APPLICATIONS. DATA IS BIASED TO REPORT MORE EVENTS IN NSSS THAN IN BOP SYSTEMS. EFFECT OF THIS BIAS ON DATA IS NOT KNOWN.

MAINTENANCE BURDEN ATTRIBUTABLE TO VALVES

WE FOUND NO RECORDED DATA ON THE AMOUNT OF MAINTENANCE EFFORT AT A STATION OR IN A UTILITY COMPANY WHICH SHOWED THE PROPORTION OF MAINTENANCE EFFORT DEVOTED TO VALVES AND/OR VALVE OPERATORS.

ESTIMATES WERE OBTAINED FROM KNOWLEDGEABLE MAINTENANCE SUPERVISORS AND MANAGERS DURING THIS STUDY. THESE ESTIMATES SHOW THE MAINTENANCE BURDEN FOR VALVES TO BE SUBSTANTIAL.

ON AN AVERAGE OF A YEAR OR MORE OF COMMERCIAL OPERATION - ABOUT 30% OF THE TOTAL PLANT MAINTENANCE EFFORT IS DEVOTED TO VALVES. A MINIMUM IS 20%.

PEAK EFFORTS ARE NEEDED DURING SCHEDULED OUTAGES TO ACCOMPLISH ALL THE NECESSARY VALVE MAINTENANCE IN THE ALLOTTED TIME. UP TO 80% OF THE MAINTENANCE IN PROGRESS ON A GIVEN DAY MAY BE DEVOTED TO VALVES.

MAINTENANCE BURDEN ATTRIBUTABLE TO VALVES (CONTINUED)

THE NATURE OF MAINTENANCE BEING DONE ON VALVES IN NUCLEAR STATIONS IS ABOUT THE SAME AS DONE AT FOSSIL STATIONS. THESE MAINTENANCE ACTIONS CAN BE CHARACTERIZED AS FOLLOWS:

RENEW THE VALVE STEM SEAL, USUALLY PACKING;

DISASSEMBLY, CLEAN SEATING SURFACE, RENEW GASKET, AND ASSEMBLY BODY-TO-BONNET JOINT;

ADJUST VALVE OPERATOR CONTROL CIRCUITS, LINKAGE, LIMIT OR TORQUE SWITCHES;

RENEW PIVOT PIN SEALS IN CHECK VALVES;

RELAP (RECONDITION) OR REPLACE DISC-TO-BODY OR PLUG-TO-BODY SEATING SURFACES;

REPLACE ERODED PARTS IN INTERNALS OF FLOW CONTROL VALVES;

WELD REPAIR PRESSURE BOUNDARY PARTS (RELATIVELY INFREQUENTLY).

THERE ARE A SIGNIFICANT NUMBER OF MODIFICATIONS MADE TO VALVES, VALVE OPERATORS AND ASSOCIATED CONTROL CIRCUITS AS PART OF THE "NORMAL MAINTENANCE OF VALVES." RECORDS ARE NOT COMPLETE AND VERY LITTLE OF THE SUCCESS OR FAILURE OF MODIFICATIONS TO INDIVIDUAL VALVES IS FED-BACK TO UTILITY ENGINEERING STAFFS FOR INCORPORATION INTO SPECIFICATIONS FOR NEW OR REPLACEMENT VALVES.

MODIFICATIONS

THIS STUDY FOUND THAT VALVES AND VALVE OPERATORS WERE BEING MODIFIED IN THE FOLLOWING AREAS:

SEAT TO DISC CONTACT ANGLES, AND/OR MATERIALS TO SOLVE REPETITIVE SEAT LEAKAGE PROBLEMS,

REPLACEMENT OF VALVE STEMS WITH LARGER STEMS IN AN ATTEMPT TO PREVENT THE VALVE OPERATOR FROM BENDING THE STEM.

REPLACEMENT OF VALVES TO REDUCE LEAKAGE AT BODY-TO-BONNET JOINTS AND STEM SEALS (PACKING) AND TO IMPROVE ACCESS FOR MAINTAINABILITY.

MODIFICATIONS TO THE STATION TO INSTALL LIFTING EQUIPMENT TO REPAIR LARGE SIZE VALVES.

REPLACEMENT OF ELECTRIC MOTOR OVERLOAD HEATERS WITH DIFFERENT RATING OF HEATER TO REDUCE SPURIOUS TRIPS OF THE VALVE MOTOR OPERATOR OR TO REDUCE INCIDENTS OF MOTOR BURNOUT.

REPLACEMENT OF VALVE INTERNALS TO REDUCE EROSION OF THESE PARTS, MOSTLY IN FLOW CONTROL VALVES.

REDESIGN OF VALVE PARTS WHICH FRACTURE OR FAIL PROGRESSIVELY IN SERVICE. NO PARTICULAR PATTERN WAS OBSERVED.

SUMMARY OF EXPERIENCE OBTAINED FROM UTILITY PERSONNEL

1. NUCLEAR AND FOSSIL STATION VALVE PERFORMANCE

PERSONNEL INTERVIEWED WHO HAD BOTH NUCLEAR AND FOSSIL STATION EXPERIENCE WERE CONVINCED THAT PERFORMANCE OF VALVES AND VALVE OPERATORS WERE IDENTICAL.

2. NUCLEAR STATION APPLICATION MORE DIFFICULT TO MAINTAIN

AT A NUCLEAR STATION THE SAME PERFORMANCE IS MORE DIFFICULT TO LIVE WITH BECAUSE OF RESTRICTED ACCESS TO INSPECT AND ADJUST COMPONENTS INSIDE CONTAINMENT AND THE MAINTENANCE ON VALVES IN RADIATION AREAS IS VERY EXPENSIVE. VERY STRINGENT LEAKAGE LIMITS REQUIRE MORE MAINTENANCE ON VALVE SEATS, PACKING GLANDS, AND BODY-TO-BONNET JOINTS.

3. LACK OF NECESSARY INFORMATION FROM SUPPLIERS

THERE WAS UNIVERSAL AGREEMENT THAT VALVE SUPPLIERS DO NOT PROVIDE SUFFICIENT DIMENSIONAL AND OTHER TECHNICAL INFORMATION FOR PERSONNEL AT THE STATION TO PROPERLY MAINTAIN VALVES. STATION PERSONNEL SPEND MANY MANHOURS TELEPHONING AND/OR WRITING TO VALVE SUPPLIERS FOR THE NECESSARY INFORMATION. SOMETIMES IT IS DENIED ON THE BASIS OF "PROPRIETARY INFORMATION" TO THE VALVE COMPANY.

4. NEED TO REDUCE MAINTENANCE WORK ON VALVES

THERE WERE MANY EXPRESSIONS OF THE NEED TO REDUCE THE TOTAL MAINTENANCE WORK LOAD FOR VALVES PARTICULARLY THOSE VALVES LOCATED IN RADIATION AREAS. TRAINING OF SUFFICIENT NUMBERS OF PERSONNEL TO PERFORM THE NECESSARY MAINTENANCE WORK IS BECOMING AN INCREASELY DIFFICULT PROBLEM. IN SOME AREAS THE TOTAL QUALIFIED WORK FORCE AVAILABLE, CONTRACTORS PLUS UTILITY, IS BEING USED TO ITS LIMIT.

SUMMARY OF EXPERIENCE OBTAINED FROM UTILITY PERSONNEL (CONTINUED)

5. MISAPPLICATIONS OF SPECIFIC VALVE TYPES WERE IDENTIFIED

   A. SOLID WEDGE GATE VALVES IN SYSTEMS WITH TEMPERATURE CHANGES OF MORE THAN 200°F (COLD SHUTDOWN TO NORMAL [illegible]

   B. USES OF CHECK VALVES WHICH DEMAND LEAK TIGHTNESS OF THE SEAT.

   C. LOCATING A VALVE (ANY TYPE) IN A PIPING SYSTEM SO THAT MAINTENANCE OF THE VALVE OR ITS VALVE OPERATOR REQUIRES MAJOR PIPING WORK TO GET AT THE VALVE OR OPERATOR.

6. ORIENTATION OF VALVE STEMS FOR BEST PERFORMANCE

   THERE WAS UNIVERSAL AGREEMENT THAT VALVE STEMS ORIENTED VERTICALLY-UP GAVE MUCH BETTER PERFORMANCE THAN VALVES WITH STEMS IN OTHER ORIENTATIONS. STEM SEALS LEAK MUCH LESS OFTEN. CONTROL VALVES FUNCTION MUCH MORE CONSISTENTLY WHEN ORIENTED WITH STEMS VERTICALLY-UP.

7. QUALITY ASSURED VALVES PERFORM THE SAME AS OTHER VALVES

   THERE WAS A UNANIMOUS AND VOLUNTARY EXPRESSION OF OPINION THAT THE PERFORMANCE OF VALVES SUPPLIED TO FULL QUALITY ASSURANCE PROGRAM REQUIREMENTS PERFORMED THE SAME AS VALVES PURCHASED WITHOUT THESE REQUIREMENTS. THE DIFFERENCE IN PAPER WORK WAS VERY APPARENT.

GENERIC TECHNICAL PROBLEMS

SECTION VI OF THE REPORT DISCUSSES THESE PROBLEMS IN SOME DETAIL. THIS STUDY FOUND THE FOLLOWING TECHNICAL PROBLEMS TO BE GENERIC.

1. LACK OF COMPATIBILITY OF THE MOTOR OPERATOR, VALVE AND ASSOCIATED CONTROL CIRCUITS, PARTICULARLY SEVERE FOR FAST ACTING VALVES, I.E., STEM SPEEDS OF 36 INCHES/MINUTE OR MORE.

2. VALVE STEM SEALS ARE CHRONIC LEAKERS AND REQUIRE MUCH MAINTENANCE.

3. BODY-TO-BONNET GASKETED JOINTS ARE CHRONIC LEAKERS AND REQUIRE MUCH MAINTENANCE.

4. LEAK TIGHTNESS OF THE VALVE SEAT TO DISC, PLUG, OR FLAPPER OFTEN FAILS TO PASS TIGHTNESS TESTS.

5. MISAPPLICATION OF VALVES FOR THE INTENDED SERVICE.

TYPICAL (NORMAL) CORRECTIVE PROCESS FOR A GENERIC PROBLEM

GENERIC PROBLEM - LEAKAGE OF BORATED REACTOR COOLANT AROUND VALVE STEMS LOCATED INSIDE CONTAINMENT OF A PWR STATION.

CHRONOLOGY

STATIONS WERE DESIGNED IN EARLY 1960s.

PLACED IN COMMERCIAL OPERATION IN LATE 1960s TO 1970.

CONVENTIONAL HIGH TEMPERATURE, HIGH PRESSURE PACKING WAS USED, I. E., JOHN CRANE STYLE 187-I, ASBESTOS YARN WITH INCONEL WIRE INSERT AROUND CORE OF GRAPHITE IMPREGNATED ASBESTOS.

BY 1970 EXPERIENCE AT PWRs SHOWED THAT BORATED REACTOR COOLANT LEAKED PAST THE 187-I PACKING AROUND VALVE STEMS. SHUTDOWNS WERE REQUIRED 3 TO 4 TIMES PER YEAR DUE TO CUMULATIVE LEAKAGE INTO THE CONTAINMENT ATMOSPHERE.

COMPETING PRODUCTS TO REMEDY THIS PROBLEM WERE DEVELOPED AND MARKETED IN 1975.

GRAFOIL PACKING

DIAPHRAGM VALVES

BELLOWS VALVES

SUFFICIENT EXPERIENCE FROM PWR STATIONS SHOULD BE AVAILABLE BY 1980 TO JUDGE THE ADEQUACY OF THESE PRODUCTS.

SUMMARY OF PRESENT PRACTICES FOR SELECTING, SPECIFYING, AND PURCHASING VALVES

1. RELY ALMOST COMPLETELY ON THE VALVE SUPPLIER TO PROVIDE A CORRECT PRODUCT FOR THE APPLICATION.

2. AWARD OF PURCHASE TO THE LOWEST BIDDER.

3. INVOKE FEW SPECIFIC PERFORMANCE REQUIREMENTS TO DEFINE ACCEPTABLE FUNCTIONAL PERFORMANCE.

4. INVOKE NO SPECIFIC REQUIREMENTS WHICH DEFINE AN ACCEPTABLE MAINTENANCE BURDEN FOR SPECIFIC APPLICATIONS IN AN ELECTRIC GENERATING STATION.

5. ACCEPTABLE LEVELS OF FUNCTIONAL PERFORMANCE AND MAINTENANCE BURDEN ARE DETERMINED BY INDIVIDUALS AT INDIVIDUAL STATIONS AFTER THE STATION IS IN COMMERCIAL OPERATION.

6. WHEN MODIFICATIONS TO SPECIFIC VALVES ARE NEEDED, THEY ARE TREATED AS A UNIQUE CASE BETWEEN ONE STATION AND ONE VALVE SUPPLIER.

7. THE INDUSTRY SPENDS A LOT OF MONEY FOR VALVES, MUCH ADDITIONAL MONEY TO MAINTAIN AND MODIFY VALVES AND ALMOST NOTHING TO DEVELOP AND RETAIN IN-HOUSE EXPERTISE TO SPECIFY, REVIEW, AND SELECT VALVES FOR SPECIFIC SERVICE APPLICATIONS, I. E., THERE IS A DISPROPORTIONATE RELIANCE ON A COMPETITIVE MARKET.

GENERAL ASSESSMENT

FOUR PRINCIPAL CONCLUSIONS RESULTED FROM THIS PROJECT.

1. THERE IS A GENERAL (WIDESPREAD) FAILURE TO TREAT-AS-AN-ENTITY THE VALVE, ITS POWERED OPERATOR, ITS *SPECIFIC APPLICATION IN A GIVEN FLUID SYSTEM, AND THE* SPECIFIC ENVIRONMENT IN WHICH IT OPERATES AND IS MAINTAINED.

   THIS IS THE ROOT CAUSE FOR MOST OF THE REPETITIVELY REPORTED INDIVIDUAL "VALVE PROBLEMS."

2. GENERAL FAILURE TO RECOGNIZE THAT MANY VALVES, VALVE OPERATORS, AND ASSOCIATED CONTROL CIRCUITS IN USE TODAY AT NUCLEAR GENERATING STATIONS WERE DESIGNED AND SUPPLIED TO PERFORMANCE STANDARDS DIFFERENT FROM THOSE BY WHICH THESE ITEMS ARE JUDGED.

3. PRESENT METHODOLOGY FOR RESOLVING "VALVE-PROBLEMS" IS ALMOST EXCLUSIVELY A CASE-BASIS APPROACH BETWEEN INDIVIDUAL STATIONS AND EQUIPMENT SUPPLIERS. ROOT CAUSES ARE NOT USUALLY DETERMINED. NEW AND OTHER OPERATING STATIONS BENEFIT FROM ONLY A SMALL PORTION OF THE SERVICE EXPERIENCE.

4. PURCHASING PRACTICES FOR KEY VALVES (5 TO 10% OF THE TOTAL) SHOULD BE CHANGED.

SUMMARY OF RECOMMENDATIONS

BASICALLY THE RECOMMENDATIONS ARE DIRECTED TO THE UTILITY INDUSTRY AS THE USER AND MAINTAINER OF VALVES.

IT IS RECOMMENDED THAT UTILITIES TAKE ACTION TO:

- DEFINE KEY VALVE APPLICATIONS.
- SET PERFORMANCE AND MAINTENANCE GOALS FOR KEY VALVES.
- PURCHASE VALVES FOR KEY APPLICATIONS SEPARATELY FROM *OTHER* VALVES.
- SELECT VALVES FOR KEY APPLICATIONS AFTER:
  1. REVIEW OF SPECIFIC VALVE DESIGNS IN KEY APPLICATIONS AGAINST SERVICE EXPERIENCE OF THOSE DESIGNS IN THAT SERVICE.
  2. REVIEW OF PHYSICAL ARRANGEMENT OF KEY VALVES IN PIPING SYSTEMS AND STRUCTURAL SURROUNDINGS AT THE INDIVIDUAL STATION.
- PROVIDE CLOSE FOLLOW-UP OF EACH PROBLEM IN A KEY VALVE TO DETERMINE ROOT CAUSE OF THE PROBLEM.
- PROVIDE ADEQUATE REPORTING OF SERVICE EXPERIENCE AND PROBLEM RESOLUTIONS IN KEY VALVES SO OTHERS CAN BENEFIT QUICKLY.
- REVISE INDUSTRY DATA REPORTING SYSTEMS TO ADDRESS KEY APPLICATIONS AND ALLOW ACCESS TO ALL DATA AND ANALYSES OF THE DATA TO ALL PARTICIPATING UTILITIES AND EPRI.
- SPONSOR AND FUND RESEARCH AND DEVELOPMENT BY EPRI TO SOLVE PERSISTENT PROBLEM AREAS IN KEY VALVE APPLICATIONS.

IMPLEMENTATION OF RECOMMENDATIONS

AS A PRACTICAL MATTER, IMPLEMENTATION OF GENERAL RECOMMENDATIONS MUST FIT WITHIN THE ONGOING EFFORTS TO OPERATE EXISTING STATIONS AND TO DESIGN AND CONSTRUCT NEW STATIONS.

THEREFORE, THE GENERAL RECOMMENDATIONS ARE ORGANIZED INTO CATEGORIES WHICH CAN BE IMPLEMENTED WITHIN THE DESIGN, CONSTRUCTION, AND COMMERCIAL OPERATIONS PHASES OF A STATIONS LIFE CYCLE.

RECOMMENDATIONS IN THE REPORT ARE PRESENTED FOR:

1. ALL STATIONS (NEW AND EXISTING)
2. NEW STATIONS IN THE DESIGN PHASE
3. NEW STATIONS IN THE CONSTRUCTION PHASE
4. EXISTING STATIONS IN COMMERCIAL OPERATION
5. RESEARCH AND DEVELOPMENT ITEMS

SUMMARY OF

SELECTED INFORMATION FROM SECTION VI

TECHNICAL ASPECTS OF GENERIC PROBLEMS

FROM EPRI REPORT NP-241

ASSESSMENT OF INDUSTRY VALVE PROBLEMS

A N D

UPDATED TABLE B-2

UNIT SHUTDOWNS INVOLVING VALVES,
VALVE OPERATORS AND ASSOCIATED CONTROL CIRCUITS

JULY 1974 THROUGH JUNE 1977

LACK OF COMPATIBILITY OF THE MOTOR OPERATOR AND VALVE

SYMPTOMS CAN BE:

BENT VALVE STEMS

CRACKED DISCS OR SEATS

DEFORMED VALVE BODY OR YOKE

SPURIOUS FAILURES TO POSITION OR RE-POSITION THE VALVE

BURNED-OUT MOTORS

PROBLEM IDENTIFICATION

SYMPTOMS OF THIS PROBLEM STANDS OUT FROM DATA AVAILABLE IN LICENSEE EVENT REPORTS TO NRC AND IN THE NUCLEAR POWER PLANT RELIABILITY DATA SYSTEM. ALSO, UTILITY PERSONNEL VERIFIED THAT THIS IS A SEVERE PROBLEM.

DISCUSSION

A THOROUGH DISCUSSION IS PRESENTED IN THE REPORT. BRIEFLY, MANY OPERATORS ARE OVERSIZED DURING THE DESIGN PROCESS FOR VARIOUS REASONS. FIGURE 4 SHOWS THAT LARGE TORQUE LOADS RESULT.

SOLUTIONS ARE KNOWN

PROPER SIZING OF OPERATOR AND MOTOR OVERLOADS. (SOME TESTING OF HIGH SPEED VALVES MAY BE NECESSARY.) TRAINING AND DISCIPLINE OF MAINTENANCE PERSONNEL.

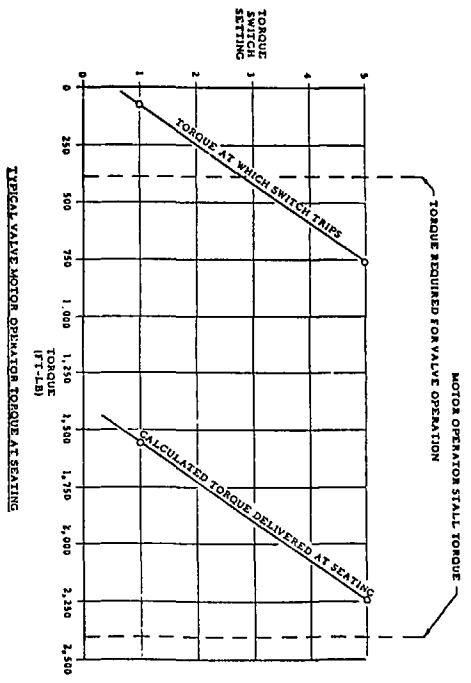

FIGURE 4
TYPICAL VALVE MOTOR OPERATOR TORQUE AT SEATING

VALVE STEM SEALS

LEAKAGE OF FLUID ALONG THE VALVE STEM BETWEEN THE SEAL AND THE STEM IS A COMMONPLACE OCCURRENCE.

SYMPTOMS ARE:

VISIBLE LEAKAGE OF STEAM AND WATER AT VALVE STEMS

VISIBLE BUILDUP OF BORIC ACID CRYSTALS AROUND VALVE STEMS IN PWRs

RUPTURED BELLOWS

BUILDUP OF MOISTURE AND RADIOACTIVITY IN CONTAINMENT ATMOSPHERE

LOW PRESSURE ALARMS IN GAS SYSTEMS

UNSCHEDULED CHANGE OF VALVE POSITION FROM LOSS OF PRESSURE IN VALVE ACTUATOR.

PROBLEM IDENTIFICATION

THIS PROBLEM DOES NOT SHOW UP IN FAILURE DATA. IT DOES SHOW UP IN MAINTENANCE SUMMARY SECTIONS OF SEMI-ANNUAL OPERATING REPORTS. IT DOES NOT SHOW UP IN PROPORTION TO ITS IMPORTANCE ON THE MAINTENANCE BURDEN TO CORRECT LEAKAGE.

DISCUSSION

A LENGTHY DISCUSSION IS IN THE REPORT. OBVIOUSLY, THERE ARE MANY DIFFERENT CAUSES OF STEM SEAL LEAKAGE DEPENDING ON THE GEOMETRY, SEAL METHOD, MATERIALS, PRESSURE, TEMPERATURE AND FLUID TO BE SEALED. MANY COMPETING PRODUCTS ARE ON THE MARKET. MOST ADVERTISE APPLICABILITY TO A WIDE VARIETY OF APPLICATIONS. NONE CLEARLY STATES THE MAINTENANCE BURDEN FOR PARTICULAR APPLICATIONS.

VALVE STEM SEALS (CONTINUED)

GOOD SOLUTIONS TO EVERY APPLICATION ARE NOT KNOWN

SOME SPECIFIC, CAREFULLY COORDINATED R&D EFFORT IS NEEDED TO DETERMINE USEFUL SERVICE LIFE OF STEM SEALS FOR GENERATING STATION APPLICATION. BACK-UP SEALS MAY BE NECESSARY IN SOME APPLICATIONS.

BODY-TO-BONNET GASKETED JOINTS

A SIGNIFICANT PORTION OF THE MAINTENANCE BURDEN IS EXPENDED TO CORRECT LEAKAGE THROUGH VALVE BODY-TO-BONNET GASKETED JOINTS, PARTICULARLY ON VALVES IN STEAM SERVICE.

PROBLEM IDENTIFICATION - THIS PROBLEM IS EVIDENT AT THE STATIONS AND IN MAINTENANCE SUMMARIES BUT NOT IN THE FAILURE DATA. ONLY A FEW FORCED OUTAGES RESULT FROM SUCH LEAKAGE.

INTERIM SOLUTIONS

COLLECTING LEAKAGE BY TEMPORARY DEVICES AND LEADING IT TO FLOOR DRAINS IN THE VICINITY OF THE LEAKING VALVE.

APPLYING TEMPORARY SEALANTS EXTERNAL TO THE GASKETED JOINT, MOSTLY WITH PROPRIETARY PROCESSES PERFORMED BY A CONTRACTOR.

SEAL WELDING THE LEAKING JOINT IF GEOMETRY PERMITS.

RENEWING THE GASKET AND APPLYING ADDITIONAL CLAMPING FORCE.

CHANGING GASKET THICKNESS

LONGER TERM SOLUTIONS

RESEARCH AND DEVELOPMENT ARE NEEDED. TABLE 3 SHOWS THE WIDE DISPARITY AMONG TECHNICAL GROUPS.

TABLE 3

GASKET FACTORS AND SEATING STRESSES

SOURCES	GASKET SEATING STRESS, Y (PSI)	GASKET FACTOR, M
1. ASME CODE, SECTION VIII, DIVISION 1 - 1974	4,500	3
2. GASKET MANUFACTURERS, FLEXITALLIC GASKET CO. DESIGN CRITERIA (CATALOG 171).	9,000	3
3. MILITARY SPECIFICATION, MIL-G-21032D GASKETS, METALLIC-ASBESTOS, SPIRAL-WOUND.	6,000	3
4. CANADIAN NUCLEAR INDUSTRY, SPIRAL-WOUND GASKETS FOR LEAK-TIGHT JOINTS (74-WA/PVP-5), ASME.	32,000	7
5. ORNL REPORT, STATIC SEALS AND THEIR APPLICATION IN WATER-COOLED NUCLEAR REACTOR SYSTEM (ORNL TM-3308).	6,000 - 18,000	NOT GIVEN

LEAKAGE ACROSS VALVE SEATS

SYMPTOMS ARE:

VISIELE FLUID LEAKAGE FROM A VENT OR DRAIN WHEN AN ISOLATION VALVE IS IN A CLOSED POSITION.

MORE LEAKAGE IS MEASURED THAN ALLOWED BY APPLICABLE TEST PROCEDURES WHEN A FORMAL LEAK TEST IS PERFORMED.

PROBLEM IDENTIFICATION

THE EXTENT OF THIS PROBLEM IS NOT APPARENT FROM FAILURE DATA. MAINTENANCE SUMMARIES AND VISITS TO STATIONS IDENTIFIED THIS PROBLEM AS GENERIC.

DISCUSSION

INDUSTRY PRACTICE FOR MANY YEARS HAS BEEN TO CORRECT SEAT LEAKAGE WHEN INDIVIDUAL VALVES LEAK TO SUCH A DEGREE THAT THE INTENDED FUNCTION OF THE VALVE IS NOT ACHIEVED. FOR EXAMPLE, COMPONENT ISOLATION VALVES LEAK TOO MUCH TO PERMIT REPAIR OF THE COMPONENT.

ADDITIONALLY, AT NUCLEAR STATIONS, PERIODIC LEAK TESTS ARE NOW REQUIRED OF VALVES LOCATED IN CERTAIN APPLICATIONS SUCH AS CONTAINMENT ISOLATION. THESE LEAKAGE LIMITS ARE EXTREMELY DIFFICULT TO MEET.

SOLUTIONS

INTERIM - TRIAL AND ERROR AT INDIVIDUAL STATIONS

LONG RANGE - R&D TO DEVELOP EFFECTIVE SEALS FOR SPECIFIC APPLICATIONS.

MISAPPLICATION OF VALVE TYPES OR DESIGNS

SYMPTOMS ARE:

VALVES STUCK SHUT.

EXCESSIVE MAINTENANCE REQUIRED TO KEEP LEAKAGE TO ACCEPTABLE LIMITS.

CUTTING AND REWELDING PIPING OR STRUCTURE TO OBTAIN NECESSARY ACCESS TO WORK ON A VALVE.

CUSTOM TOOLS REQUIRED TO SERVICE A VALVE IN PLACE IN A SYSTEM.

PROBLEM IDENTIFICATION

DISCUSSION AT STATIONS IDENTIFIED THIS PROBLEM AREA AS GENERIC.

DISCUSSION

SOLID WEDGE GATE VALVES STICK SHUT FROM DIFFERENTIAL CONTRACTION OF VALVE PARTS WITH TEMPERATURE CHANGES.

USE OF CHECK VALVES IN BWR FEEDWATER SYSTEMS AS TIGHT SHUTOFF VALVES FOR ACCIDENT MITIGATION REQUIRE EXCESSIVE MAINTENANCE TO PASS SEAT TIGHTNESS TESTS.

CHECK VALVES OF DIAGONAL SPLIT BODY DESIGN WELDED INTO PIPING SYSTEMS REQUIRED CUTTING OF SCHEDULE 80 16" PIPING TO RENEW BODY JOINT GASKET WHICH WAS A CHRONIC LEAKER.

ANGLED WEDGE GATE VALVES REQUIRE SPECIAL LAPPING MACHINES AND ACCESS FOR SUCH MACHINE TO BE USED.

MISAPPLICATION OF VALVE TYPES OR DESIGNS
(CONTINUED)

SOLUTIONS

PERFORM PRE-SELECTION DESIGN REVIEWS

PERFORM POST-SELECTION DESIGN REVIEWS

ESTABLISH MAINTENANCE ENVELOPE FOR EACH VALVE.

DEVELOP AND PUBLISH DETAILED APPLICATION MANUALS FOR "KEY VALVE" LOCATIONS TAILORED TO PWRs, BWRs, AND FOSSIL STATIONS.

TABLE B-2

COMPILATION OF PWR SHUTDOWN DATA

(UPDATED THROUGH JUNE 1977)

PWR SHUTDOWNS IN APPLICATION CATEGORIES

ALL DATA IS FROM NRC PUBLICATION NUREG-0020, "OPERATING UNITS STATUS REPORT", MONTHLY.

CALENDAR YEAR	1974	1975	1976	1976*	1977*	
NO. OF MONTHS	6	12	3	9	6	TOTALS
NO. OF UNITS	28	30	30	34	37	
NUMBER OF OUTAGES FROM VALVE APPLICATIONS IN						
NSS SYSTEMS	25	62	6	26	21	140
NSS RELIEF VALVES	1	4	0	0	0	5
NSS MSIV	10	14	0	0	0	24
NSS FEEDWATER CONTROL	2	26	5	14	5	52
NSS PRESSURIZER SPRAY	5	6	0	0	3	14
BOP SYSTEMS	12	43	6	7	10	78
BOP TURBINE VALVES AND CONTROL	8	24	4	5	7	48

* REPORTING OF BOP VALVE PROBLEMS APPEARS TO HAVE DECREASED.

TABLE B-2

COMPILATION OF PWR SHUTDOWN DATA

(UPDATED THROUGH JUNE 1977)

PWR SHUTDOWNS IN CAUSE CATEGORIES

ALL DATA IS FROM NRC PUBLICATION NUREG-0020, "OPERATING UNITS STATUS REPORT", MONTHLY.

CALENDAR YEAR	1974	1975	1976	1976*	1977*	
NO. OF MONTHS	6	12	3	9	6	TOTALS
NO. OF UNITS	28	30	30	34	37	
NUMBER OF OUTAGES CAUSED BY:						
SEAT LEAKAGE	3	4	0	5	1	13
STEM SEAL LEAKAGE	4	9	2	0	3	18
BODY-TO-BONNET SEAL	0	3	0	2	1	6
VALVE TO PIPE FLANGE	0	0	0	0	0	0
VALVE OPERATOR	6	15	1	1	6	29
CONTROL CIRCUIT	4	22	0	3	2	31
UNKNOWN	19	48	8	22	17	114
OTHER	3	7	1	0	1	12
TOTAL OF OUTAGES	39	108	12	33	31	223
UNIT MONTHS (NO. UNITS X NO. MOS.)	168	360	90	306	222	1146

* REPORTING OF BOP VALVE PROBLEMS APPEARS TO HAVE DECREASED.

TABLE B-2

COMPILATION OF BWR SHUTDOWN DATA

(UPDATED THROUGH JUNE 1977)

BWR SHUTDOWNS IN APPLICATION CATEGORIES

ALL DATA IS FROM NRC PUBLICATION NUREG-0020, "OPERATING UNITS STATUS REPORT", MONTHLY.

CALENDAR YEAR	1974	1975	1976	1976*	1977*	
NO. OF MONTHS	6	12	3	9	6	TOTALS
NO. OF UNITS	20	23	24	25	25	
NUMBER OF OUTAGES FROM VALVE APPLICATIONS IN						
NSS SYSTEMS	36	45	14	34	17	146
NSS RELIEF VALVES	14	14	0	17	8	53
NSS MSIV	9	7	1	4	2	23
BOP SYSTEMS	12	19	6	9	3	49
BOP TURBINE VALVES AND CONTROL	3	10	2	3	2	20

* REPORTING OF BOP VALVE PROBLEMS APPEARS TO HAVE DECREASED.

TABLE B-2

COMPILATION OF BWR SHUTDOWN DATA

(UPDATED THROUGH JUNE 1977)

BWR SHUTDOWNS IN CAUSE CATEGORIES

ALL DATA IS FROM NRC PUBLICATION NUREG-0020, "OPERATING UNITS STATUS REPORT", MONTHLY.

CALENDAR YEAR	1974	1975	1976	1976*	1977*	
NO. OF MONTHS	6	12	3	9	6	TOTALS
NO. OF UNITS	20	23	24	25	25	
NUMBER OF OUTAGES CAUSED BY:						
SEAT LEAKAGE	5	3	0	7	4	19
STEM SEAL LEAKAGE	5	15	5	4	2	31
BODY-TO-BONNET SEAL	3	1	0	0	0	4
VALVE TO PIPE FLANGE	0	0	0	0	0	0
VALVE OPERATOR	6	1	3	2	1	13
CONTROL CIRCUIT	6	8	4	3	1	22
UNKNOWN	18	26	10	30	13	97
OTHER	5	9	0	0	0	14
TOTAL OF OUTAGES	48	63	22	46	21	200
UNIT MONTHS (NO. UNITS X NO. MOS.)	120	276	72	225	150	843

* REPORTING OF BOP VALVE PROBLEMS APPEARS TO HAVE DECREASED.

A STUDY OF VALVE FAILURES WHICH IMPACT THE SAFETY AND OPERATION OF LIGHT WATER NUCLEAR POWER PLANTS

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ABSTRACT

This paper presents the results of a pilot program initiated by Sandia Laboratories under the Department of Energy, Light Water Reactor Safety Research and Development Program. The program was conceived as a result of earlier LWR safety and reliability studies which indicated that a substantial number of plant trip incidents were caused by failure of system components such as valves. The specific objectives of this program are: 1) to identify the principal types and causes of failures in valves, valve operators and their controls and associated hardware, which lead to, or could lead to plant trip, and, 2) to suggest possible remedies for the prevention of these failures and recommend future research and development programs which could lead to reducing these valve failures or to mitigating their effect on plant operation.

The data surveyed covers incidents reported over the six-year period, beginning 1973 through the end of 1978. Three sources of information on valve failures have been consulted: 1) failure data centers, 2) participating organizations in the nuclear power industry, and 3) technical documents.

The results of this study indicate that frequent failure modes in valves include lack of leak tightness in both stem packing seals and valve seats, and operational malfunction resulting from problems with actuators, their power controls and instrumentation. The failure data analyses results are presented in tabulated form and a discussion of the information obtained from the three data sources is included.

Recommendations are presented for future programs. Included is a statement of the objectives and a description of the major elements of the programs.

INTRODUCTION

Background

It has been observed that valves used in commercial nuclear electric power generation systems account for a significant proportion of component failures which interrupt electrical generation or affect plant operation due to the increased maintenance work load during scheduled outages. A survey of reported valve failures, conducted by the Nuclear Safety staff from a 1973 Reactor Operations Experience report by the AEC Office of Operations Evaluation [1]for the period 1967 to 1972, indicates a rate of 2.5 to 2.8 failures per plant per year. These failures were found to be caused by deficiencies in design, fabrication, installation, operation and maintenance and manifested themselves primarily in the form of lack of leak tightness and improper operation.

Independent reviews of licensee reports submitted to the U.S. Nuclear Regulatory Commission (NRC) during the years 1976 and 1977 [2] indicate that approximately twenty percent of the reportable occurrences for each of those years were accountable to valve failures for each year. The more recent data shows indications that the incidents of valve malfunction may be increasing rather than decreasing.

Structural failures of valve pressure boundary parts are so infrequent that their effect on plant operating and maintenance time is virtually negligible. Structural failures of other valve parts occur a bit more frequently but contribute only slightly to overall plant down time. The reason for this relatively low incidence of structural failure can be attributed to the provisions of the applicable codes and standards, federal regulations and a long history of successful manufacturers' practices. However, these structural integrity principles are specifically directed to assurance of pressure boundary integrity of a passive structure and provide little or no assurance that the valve will perform its mechanical function when called

upon to do so.

Some guidance for operability assurance is provided in NRC Regulatory Guides [3] and Standard Review Plans [4] and testing requirements to verify operational readiness are contained in the ASME Code, Section XI, Rules for Inservice Inspection [5]. Yet experience indicates that valve malfunction continues to be a leading cause of interruptions to electrical generation and the source of a substantial amount of maintenance work performed on operating nuclear power plants.

PROGRAM DESCRIPTION AND RESULTS

The present study [6], initiated by Sandia Laboratories under the Department of Energy Light Water Reactor (LWR) Safety Research and Development Program, had the following specific objectives:

1) to identify the principal types and causes of failures in valves, valve operators and their controls and associated hardware, which lead to, or could lead to plant trip. Plant trip, as used herein, refers to any interruption of electrical generation;

2) to suggest possible remedies for the prevention of these failures and recommend future research and development programs which could lead to minimizing these valve failures or to mitigating their effect on plant operation.

Three sources of information were used:

1) data files such as the NRC Licensee Event Reports (LER) and the Nuclear Safety Information Center (NSIC),

2) participating organizations in the nuclear power industry such as NSSS vendors, valve manufacturers, utilities and nuclear power stations, and

3) technical documents.

Failure Data Files

The data surveyed covers incidents reported over the six-year period, beginning 1973 through the end of 1978 and is retrievable from computer files in the form of approximately one hundred word abstracts [7].

Two significant limitations exist in the use of these data sources for the purpose of interpretation and evaluation of the failures.

First, the event descriptions are prepared by personnel at each individual plant site and must be transmitted to the NRC promptly. More detailed follow-up information is not always included in the LER description. Therefore, a large variation exists in the amount and detail of the information provided. This makes the analysis of the data difficult and some judgment and deduction is necessary in identifying root causes of the failure.

Second, only those failures which affect safety-related systems are filed in the data banks. (Safety-related systems are those systems necessary to ensure the capability to shut down the reactor and maintain it in a safe shutdown condition, or to prevent or mitigate the consequences of accidents that could result in potential offsite exposures to radiation.) However, plant trips are known to occur as a result of valve failures in other than safety-related systems and none of the available data sources presently contain failure information for these systems.

For purposes of analysis of this data, valve failures were classified and defined as follows:

1) structural - refers to failure of pressure retaining parts and attachments and/or parts which transmit or apply operator loads,

2) excessive leakage - refers to leakage of valve seats, stem packing, gaskets and other seals in excess of the rates permitted for the application,

3) operational malfunction - refers to loss of capability to perform intended function or initiation of undesired function, and

4) procedural - refers to failure as a direct result of procedural error in construction, operation or maintenance.

The valve related failures identified in this study numbered 138. Of these, 62% occurred in BWR plant systems and 38% in PWR systems. The major types of failures and their incidence are as follows: leakage 44%, operating malfunction 37%, procedural 11% and structural 8%. Of the leakage failures, 49% were attributed to failure of the stem packing seal and 48% to leakage past disc seating surfaces. It should be noted that three-quarters of the total number of seat leakage failures are attributed to safety valves. However, most of these

relate to pilot valve actuators whose secondary effect is to actuate main disc opening. Therefore, the incidence of plant shutdown initiated by main seat leakage is small, about 10%. This is consistent with the opinions expressed by utility and valve vendor personnel that shutdown from power operation due to main seat leakage is not a common occurrence. Further discussion on this point is included under Industry Parties. Procedural errors consisted of improperly installed gaskets or parts, improperly set switches and errors in disc position settings during or after maintenance and testing.

Three incidents of defective or failed stem packing were identified. However, the apparent cause of most stem packing leakage failures is attributed to limitations in sealing life due to wear. Although the data did not indicate the effect of stem orientation, discussions with valve suppliers and plant maintenance personnel indicated off-vertical installations reduce packing life significantly.

The majority (76%) of disc seat leakage failures occurred in safety/relief valve applications with the remainder being distributed between control/regulation, isolation and check valves. Failure of the valve disc to reseat after blowdown accounted for 18% of safety/relief valve failures. Leakage past pilot valve seats was the most common mode of failure (53%). However, at least 30 % of these could be identified to occur on valves of one specific supplier. The most common failure mode reported for isolation valves was stem packing leakage which accounted for 40% of all isolation valve failures. Table 1 summarizes the data analysis.

TABLE 1 REPORTED FAILURES BY TYPE AND APPLICATION

Valve Type/ Application	PWR	BWR	Total	Proc	Struct	Leakage Pack	Seat	Gask	Oper
Safety/ Relief	6	34	40	4	4		22		10
Isolation	19	19	38	8	5	15	2	2	6
Check	2	3	5	2	1	1	1		
Control/ Regulation	5	4	9			4	3		2
Other	7	9	16	1		10			5
Acutator	11	13	24		1				23
Instrument	2	4	6	—	—	—	1	—	5
	52	86	138	15	11	30	29	2	51

Operational malfunction resulted from deficiencies in the design and installation of valve parts, actuators, power controls and instrumentation circuits. Typical problems involved failures of elastomer diaphragms, dirty or leaky air and oil lines, incorrect actuator torque switch or limit switch settings and erroneous instrument pressure switch indicators. Of the operator malfunction events reported, 45% were caused by failure of the actuator or actuator parts and 10% by failure of indicating instruments. Twelve percent were attributable to failures in power control circuit components. Safety/relief valves were involved in 20% of the operational malfunction events. Causes of safety valve malfunction were improper set point adjustment, pressure switch failures, bellows failures and corrosion or foreign material on valve parts. Of the forty safety/relief valve failures recorded, 85% occurred in BWR systems.

Industry Parties

It was recognized that the information obtained from data banks would provide limited use in identifying root causes of valve failures. Therefore, supplementary input from a broad spectrum of organizations involved in the various aspects of nuclear power plant design, construction and operation was needed. The organizations consulted were:

1) Nuclear Steam Supply System Vendors
   a) Pressurized Water Reactor System
   b) Boiling Water Reactor System
2. Nuclear Valve Suppliers
   a) Safety-Relief Valves
   b) Main Steam Isolation Valves
3) The Nuclear Regulatory Commission
   a) Office of Management Information and Program Control
   b) Office of Inspection and Enforcement

4) Utilities and Nuclear Power Stations

Participants consisted of a variety of personnel engaged in the design, manufacturer, procurement, installation and maintenance of nuclear valves. In view of the scope limitations, time did not permit examination of relevant failure records and reports on file at these organizations. Instead, reliance was primarily placed on the impressions and experiences of the participants.

The discussion which follows addresses those areas which, by consensus, appear to be the most common and/or most disruptive to electrical generation. Additional comments of general interest assembled in the course of the discussion are also presented.

Seat Leakage

Valve seat leakage is a universal problem in electric power generation. In nuclear applications, this problem becomes more acute because of the severe restrictions imposed on permissible leakage rates. Utility personnel report that this problem occurs most during off power testing, when pressure differentials across the disc are low. Therefore, it is not a major disruptive factor during plant power operation but it is a major source of maintenance activity during outages. Opinions of utility personnel attribute this problem primarily to the severity of leakage limitations and changing leak test requirements coupled with the difficulty in obtaining leak tight repeatability in valves. In addition, leakage indicated in a gaseous test medium such as nitrogen is not considered to necessarily indicate excessive leakage under the LWR operating medium.

Containment isolation valves are a continuing problem in the area of seat leakage. These valves, which are of the butterfly type, vary widely in size, some as large as forty or more inches in diameter and are designed with either soft (nonmetallic) or hard seats. Failure rates as high as fifty percent have been experienced during leak testing of these valves, although one utility indicated that a large reduction in failure rate was experienced in subsequent test cycles. The opinion was expressed that the leakage problem experienced with these valves is attributed to their misapplication in an isolation function.

Main seat leak tightness in main steam isolation and feedwater check valves was reported as a major source of maintenance work. These hard seat valves require long periods of maintenance or repair on site and may involve removal of bonnets and welding, grinding and lapping of seat surfaces.

Stem Packing Leakage

Leakage through valve stem packing is a common occurrence at operating plants. Improved performance has been obtained by incorporating changes in packing material and construction, anti-extrusion devices, lubricants, stuffing box design and installation techniques. The trend in packing construction in use is moving from the compressed laminated rings to the preformed graphite ribbon type. The utility personnel interviewed unanimously expressed that better results have been obtained with the graphite ribbon type material.

Indications are that installation procedures have some influence on the performance of stem packing seats. One utility made a strong recommendation that trained permanent personnel be used for all packing installations and that procedures and history of operation be documented for future evaluation. Packing leakage problems have been reduced since a program of this type was instituted in this utility's plants.

Other comments made regarding packing leakage are indicated below:

Tightening of packing gland nuts is done primarily by "feel". In general, the higher the service pressure and temperature for the application, the greater the incidence of leakage problems.

Horizontal stem installations and, to some degree, other nonvertical stem installations experience more leakage problems than vertical installations.

In some instances, packing replacement has been hampered by failure to consider accessibility in design and installation.

Translating stem valves appear to be more susceptible to packing leakage than rotating stems, except that modulating control valves with rotating stems also experience a high degree of leakage problems.

Some plant maintenance crews have successfully applied a process known as "Fermanite", which consists of a viscous substance injected into the existing packing.

Valve-Actuator-Controls

Problems associated with limit switches and torque switches are a major contributor to plant maintenance. Reports are that switches move out of adjustment during operation but one utility indicated that, oftentimes, switches are not properly set, initially.

Problems with operator-valve compatibility exist primarily in oversizing of electric motor operators, and failures in valve parts, such as stems and yoke legs, have been attributed to overload by the operator.

Large loads can be applied to valve parts when the inertia of the motor-stem-disc system is not taken into account in setting of limit and torque switches. Valve operators which are sized for power operation conditions can cause damage when exercised at atmospheric conditions.

Safety/Relief Valves

Most organizations interviewed had basically the same set of comments regarding safety relief valve problems, namely:

Set point drift is a basic problem.

A common problem associated with a pilot operated relief valve of one particular design is being resolved.

Qualifying valves under current Section XI requirements is difficult.

Testing under alternative test media is desirable. However, collection and correlation of data is needed.

Facilities with total safety relief valve test capability are needed.

Qualification of safety relief valves should be obtained under two-phase flow conditions.

Problems of General Interest

The misapplication of specific valve types to isolation and flow control functions is a common cause of problems.

Adequate maintenance tooling is not usually supplied by vendors.

Flushing of lines prior to maintenance reduces personnel exposures.

Greater participation of the power production group during the valve selection stage of plant design effort is desirable.

Participation of vendor personnel in the maintenance training process is important.

Valve designs currently installed in plant systems oftentimes are subjected to test and service conditions which are more severe than those for which they were designed.

Technical Documents

The valve industry problems identified in this pilot program based on the data files and industry party interviews are in agreement with those identified by the other documented studies referenced herein.

The MPR study [8] is based on a broader information base including, in addition to that of the present study, review of the Semiannual Operating Reports on file at the NRC Public Document Room and review of operating records made available at plant sites. Among the problem areas reported which are in agreement with those identified in the present study are:

1) valve stem leakage,
2) fluid tightness across valve seats,
3) compatibility of motor operator and valve and associated control circuits,
4) misapplication of valves for the service intended, and
5) engineering follow-up on specific plant solutions and dissemination of information to other facilities.

The present study assigns a greater emphasis on safety/relief valve problems than is indicated by other reports. Thus improvements in design and testing which address the comments relative to safety/relief valves are considered essential.

A one-to-one comparison between the data contained in the Nuclear Safety Study [1] *and the present study* could not be meaningfully accomplished because of the overlapping of time intervals and the independently established failure categories. However, a general consistency is apparent. Failures have occurred in both PWR and BWR plants operated and constructed by a variety of utilities and architect-engineer firms. Failure modes included lack of leak tightness and operational malfunction resulting from problems with actuator power controls and instrumentation.

CONCLUSIONS AND RECOMMENDATIONS

The major conclusions resulting from the survey of information sources considered in this study are given below and are followed by recommendations for future programs addressing these problems.

1. Evaluation Center for Industry Valve Problems

Background:

There appears to be a basic shortcoming in the present practices of the nuclear industry in its approach to addressing and treating industry valve problems. The resolution of valve problems which interrupt or threaten to interrupt plant operation is addressed, in general, on an individual basis. That is, correction of the immediate problem and its related consequences is of primary consideration. Once a solution is formulated and corrective action initiated, the efforts of utility personnel turn to other tasks crucial to plant operation. Steps are not generally taken to follow up on solutions for the purposes of determining root causes, identifying generic problems or disseminating information gained for the benefit of the entire industry.

This follow-up evaluation is essential to any program directed at improving industry wide valve reliability. The currently existing data centers which file failure information are not, in themselves, equipped for the engineering evaluation required in improving valve reliability and availability. What appears to be lacking at the moment is a coordinated engineering approach under the direction of a responsible organization or organizations, which draw upon the expertise of all nuclear valve industry participants.

Program Description:

Study the feasibility and organization of a coordinated engineering approach for effecting timely solutions to generic problems in valves which affect valve availability, maintenance and plant operation. The following should be taken under consideration in the performance of this study:

1) The various sources of documented valve failure data and information, including Data Banks (NRC-LER, NSIC, NPRDS), maintenance files at operating plants and published and unpublished technical documents.

2) The problems associated with interfacing between the various industry participants such as valve manufacturers, utility engineering staff, power plant maintenance staff and suppliers of purchased valve parts such as packing and operators.

3) The feasibility of devising a system for categorizing viable valve problem data and solutions with the ability for quick and easy recovery during time of need.

2. Valve Stem Packing Leakage

Background:

Excessive leakage through valve stem packing seals continues to be a common problem in nuclear power plant operation and safety. This is indicated by all three sources of information surveyed under this pilot program. Excessive leakage usually occurs in a previously tight packing assembly following some period of service and valve actuation. In some instances improperly installed packing or defective packing has been reported as the source of the leakage failures. However, the apparent major cause of failure is simply wear on the packing imparted by the moving stem. Periodic retightening of the packing gland provides a temporary fix. However, eventually packing materials now in use tend to lose their resilience and must be changed. Overtightening results in large friction loads which could affect valve operation or require larger valve operating units. Some packing materials which deposit particles on the adjacent polished stem induce corrosion which increases friction loads with use.

Some improvements in wear life have been made with the introduction of new lubricants, packing construction and stuffing box design. A significant improvement in design life has been indicated in tests and during service by a newly developed packing system which uses two types of packing construction [9]. This, in combination with a specific stem material, has resulted in increases in life by a factor of 20 or better.

Program Description:

It is recommended that a program directed at improving valve stem seal design be undertaken. This program should address the following:

1) Study in more detail, the packing failure service experience at operating nuclear power plants. Determine which types of packing design are in use and their susceptibility to failure. Determine the effects on packing life of: packing configuration, packing material, lubricant, fluid service, installation procedures, stem orientation, stem material, and other contributary parameters.

2) Conduct a survey of packing manufacturers and users to determine state-of-the-art of packing seal design.

3) Promote and coordinate development of promising design concepts through funding of design development and testing programs.

4) Promote and coordinate in-service surveillance programs and evaluation.

3. Leak Tightness in Valve Seat.

Background:

Leakage past valve seats continues to be a problem in nuclear power plant operation and safety. The stringent permissible leak rate requirements imposed, particularly for low pressure differential across discs, are difficult to satisfy. This is further aggravated by the changing requirements which impose lower limits on valves procured under less limiting leakage requirements.

Excessive leakage problems occur usually during preoperational and periodic testing. This has been established primarily in discussions with plant personnel and valve vendors and confirms the findings of previous studies in this regard. Inability to satisfy leakage requirements for valves in operating plants may require examination and rework of seats resulting in personnel exposure to radiation and possible delay of plant start-up.

Program Description:

A program to address seat leakage has been recommended in a previous study of this problem. MPR Associates in a report entitled "Assessment of Industry Valve Problem", EPRI NP-241, November 1976, recommends, in summary, the following:

1) Find improved methods of achieving seat tightness for main steam isolation valves and feedwater check valves in BWRs, and containment isolation valves in PWRs and BWRs.

2) Develop leak testing methods and techniques which are directly applicable to nuclear stations.

3) Sponsor a long-range program to develop technology for achieving leak-tight seating designs in steam, gas and high pressure, high temperature water applications. This program would address material combinations, seat geometry, surface wear, corrosion, radiation damage and alignment of moving parts.

4) Develop maintenance procedures, tooling and techniques for restoring seat tightness while keeping radiation exposure to maintenance personnel at a minimum.

Our review of failure data indicated that a substantial proportion of seat leakage incidents (75%) involved safety valve seat leakage which caused plant shutdown. This subject is discussed previously under Failure Data Files, and notes that a substantial number of these failures were related to pilot valve failures of a specific designer. An additional task which would address safety valve seat leakage could be included in task 1) above.

4. Improvement of Valve-Actuator-Controls Systems

Background:

A multitude of problems resulting in operational malfunction of valves is indicated from this study. The root causes of many of these problems cannot in all instances be identified from the failure data reviewed.

However, apparent causes can be attributed to deficiencies in the design and installation of valve parts, actuators and control and instrumentation circuits. Typical problems involve failures in elastomer diaphragms, air and oil lines, actuator limit or position switches and instrument pressure switch indicators. Structural failures of valve parts, such as yoke legs and stems, often result from excessive loads applied by the actuator due to torque or limit switches being out of adjustment. The tendency is for valve actuators to be oversized for the particular application and needed guidance on actuator sizing is indicated. The consensus appears to be that electric motor operated valves are more troublesome than other actuation techniques.

Program Description:

Programs, are required, which will provide needed guidance in the design, selection, construction and maintenance of valve operators for LWR service. Specific program recommendations are provided by Riddington and Reyer in the accompanying paper [10].

5. Large Scale Valve Test Facility

Background:

The survey of industry parties indicated activity and interest in the establishment of a full scale valve testing capability under near actual plant conditions. Constraints in presently available facilities include limitations in valve size, flow rate, temperature, type and magnitude of loadings, steam capacity, multiphase flow and available flow media. Capability for full size testing of large valves for isolation valve seat leakage and closing speed, relief valve set pressure and closing pressure and control valve performance under concurrent loadings of pipe reactions, inertia, fluid flow, thermal transients, pressure and other applicable loadings required. Private sponsorships of such facilities by independent organizations or even on an industry level may not be possible. A study of industry requirements and availability of facilities for this prupose is recommended.

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THE IMPACT OF VALVE FAILURES ON THE SAFETY & RELIABILITY OF LIGHT WATER NUCLEAR POWER PLANTS

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ABSTRACT

A study of the causes of, and solutions for, recurrent valve failures has been performed. The frequency and root causes of valve problems were identified from licensee event reports and meetings with utility, NSSS, and valve manufacturer personnel. Three generic problems (Stem leakage, seat leakage, and inadequate specification) and four valve specific problems were identified. The four valve specific problems and their principal causes are: (1) BWR pilot operated safety relief valves (pilot valve leakage); (2) spring loaded safety relief valves (water solid and two-phase flow behavior); (3) PWR feedwater regulating valves (trim degradation and packing failures); and (4) air operated solenoid valves (jamming due to foreign matter in service air). The first two valve specific problems are the subject of current industry programs. Programs intended to address stem leakage, seat leakage, timely exchange of valve failure information, testing of valves, and adequate specification, selection, and maintenance of valves will be outlined.

INTRODUCTION

An analysis of component failures from information in the computerized Nuclear Safety Information Center (NSIC) data bank shows that for both PWR and BWR plants the component category most responsible for shutdowns is valves [1]. Valves are responsible for approximately 19.3 percent of light water reactor power plant shutdowns [2]. A detailed investigation of the valve failures in LWRs was performed.

DATA SOURCES, COLLECTION AND ANALYSIS

The primary source of data on valve failures used was the computerized nuclear safety information center (NSIC) data bank at Oak Ridge National Laboratory. The data bank comprises data condensed by NSIC staff from Licensee Event Reports (LER's) submitted by Utilities in accordance with 10 CFR Part 50, Section 50.36. The data analyzed were all valve failures leading to plant trips and shutdowns, between December 1972 and December 1978, for all U.S. domestic PWR and BWR plants and all valve failures occurring at ten (10) selected plants, covering 20 units, 16 PWRs and 5 BWRs.

Other sources of information used were Monthly Operating Status Report NUREG-0020, Nuclear Power Experience [3], NRC Inspection and Enforcement (I&E) Bulletins.

Tables I and II "Valve Failures Causing Trips" and "Valve Failures Causing Orderly Shutdowns" respectively, summarize the valve failures causing light water reactor shutdowns and trips for the period from December 1972 to March 1979.

The greatest cause of shutdowns in LWRs due to valve failures is leakage from valve stem packing. Both BWR plants and PWR plants have stem leakage problems (BWRs, 21% and PWRs, 34%).

In BWR plants, pilot operated main steam safety relief valves are the greatest single cause of valve initiated shutdowns (25.5% of all shutdowns). This is followed by motor operated isolation valve failures (12.8%), main steam isolation valve failures (4.2%), containment isolation valve failures (3.2%), and others.

In PWR plants, the feedwater regulating valves and feedwater system valves (12.1% combined) are the principal causes of valve initiated reactor shutdowns. This is followed by pressurized spray valve failures (8.6%); main steam isolation valve failures (6.9%); main steam safety relief valve failures (5.2%) and others.

Our investigation focused on these principal valve problems. Discussions were held with Utilities, manufacturers and NSSS vendors to determine the root causes of these problems. Six Utilities, Forteen manufacturers and the four NSSS vendors provided input.

ROOT CAUSES OF VALVE FAILURES

Valve Stem Leakage: The means for sealing the valve stem has remained basically unchanged from that used in conventional (fossil) power plants. In conventional power plants, leakage through the packing results in constant maintenance such as repacking and tightening of the gland. In nuclear plants, however a minor leak frequently violates the technical specification and leads to a required shutdown. Development programs in the area of gland seal material and packing box design have been undertaken but additional work is necessary.

Pilot Operated Safety Relief Valves: Pilot operated main steam relief valves have been the greatest single cause of shutdowns in BWR plants. The major problem has been and still is, leakage past the pilot valve resulting in opening of the main valve. Pilot valve leakage has been caused by dirt, debris, moisture, and steam line vibration induced wear. A number of utilities completely replace these valves at each shutdown in order to keep shutdowns to a minimum. Even with such a maintenance program some of the valves still require maintenance before the refuelling shutdown is reached. For BWR plants in the design and construction phase, the pilot operated type of power operated safety relief valve is now displaced by the dual function, piston operated, spring loaded relief valve.

On PWRs the pilot operated type of valve is used as a non-code valve, functioning as a pilot operated pressurizer safety relief valve. These valves caused substantially less reactor trips than for BWR's. Two (2) NSSS manufacturers no longer use pilot operated safety relief valves for pressurizer applications. A failure of this type of valve to close after actuation has been identified as a contributing factor at Three Mile Island Unit 2 (TMI-2).

A high level of maintenance is necessary to ensure satisfactory operation of the pilot operated safety relief valves. They may not be the most suitable valve for use in high radiation level areas, such as pressurizers.

Spring Loaded Safety Relief Valves: Early problems of seat leakage and pressure setpoint drift on these valves in main steam relief and pressurizer relief applications have largely been solved, with only isolated such events now occurring. Considerable progress has been made in accurately defining the factors that effect the set point of these valves, in particular the influence that operating ambient temperatures have on the set point. One serious problem with the spring loaded safety valve in the PWR pressurizer and BWR main steam applications is the unknown capability of the valve to handle liquid or two (2) phase flow. The valves are designed to relieve steam flow only. For example it is thought that the TMI-2 code pressurizer relief valves were subjected to such flow conditions, since the pressurizer was completely filled with water. Tests have not been performed on this type of valve for liquid or two (2) phase flow conditions and it is recommended that such testing be done.

Main Steam Isolation Valve: Two major problems have been found with main steam isolation valves. The first is poor main valve control system component performance which degraded the ability to open or close the valve. The second (also the largest number of malfunctions for BWR plants) is the inability of the valve to satisfy leak rate requirements defined in the plant technical specification. Recent development programs have been implemented to solve the control system failures. New components have been developed and tested under simulated operational and accident conditions. However, main steam isolation valves are still unable to meet seat leakage requirements without performance of extensive maintenance during each shutdown on these valves.

Feedwater Regulator Valves: The greatest causes of feedwater regulator valve malfunctions have been: defects of mechanical components, deficiencies in engineering design, and improper material selection. The largest number of valve mechanical defects have been valve seat and/or valve plug degradation, and stem packing, problems. Common to a number of plants are valve malfunctions due to engineering and design deficiencies in some cases resulting in a valve size much larger in flow area than necessary. Such over sizing has caused instability, vibrations and water hammer. These conditions resulted in plant trips or malfunctions that required plant shutdowns. Inappropriate selection of valve trim type and materials for several nuclear installations reflected the valve manufacturer's insufficient knowledge of operating conditions.

Pressurizer Spray Valves: The most frequent failure of pressurizer spray valves has been valve stem leakage which invariably causes a reactor shutdown. Severe stem leakage problems led to replacement with the bellows type of seal. These however, suffered from fatigue failures and were unsatisfactory in the service. A rotary ball type valve is now used by one PWR vendor, and a newly developed hermetically sealed type of solenoid valve is being used by another PWR vendor.

Solenoid Valves: The most common cause of solenoid valve failures was found to be foreign matter (such as dirt, grit, oil) entering the valve and causing it to stick. A fairly widespread problem with these valves has been improper sizing or selection of solenoids. This has usually been the result of insufficient guidance from the solenoid manufacturer to the main valve manufacturer. Closer cooperation between the two would eliminate many of these problems. Considerable development work has been done jointly by solenoid manufacturers, main valve and NSSS manufacturers to qualify solenoid valves for the required service. There is a need for more attention to be given to defining clearly solenoid valve operating and accident conditions. Solenoid valve performance would greatly benefit from thorough testing under operating and accident conditions.

Valve Actuators: Electric valve actuators have been the work horse of the fossil power plant industry for thirty years and have performed well. However, nuclear applications placed many additional requirements on valves equipped with motor operators such as increased operating speed, and operation at reduced voltage, at high temperature, and during seismic events.

The root causes of many motor operated isolation valve failures can be attributed to the utilization of motor operators that develop, under stall conditions, four to five times the design thrust of the operating torque. The applicable codes mainly address the assurance of the pressure-retaining integrity of valves, but do not deal with proper mating of the valve and actuator to provide the equally important assurance of operability.

The stall torques of the valve actuators in use today are so high that destruction of the valve mechanism and the electric actuator is possible. Some manufacturers have developed improved motor driven actuators for nuclear applications. However, market penetration of valves equipped with these improved actuators has been slow.

Packless Valves: For some valve applications the use of packless valves provides one solution to stem leakage. Metal diaphragm valves of sizes up to two inches are used for instrument line isolation (root) valves, vent valves and drain valves. Problems with these valves occur most frequently during initial plant startup and are usually caused by foreign matter lodging in the valve seat/ port area, resulting in the valve failing to close. Because many seals require a high torque to achieve the required seal tightness, leakage at the body-bonnet joint often results. The bellows stem seal type of packless valve, has failed frequently due to torsional fatigue of the bellows.

PROGRAM RECOMMENDATIONS

From the history of failures of valves in LWR's, it can be concluded that not enough attention has been given to the specification, selection of the manufacturer, and testing of valves to insure that they are suitable for the intended service. It is clear that a major industry effort is necessary to tackle valve problems.

As part of this major industry effort, valve qualification or certification for a specified service should be undertaken. Valves important to safety and plant availability (key valves) should be certified as suitable for their intended service either by operating history or by tests. In addition, standard purchasing and test specifications should be developed for these key valves to assure that they are adequate for the intended service.

Based on this study, development programs, which deal with the following problems seem advisable:

- Elimination of stem leakage
- Improvement of motor operated and to a lesser degree other types of power operated safety system valves
- Testing of main steam and pressurizer safety relief valve performance for liquid and two phase flow
- Determination by appropriate testing of the effects of installation on safety relief valve operation
- Reduction of main steam isolation valve seat leakage
- Reduction of existing pilot operated safety relief valve maintenance

A better reporting system carrying more detailed information of valve failures is necessary, if the industry is to expeditiously solve its valve problems. The type of valve failure, the valve manufacturer and model number, details of the valve failure and the subsequent repair should be included.

Meetings or conferences with A/E's, utilities and manufacturers should be held to ensure that the findings of this investigation are given the widest industry exposure.

Also, overseas experience with valve problems should be investigated, in order to obtain the data available about valve operating experiences at LWR nuclear plants outside of the U.S.

Finally, the need for full-scale test facilities for liquid, steam and two-phase flow to adequately test valves is apparent. A large number of manufacturers have stated the need for such facilities. Testing large equipment in the few U.S. independent laboratories capable of doing so is very expensive and the U.S. facilities are limited to quality valves for full flow testing. A national test facility in which manufacturers could test, develop and qualify their valves for use in light water reactors would significantly increase their reliability and effectiveness.

TABLE I

VALVE FAILURES CAUSING TRIPS

LIGHT WATER REACTORS

DECEMBER 1972 TO MARCH 1979

CATEGORIES	BWR		PWR	
	Events	% of Total	Events	% of Total
Pilot Operated Safety Relief Valves	19	57.6	1	3.3
Spring Operated Safety Relief Valve (Main Steam)	0	0.0	1	3.3
Main Steam Isolation Valve	4	12.2	7	23.3
Feedwater Regulating Valves	1	3.0	10	33.3
Turbine Control Valves	3	5.0	1	3.3
Valve Leaks in Containment	3	9.0	1	3.3
Feedwater System	-	-	4	13.3
Pressurizer Spray Valve	-	-	1	3.3
Operator Error	2	6.0	-	-
Others	1	3.0	2	6.3
	33		30	

TABLE II

VALVE FAILURES CAUSING ORDERLY SHUTDOWN

LIGHT WATER REACTORS

DECEMBER 1972 TO MARCH 1979

CATEGORIES	BWR		PWR	
	Events	% of Total	Events	% of Total
Leakage from Stem Packing	20	21.0	20	34.5
Leakage from Bonnets	1	1.0	4	6.9
Valve Operator Failure	12	12.8	3	5.2
Pilot Operated Safety Relief Valve	24	25.5	0	0
Spring Operated Safety Relief Valve (Main Steam)	2	2.0	3	5.2
Main Steam Isolation Valve	4	4.2	4	6.9
Control Rod Drive System Scram Pilot Valve	3	3.2	0	0
Containment Isolation Valve	3	3.2		
Pressurizer Spray Valves			5	8.6
Feedwater Regulating Valves			3	5.2
Feedwater System valves			4	6.9
Turbine Control Valves			4	6.9
Others	5	5.3	8	13.7
	74		58	

NOTE: Valve Operator Failures in BWR were mainly motors for isolation valves. In PWR, pneumatic diaphragm operators failed most.

ACKNOWLEDGEMENTS

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Valve Stem Packing Improvements

Project Objectives: To identify specific valve stem leakage causes and to conduct research to recommend development and testing programs to improve stem packing systems.

Project Parameters

Packing Systems: stem packing materials, temperature/pressure effects, maintenance practices.

Valves: stem/valve materials, stuffing box design, valve size/type, stem packing pre-load.

Operating/Maintenance Environment: vibration and radiation effects, process media, chemical additives, maintenance practices.

Status: Contract being negotiated.

BWR Main Steam Isolation Valve Seat Leakage

Project Objectives: (1) Identify basic causes of failure to consistently achieve in-service leak test criteria in BWR main steam isolation valves;

(2) Identify required corrective action changes to the valve and verify by test the effectiveness of these changes in a prototype unit.

Project Parameters: seat lapping eccentricity, disc guide clearance, surface finish of disc and seat, stem loading effects, thermal cycling effects, seat geometry, pipeline welding effects, system debris effects, pipe loading effects.

Status: Approximately 50% complete; completion expected during calendar year 1980.

Peformance Testing of Safety and Power Operated Relief Valves

Program Objective: Respond to NRC NUREG-0578 which calls for "performance verification by full scale prototypical testing for all relief and safety valves. Test conditions shall include two-phase slug flow and subcooled liquid flow calculated to occur for design basis transients and accidents."

Program Paramenters

A. Performance testing of prototypical safety valves and power operated relief valves.

B. Test Conditions

1. Saturated steam discharge through

test specimens at anticipated reactor transient conditions.

2. Saturated (nominal) and subcooled water discharge through test specimens at anticipated reactor transient conditions.

C. Test Facilities/Contractors

1. Combustions Engineereing - Steam test and water test of safety valves.

2. Duke Power Co., Marshall Station - Steam test of power operated relief valves.

3. Wyle Lab., Norco - Water testing of power operated relief valves. System capabilities for steam test.

AGENDA

EPRI/DOE Workshop

Nuclear Industry Valve Problems

EPRI Offices
1800 Massachusetts Avenue NW
Washington, DC 20036

May 20 - 21, 1980

Tuesday, May 20

9:00 a.m.	Welcome, Introduction, Focus
9:15 a.m.	EPRI Valve Improvement Programs Mr. Jeff Jeffries - EPRI Mr. Boyd Brooks - EPRI
9:45 a.m.	Coffee Break
10:00 a.m.	Pilot Program to Identify Valve Failures which Impact the Safety and Operation of Light Water Nuclear Power Plants Mr. Jim Tscoyeanes - Teledyne Engineering Services Mr. Pal Raju - Teledyne Engineering Services
10:30 a.m.	Investigation of Valve Failure Problems in LWR Power Plants Mr. John Riddington - Burns & Roe Mr. Ron Reyer - Burns & Roe
11:00 a.m.	DOE/Sandia Valve Improvement Programs Mr. Jeremy Sprung - Sandia
11:30 a.m.	Organization of Working Sessions
12:00 noon	
1:00 p.m.	Working Sessions Group 1: Stem and Seat Leakage Chairman: Mr. Jim Tscoyeanes Group 2: Key Valves Chairman: Mr. John Riddington
4:30 p.m.	Adjourn

Wednesday, May 21

Workshop Reports and Discussion

9:00 a.m.	Stem and Seat Leakage
9:30 a.m.	Key Valves
10:00 a.m.	Coffee Break
10:15 a.m.	Discussion of Workshop Reports
11:30 a.m.	Final Summary
11:45 a.m.	Adjourn

Workshop Participants

Organization	Names
Anchor/Darling	B. Knecht, J. Schlereth
Babcock & Wilcox	D. Lee, B. Cardwell, Jr.
Burns & Roe	J. Riddington, R. Reyer
Chesterton	E. Bernier, C. Grabski
Combustion Engineering	T. Kettles, G. Schukei
Commonwealth Edison	F. Highland
Crane	W. McLean
Crosby Valve and Guage	W. Greenlaw
Department of Energy	M. Norin, J. Carlson
Dresser Industries	J. Richardson, Y. Lai
Duke Power	J. Berry
EG&G	J. Hunter
EPRI	B. Brooks, J. Jeffries
Fisher Controls	L. Fleetwood
General Electric	C. Jones
Jersey Central Power & Light	B. Lang
Kerotest	R. Conley
Limitorque	J. Drab
MPR Associates	T. Walters
Oak Ridge National Lab	E. Silver
Philadelphia Electric	F. Light
Rockwell International	B. Milleville
Sandia National Laboratories	J. Sprung
Stone & Webster	J. Klein
Target Rock	D. Pattarini, J. Bocci
Teledyne Engineering Services	J. Tscoyeanes, P. Raju
TVA	C. Favreau
Velan	J. Farrell
Westinghouse Electric	I. Esekoye