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NUCLEAR ENERGY AGENCY
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

NEA/CSNI/R(2002)19
Unclassified

ICDE PROJECT REPORT: COLLECTION AND ANALYSIS OF COMMON-CAUSE FAILURE OF SAFETY VALVES AND RELIEF VALVES

JT00132584

English text only

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996), Korea (12th December 1996) and the Slovak Republic (14 December 2000). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consists of 28 OECD Member countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Portugal, Republic of Korea, Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities also takes part in the work of the Agency.

The mission of the NEA is:

- to assist its Member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as
- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

The Committee on the Safety of Nuclear Installations (CSNI) of the OECD Nuclear Energy Agency (NEA) is an international committee made up of senior scientists and engineers. It was set up in 1973 to develop, and co-ordinate the activities of the Nuclear Energy Agency concerning the technical aspects of the design, construction and operation of nuclear installations insofar as they affect the safety of such installations. The Committee's purpose is to foster international co-operation in nuclear safety among the OECD Member countries.

The CSNI constitutes a forum for the exchange of technical information and for collaboration between organisations, which can contribute, from their respective backgrounds in research, development, engineering or regulation, to these activities and to the definition of the programme of work. It also reviews the state of knowledge on selected topics on nuclear safety technology and safety assessment, including operating experience. It initiates and conducts programmes identified by these reviews and assessments in order to overcome discrepancies, develop improvements and reach international consensus on technical issues of common interest. It promotes the co-ordination of work in different Member countries including the establishment of co-operative research projects and assists in the feedback of the results to participating organisations. Full use is also made of traditional methods of co-operation, such as information exchanges, establishment of working groups, and organisation of conferences and specialist meetings.

The greater part of the CSNI's current programme is concerned with the technology of water reactors. The principal areas covered are operating experience and the human factor, reactor coolant system behaviour, various aspects of reactor component integrity, the phenomenology of radioactive releases in reactor accidents and their confinement, containment performance, risk assessment, and severe accidents. The Committee also studies the safety of the nuclear fuel cycle, conducts periodic surveys of the reactor safety research programmes and operates an international mechanism for exchanging reports on safety related nuclear power plant accidents.

In implementing its programme, the CSNI establishes co-operative mechanisms with NEA's Committee on Nuclear Regulatory Activities (CNRA), responsible for the activities of the Agency concerning the regulation, licensing and inspection of nuclear installations with regard to safety. It also co-operates with NEA's Committee on Radiation Protection and Public Health and NEA's Radioactive Waste Management Committee on matters of common interest.

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ABSTRACT

This report documents a study performed on the set of common cause failures (CCF) of safety and relief valves (SRV). The data studied here were derived from the International CCF Data Exchange (ICDE) database, to which several countries have submitted CCF event data. The purpose of the ICDE is to allow multiple countries to collaborate and exchange CCF data to enhance the quality of risk analyses that include CCF modeling. Because CCF events are typically rare events, most countries do not experience enough CCF events to perform meaningful analyses. Data combined from several countries, however, yields sufficient data for more rigorous analyses. This report is the result of an in-depth review of the SRV events and presents several insights about them. The objective of this document is to look beyond the CCF parameter estimates that can be obtained from the CCF data, to gain further understanding of why CCF events occur and what measures may be taken to prevent, or at least mitigate the effect of, SRV CCF events. The report presents details of the ICDE project, a quantitative presentation of the SRV events, and a discussion of some engineering aspects of the events.

CONTENTS

EXECUTIVE SUMMARY

This study examined 149 events in the International CCF Data Exchange (ICDE) database by tabulating the data and observing trends. Once trends were identified individual events were reviewed for insights.

The database contains information developed during the original entry of the events that was used in this study. The data span a period from 1977 through 1999. The data is not necessarily complete for each country through this period. This information includes root cause, coupling factor, common cause component group (CCCG) size, and corrective action. As part of this study, these events were reviewed again and additional categorizations of the data were included. Those categories included the degree of failure, affected subsystem, and detection method. This study begins with an overview of the entire data set (Section Five). Charts and tables are provided exhibiting the event count for each of these event parameters. This section forms the baseline for the SRV component.

Section Six contains charts that demonstrate the distribution of the same events further refined by failure mode (failure to open, failure to close and inadvertent opening) for each event parameter. Each of these charts is replicated with the further distinction that only those events classified as partial or complete are included. Distinctions are drawn as these parameters shift. Section Seven presents a qualitative assessment of the collected data, events are analysed with respect to failure symptoms and failure causes. Section Eight presents a summary and conclusions.

ACRONYMS

BWR	boiling water reactor
CCCG	common cause component group
CCF	common cause failure
CSNI	Committee on the Safety of Nuclear Installations
ECCS	emergency core cooling system
EDG	emergency diesel generator
I&C	instrumentation and control
ICDE	International Common Cause Failure Data Exchange
IRS	Incident Reporting System
LOCA	loss-of-coolant accident
LOSP	loss of offsite power
NEA	Nuclear Energy Agency
NRC	Nuclear Regulatory Commission
OECD	Organization for Economic Cooperation and Development
PSA	Probabilistic Safety Assessment
PWG1	Principal Working Group 1
PWR	Pressurized Water Reactor
RPS	Reactor protection system
SV/RV	Safety valve/relief valve

ICDE Project Report

Collection and Analysis of Common-Cause Failures of Safety Valves and Relief Valves

1. INTRODUCTION

This report presents an overview of the exchange of safety and relief valves (SV/RV) common cause failure (CCF) data among several countries. The objectives of this report are the following:

- *To describe the data profile in the ICDE database for safety and relief valves and to develop qualitative insights in the nature of the reported events, expressed by root causes, coupling factors, and corrective actions; and*

- *To develop the failure mechanisms and phenomena involved in the events, their relationship to the root causes, and possibilities for improvement.*

The ICDE Project was organized to exchange CCF data among countries. A brief description of the project, its objectives, and the participating countries is contained in Section Two. Section Three presents a definition of common cause failure. Section Four presents a description of the safety and relief valves and a short description of the sub components that comprise it. An overview of the data is presented in Section Five. Section Six contains a description of the data by failure mode and also a comparison of complete CCF events with all of the events collected in this effort. Section Seven presents a qualitative assessment of the collected data, events are analysed with respect to failure symptoms and failure causes. Section Eight presents a summary and conclusions.

2. ICDE PROJECT

This section contains information about the ICDE Project.

2.1 Background

Several member countries of OECD/NEA established the ICDE Project to encourage multilateral co-operation in the collection and analysis of data relating to CCF events.

The project was initiated in August 1994 in Sweden and was discussed at meetings in both Sweden and France in 1995. A coding benchmark exercise was defined which was evaluated at meetings held in Germany and in the US in 1996. Subsequently, the exchange of centrifugal pump data was defined; the first phase of this exchange was evaluated at meetings in Switzerland and in France in 1997.

The ICDE project is operated under the umbrella of the OECD/NEA whose representative for this purpose is the Secretariat for Working Group on Operating Experience (WGOE).

The ICDE project member countries and their sponsoring organisations are:

- *Canada : CNSC*
- *Finland : STUK*
- *France : IPSN*
- *Germany : GRS*
- *Spain : CSN*
- *Sweden : SKI*
- *Switzerland : HSK*
- *United Kingdom : NII*
- *United States : NRC*

2.2 Objectives of the ICDE Project

The objectives of the ICDE project are:

- *To collect and analyse CCF events in the long term so as to better understand such events, their causes, and their prevention.*

- *To generate qualitative insights into the root causes of CCF events, which can then be used to derive approaches or mechanisms for their prevention or for mitigating their consequences.*

- *To establish a mechanism for the efficient feedback of experience gained on CCF phenomena, including the development of defences against their occurrence, such as indicators for risk based inspections.*

2.3 Scope of the ICDE Project

The ICDE Project is envisaged as including all possible events of interest, comprising complete, partial, and incipient CCF events, called “ICDE events” in this report. The project covers the key components of the main safety systems, including centrifugal pumps, diesel generators, motor operated valves, power operated relief valves, safety relief valves, check valves, reactor protection system (RPS) circuit breakers, batteries and transmitters.

In the long term, a broad basis for quantification of CCF events could be established, if the participating organisations wish to do so.

2.4 Reporting and Documentation

All reports and documents related to the ICDE project can be accessed through the OECD/NEA web site (Ref 1).

2.5 Data Collection Status

Data are collected in an MS ACCESS based databank implemented and maintained at ES-Konsult, Sweden, the appointed NEA clearing house. The databank is regularly updated. The clearinghouse and the project group operate it.

2.6 ICDE Coding Format and Coding Guidelines

An ICDE coding format was developed for collecting the ICDE event data for the ICDE database. Definition and guidance are provided in the ICDE coding guidelines (Ref. 2).

2.7 Protection of Proprietary Rights

Incident Reporting System (IRS) procedures for protecting confidential information have been adopted. The co-ordinators in the participating countries are responsible for maintaining proprietary rights. The data collected in the clearinghouse database are password protected and are only available to ICDE participants who have provided data.

3. DEFINITION OF COMMON-CAUSE EVENTS AND ICDE EVENTS

In the modelling of common-cause failures in systems consisting of several redundant components, two kinds of events are identified:

- Unavailability of a specific set of components of the system, due to a common dependency, for example on a support function. If such dependencies are known, they can be explicitly modelled in a PSA.

- Unavailability of a specific set of components of the system due to shared causes that are not explicitly represented in the system logic model. Such events are also called "residual" CCFs, and are incorporated in PSA analyses by parametric models.

There is no rigid borderline between the two types of CCF events. There are examples in the PSA literature of CCF events that are explicitly modelled in one PSA and are treated as residual CCF in other PSAs (for example, CCF of auxiliary feed-water pumps due to steam binding, resulting from leaking check valves).

Several definitions of CCF events can be found in the literature, for example, "Common Cause Failure Data Collection and Analysis System, Vol. 1, NUREG/CR-6268": (Ref. 3)

- Common-Cause Event: A dependent failure in which two or more component fault states exist simultaneously, or within a short time interval, and are a direct result of a shared cause.

Data collection in the ICDE project comprises complete as well as potential CCF. To include all events of interest, an "ICDE event" is defined as follows:

- ICDE Event: Impairment[1] of two or more components (with respect to performing a specific function) that exists over a relevant time interval[2] and is the direct result of a shared cause.

The ICDE data analysts may add interesting events that fall outside the ICDE event definition but are examples of recurrent - eventually non random - failures.

With growing understanding of CCF events, the relative share of events that can only be modelled as "residual" CCF events will decrease.

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[1] Possible attributes of impairment are the following:

- *Complete failure of the component to perform its function*
- *Degraded ability of the component to perform its function*
- *Incipient failure of the component*

Default is component is working according to specifications.

[2] Relevant time interval: two pertinent inspection periods (for the particular impairment) or if unknown, a scheduled outage period.

4. COMPONENT DESCRIPTION

4.1 General Description of the Component

The function of the Safety Valves/Relief Valves (SV/RV) is to prevent overpressure of the components and system piping. The systems for which SV/RV are installed in and data are collected for are:

- PWR steam generators discharge headers
- PWR pressurizer vapour volume
- BWR reactor coolant system, main steam headers

Safety Valves/Relief Valves component types are the following:

- Pressurizer power operated relief valves (PWR)
- Pressurizer safety valves (PWR)
- Steam generator power operated relief valves (PWR, Magnox, AGR)
- Steam generator safety valves (PWR, Magnox, AGR)
- BWR Power operated relief valves
- ADS valves (BWR)
- Safety valves (BWR)
- Primary-Side Safety valves (Magnox, AGR)

4.2 Component Boundaries

The component boundary in this data analysis includes the following: local instrumentation, control equipment, power contactors and other component parts specific to the valve. Functional modules for main steam headers SV/RV are exemplified in figure 4.1

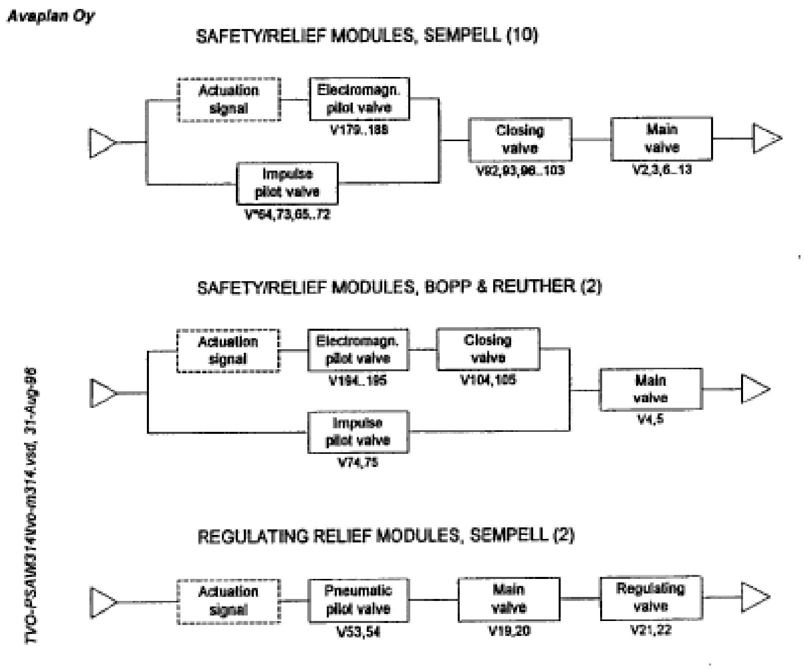

Figure 4.1 Functional modules for main steam headers SV/RV

4.3 Subcomponent Descriptions

The safety and relief valves are divided into subtypes and subcomponents according to the following table.

Sub component / Sub type	1.Valve	2.Impuls line	3.Component specific logic and control equipment	4.Solenoid valve	5.Actuator	6.Motor	7.Power supply	8.Limit and torque switches
A Impulse operated safety valve								
A1 Main valve	X							X
A.2a Impulse or spring-operated pilot valve	X	X						X
A.2b Electromagnetic pilot valve	X	X	X				X	X
A.2c Pneumatic pilot valve	X	X	X	X	X			X
A.2d Motor-operated pilot valve	X	X	X		X	X	X	X
B Spring operated safety valve	X		X*				X*	X
C Motor-operated	X		X		X	X	X	X

Sub component Sub type	1.Valve	2.Impuls line	3.Component specific logic and control equipment	4.Solenoid valve	5.Actuator	6.Motor	7.Power supply	8.Limit and torque switches
Safety/relief valve								
D Electromagnetic operated safety/relief valve	X		X				X	X
E Pneumatic operated safety/relief valve	X		X	X	X			X

X: Applicable; X*: if valve has an additional magnetic loading

4.3.1 Valve

The valve subcomponent includes the housing, the seals, the stuffing, the disk and the seat.

4.3.2 Impulse line

Piping in the impulse line.

4.3.3 Component specific logic and control equipment

Includes the component specific logic and control equipment functions.

4.3.4 Solenoid valve

Includes the specific solenoid valve.

4.3.5 Actuator

The actuator includes the gear, the clutch and the stem

4.3.6 Motor

The electrical motor provides motive force to the valve.

4.3.7 Power supply

The power supply consists of the switchyard equipment including the contactor or switch, and the fuses.

4.3.8 Limit and torque switches

The limit and torque switches provide information about the position of the valve. This information is used to indicate the position of the valve and to stop the motor after actuation of the valve. Limit and torque switches are part of the component protection system.

4.4 Event Boundary

Successful operation of a SRV is defined as opening in response to system pressure exceeding a predefined threshold, and re-closing when pressure is reduced below a predefined threshold. Note: the opening of SRVs in response to an actual system overpressure is not a failure. Subsequent failures to re-seat completely are defined as a failure to close event.

5. OVERVIEW OF DATABASE CONTENT

CCF data for safety and relief valves have been collected. Organisations from Finland, France, Germany, Sweden, Spain, United Kingdom and the United States contributed with data to this data exchange. One hundred forty nine (149) ICDE events were reported from nuclear power plants [pressurized water reactor, boiling water reactor, Magnox, and AGR]. The data span a period from 1977 through 1999. The data is not necessarily complete for each country through this period. Table 5-1 summarises, by failure mode, the SV/RV ICDE events used in this study. Complete CCF events are CCF events in which each component fails completely due to the same cause and within a short time interval. All other events are partial CCF.

Table 5-1. Summary statistics of SRV data

Event reports received	**Total**	**Degree of Failure Observed**	
		Partial	**Complete**
ICDE events			
Failure to open	104	93	11
Failure to close	31	28	3
Inadvertent opening	11	11	0
Other	3	3	0
Total	149	135	14

Figure 5-1 shows the distribution of CCF events by root cause. The dominant root cause, internal to component accounts for 26 percent of the events. Human errors account for 23 percent of the events. Other significant causes are procedure inadequacy and design or manufacture, or construction inadequacy.

Figure 5-2 shows the coupling factor distribution for the events. The dominant coupling factor, operation accounts for 58 percent of the events reported. Hardware (32 %) and environmental (7 %) coupling factors accounts for the remaining events.

Figure 5-3 shows the distribution of identified possible corrective actions for CCF events. Test and maintenance policies rank highest, accounting for 33 percent of the corrective actions. Specific maintenance/operation practice rank next, accounting for 22 percent followed by administrative/procedural actions accounting for 19 percent.

Figure 5-4 shows the distribution of how the events were discovered or detected. Testing accounts for 60 percent. The remaining detection methods, monitoring, demand and maintenance are about equally distributed among the remaining events.

Figure 5-5 shows the distribution of the exposed population size. The size ranges from 2 to 112. There is only one event with size 112, the second largest is 28. The dominating sizes are 2 (15 %) and 4 (13 %). Other sizes with many events are 3, 18 and 20.

Figure 5-6 shows the distribution by subtype.

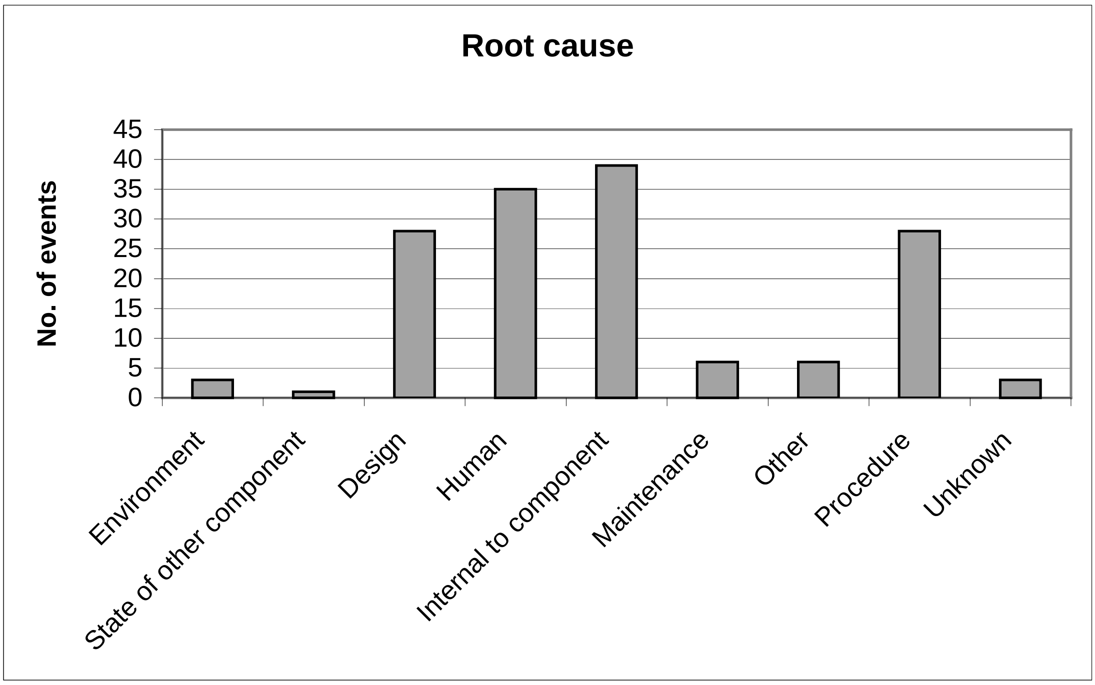

Figure 5-1 Root cause distribution

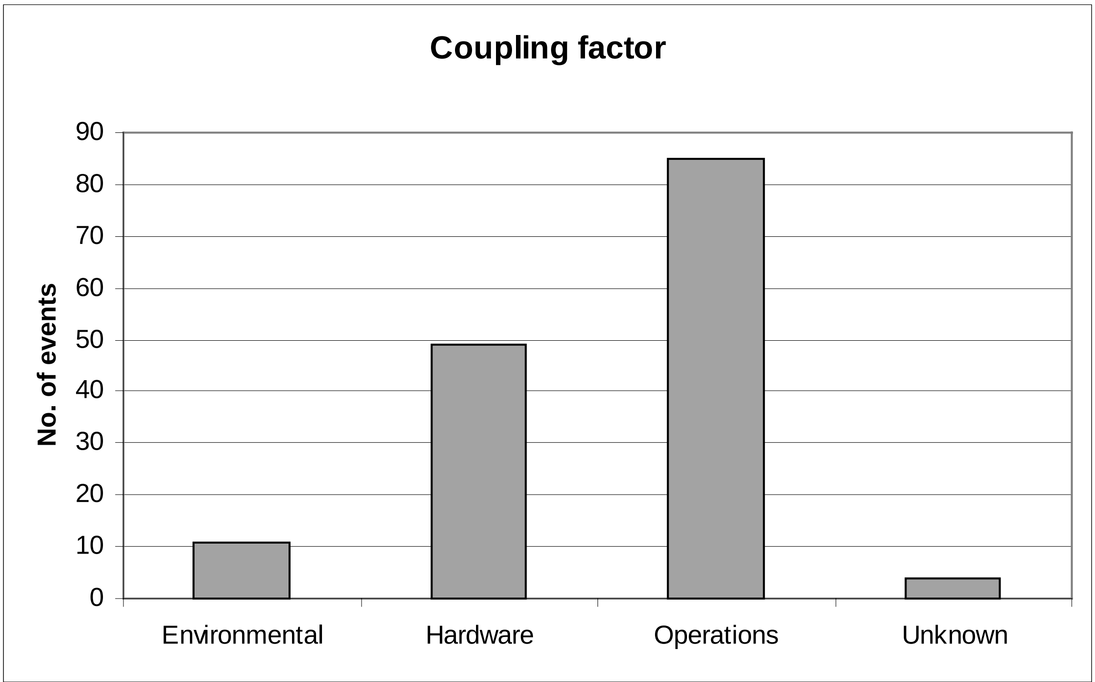

Figure 5-2 Coupling factor distribution

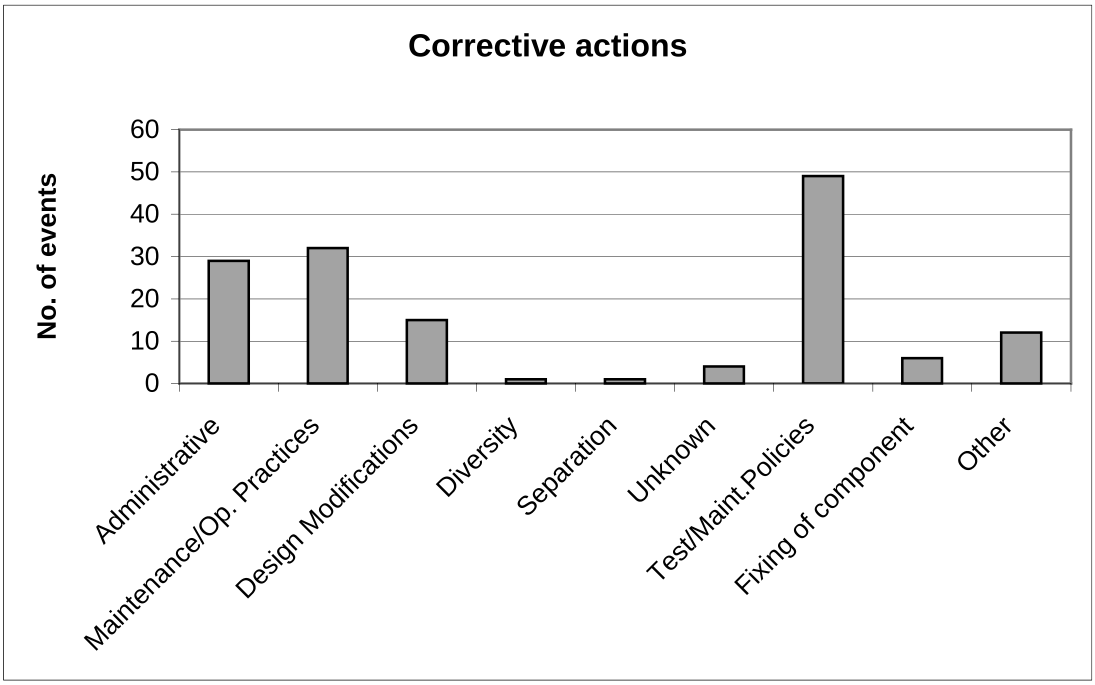

Figure 5-3 Corrective action distribution

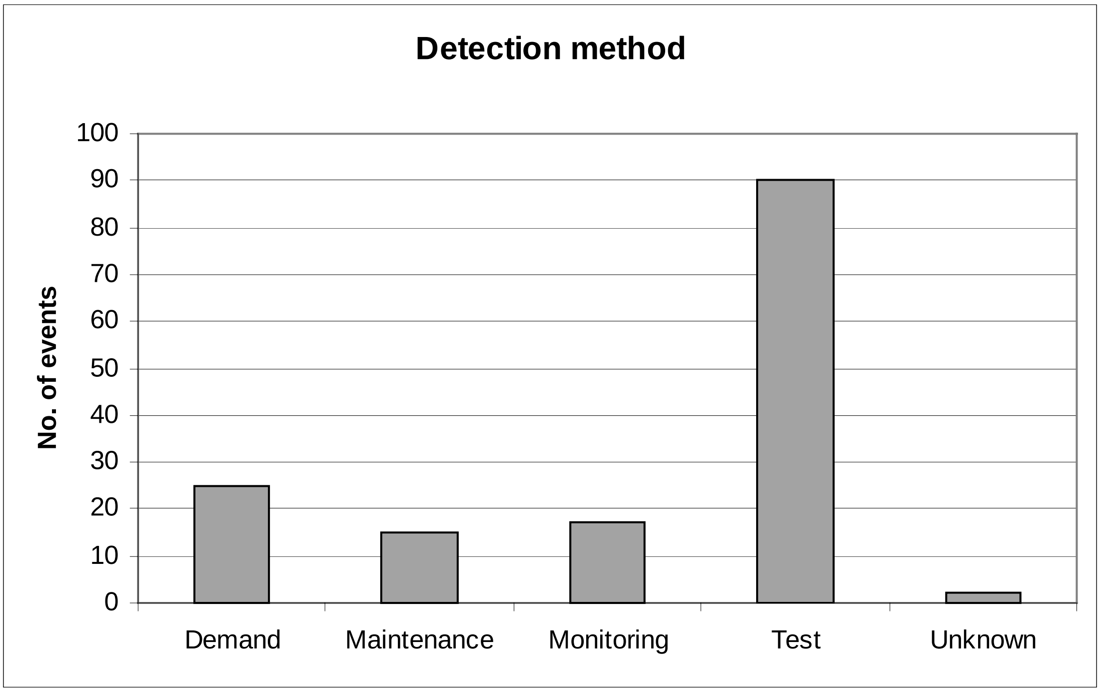

Figure 5-4 Detection method distribution

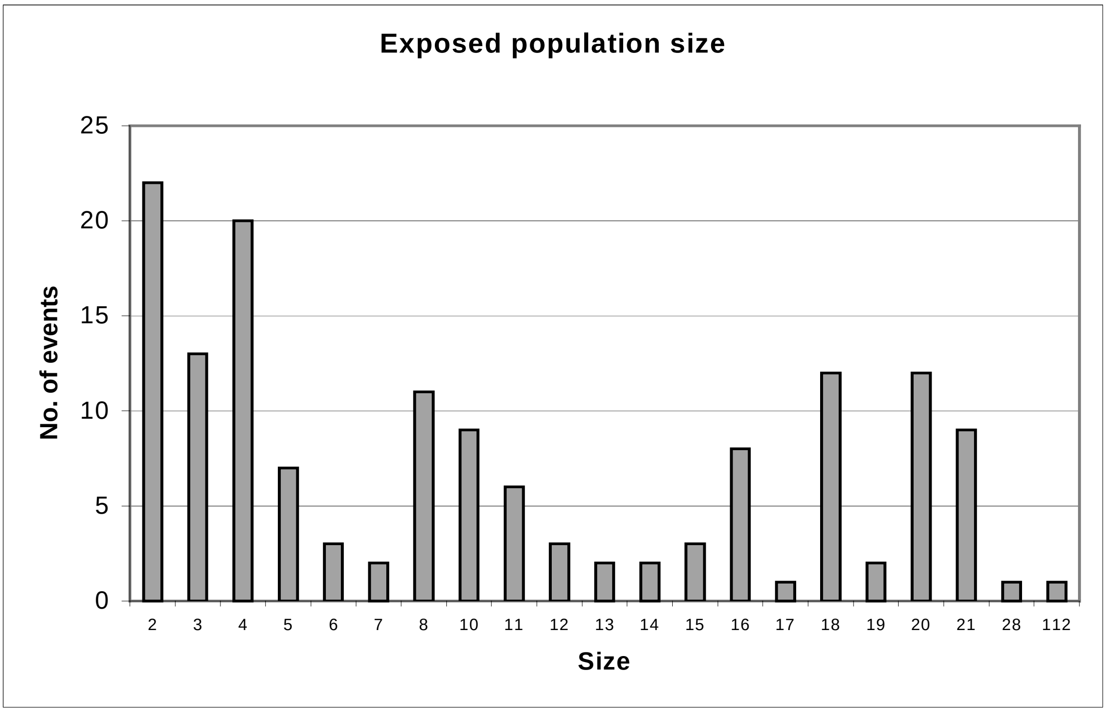

Figure 5-5 Exposed population size distribution

Table 5-2. Sub type and sub component distribution

Sub component / Sub type	1.Valve	2.Impuls line	3.Component specific logic and control equipment	4.Solenoid valve	5.Actuator	6.Motor	7.Power supply	8.Limit and torque switches
A								
A1 Main valve	29							
A.2a Impulse or spring-operated pilot valve	1							
A.2b Electromagnetic pilot valve	9	1						
A.2c Pneumatic pilot valve	20		3	7	15			
A.2d Motor-operated pilot valve					1			
B Spring operated safety valve	36							
C Motor-operated Safety/relief valve	2		1	1				
D Electromagnetic operated safety/relief valve								
E Pneumatic operated safety/relief valve	4		5					

6. OVERVIEW OF EVENTS BY FAILURE MODE AND DEGREE OF FAILURE

This section discusses the CCF events by failure mode and contrasts the distributions of complete CCF events with the distributions of the total group. The failure modes are failure to close, failure to open and inadvertent opening, three events have other failure modes, they are not considered in this analysis. The dominating failure mode is failure to open, which accounts for 104 events, failure to close accounts for 31 and inadvertent opening for 11 events.

Table 6-1 shows the distributions of CCF events for root causes for all events and complete CCF events by failure mode. Figure 6-1 shows the distributions of CCF events for root causes for all events. The dominating root causes for valves that failed to close are internal to component and design, manufacture or construction inadequacy. For valves that failed to open the dominating root cause is internal to component closely followed by human actions. Other root causes with high contribution are procedure inadequacy and design, manufacture or construction inadequacy. For valves with failure mode, inadvertent opening, human actions are the dominating root cause.

Table 6-2 shows the distributions of CCF events for coupling factors for all events and complete CCF events by failure mode. Figure 6-2 shows the distributions of CCF events for coupling factors for all events. For valves that failed to open the dominating coupling factor is operations, which accounts for 63 % of the valves in this category. Hardware accounts for 52 % of the valves that failed to close.

Table 6-3 shows the distributions of CCF events for corrective actions for all events and complete CCF events by failure mode. Figure 6-3 shows the distributions of CCF events for corrective actions for all events. For valves that failed to close and failed to open the dominating corrective action is test/maintenance policies.

Table 6-4 shows the distributions of CCF events for detection methods for all events and complete CCF events by failure mode. Figure 6-4 shows the distributions of CCF events for detection methods for all events. For valves that failed to close there is no dominating detection method. Demand, monitoring and test are about equally distributed. Test is the dominating detection method for valves that failed to open.

Table 6-1. Root cause distribution for all ICDE events and complete CCF events

Failure Mode	Root cause	Number of events	Number of complete CCF events
Failure to close	Abnormal Environmental Stress	1	0
	State of other components	0	0
	Design, manufacture or construction inadequacy	10	1
	Human actions	2	0
	Internal to component, piece part	11	2
	Maintenance	0	0
	Other	4	0
	Procedure inadequacy	3	0
	Unknown	0	0
Failure to open	Abnormal Environmental Stress	2	0
	State of other components	1	0
	Design, manufacture or construction inadequacy	18	3
	Human actions	25	5
	Internal to component, piece part	28	2
	Maintenance	5	0
	Other	1	0
	Procedure inadequacy	22	1
	Unknown	2	0
Inadvertent opening	State of other components	0	0
	Human actions	6	0
	Other	1	0
	Procedure inadequacy	3	0
	Unknown	1	0

Table 6-2. Coupling factors for all ICDE events and complete CCF events

Failure Mode	Coupling factor	Number of events	Number of complete CCF events
Failure to close	Environmental	3	0
	Hardware	16	3
	Operations	11	0
	Unknown	1	0
Failure to open	Environmental	8	0
	Hardware	30	5
	Operations	64	6
	Unknown	2	0
Inadvertent opening	Environmental	0	0
	Hardware	2	0
	Operations	8	0
	Unknown	1	0

Table 6-3. Corrective actions for all ICDE events and complete CCF events

Failure Mode	Corrective actions	Number of events	Number of complete CCF events
Failure to close	Administrative	6	2
	Maintenance/operation practices	2	0
	Design modifications	5	1
	Test/Maintenance policies	13	0
	Functional/spatial separation	1	0
	Fixing of components	0	0
	Other	4	0
Failure to open	Administrative	21	5
	Maintenance/operation practices	25	3
	Design modifications	10	0
	Diversity	1	0
	Test/Maintenance policies	32	0
	Fixing of components	5	1
	Other	7	1
	Unknown	3	1
Inadvertent opening	Administrative	1	0
	Maintenance/operation practices	4	0
	Test/Maintenance policies	3	0
	Fixing of component	1	0
	Other	1	0
	Unknown	1	0

Table 6-4. Detection method for all ICDE events and complete CCF events

Failure Mode	Detection method	Number of events	Number of complete CCF events
Failure to close	Demand	12	2
	Maintenance	1	0
	Monitoring	8	0
	Test	10	1
	Unknown	0	0
Failure to open	Demand	10	1
	Maintenance	14	0
	Monitoring	6	3
	Test	72	7
	Unknown	2	0
Inadvertent opening	Demand	3	0
	Monitoring	2	0
	Test	6	0

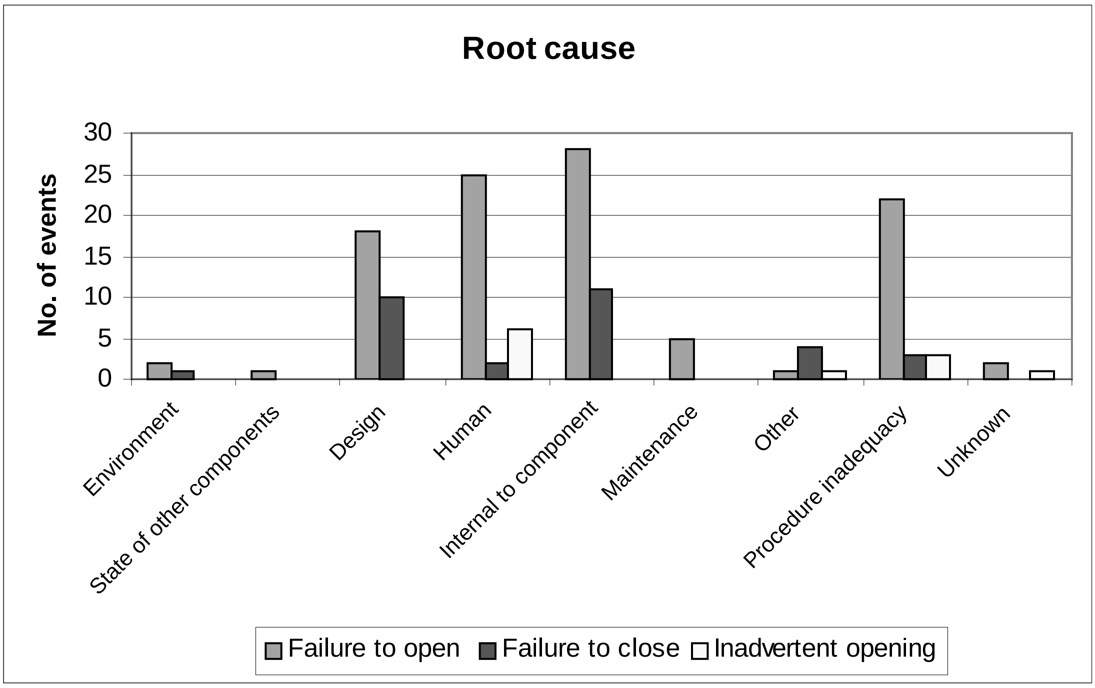

Figure 6-1 Root cause distribution by failure mode

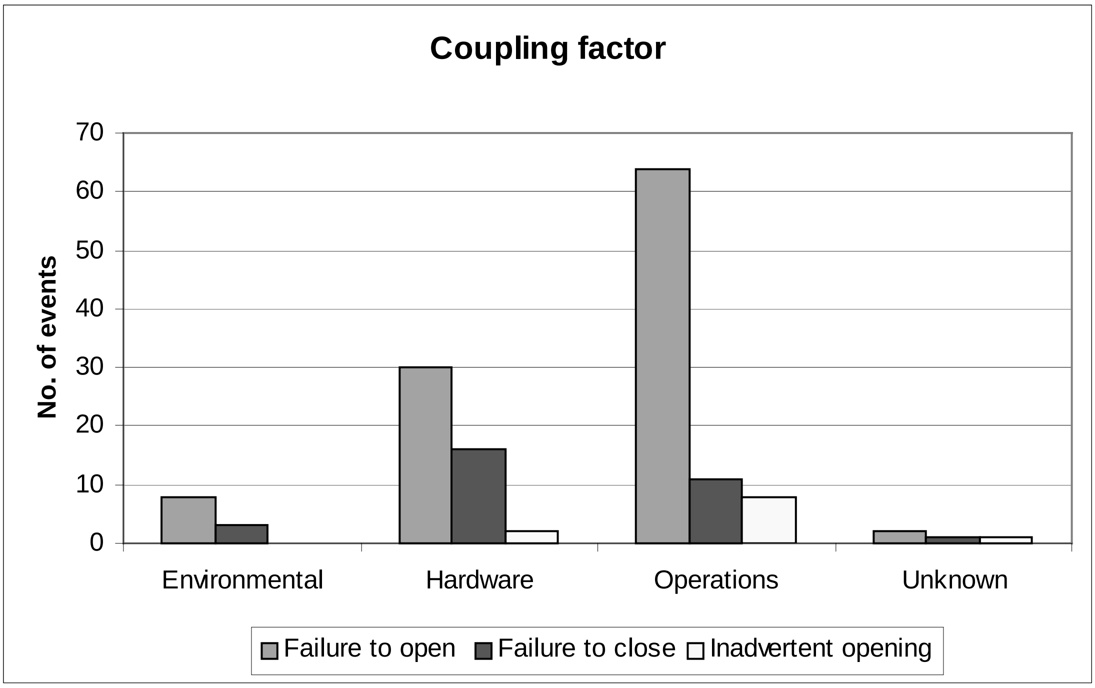

Figure 6-2 Coupling factor distribution by failure method

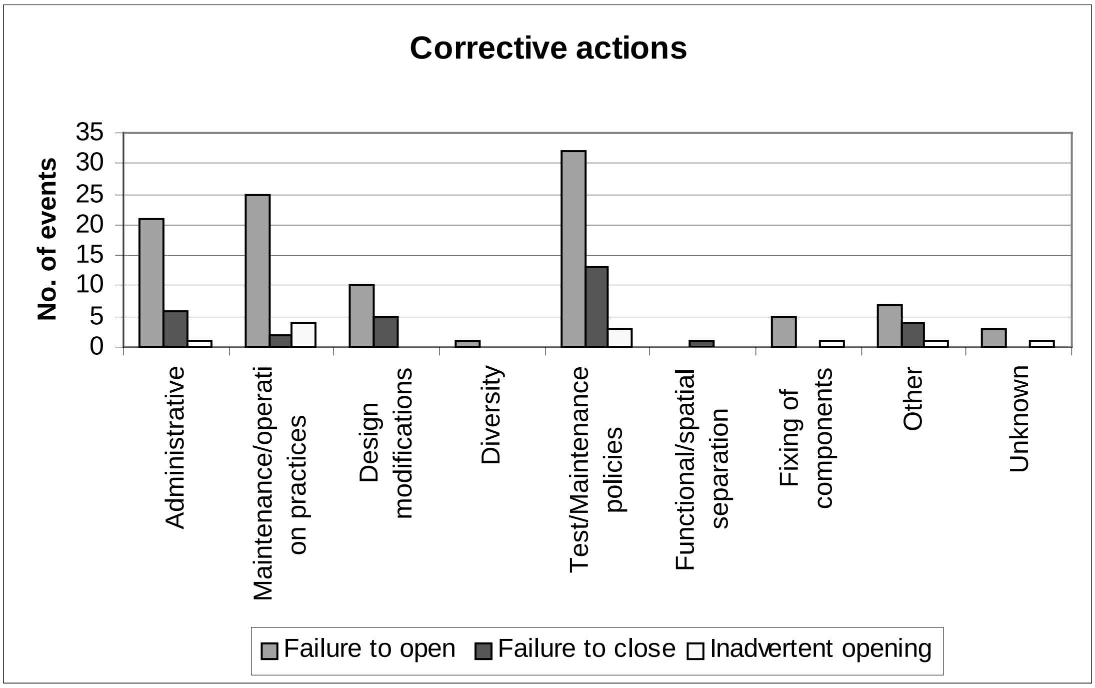

Figure 6-3 Corrective action distribution by failure mode

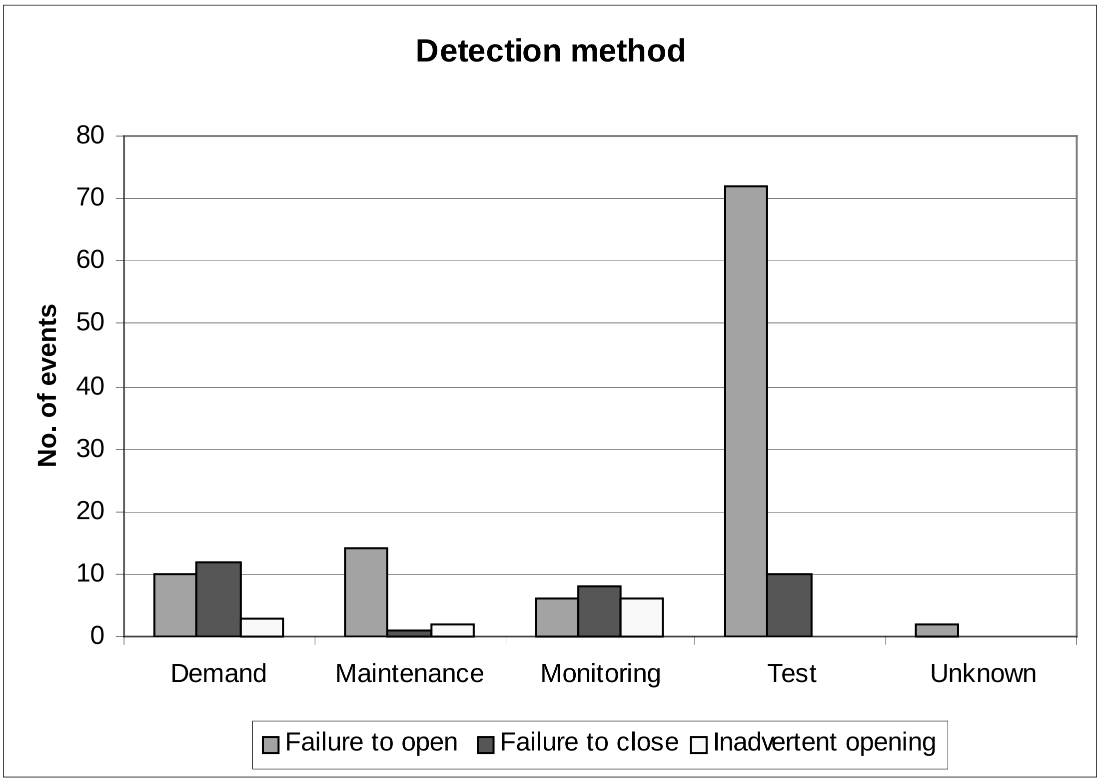

Figure 6-4 Detection method distribution by failure mode

7. ASSESSMENT OF THE COLLECTED DATA

7.1 Assessment Basis

One-hundred-forty-nine events are included in the assessment. The selected events are analysed with respect to failure symptoms and failure causes. Appropriate failure symptom categories and failure cause categories are identified. Additionally, technical fault aspects are examined.

Finally, the mapping of failure symptom categories onto failure cause categories is shown by an assessment matrix (table 7.5.1). This provides the basis for deriving insights and conclusions.

7.2 Failure Symptom Categories

Failure symptom categories are derived from the event descriptions. The following important failure symptom categories have been identified for the analysis:

B1 Valve or pilot valve movement is impeded by deposits of dirt, oxidation products, missing lubrication, bonding, damaged o-rings, etc. or valve is leaking due to disk/seat surface degradation.

B2 Valve does not open or close, or opens inadvertently or too slowly due to misalignment of switches, wrong manual valve setting, torque switch misadjustment, wrong set point, control equipment failure, etc.

B3 Valve or pilot valve movement is impeded by loose/broken/degraded screws, bolts, hinges, bushings, seals, degraded diaphragm, bent internals, etc.

B4 Others

7.3 Failure Cause Categories

Two principal groups of failure causes are introduced:

Deficiencies in operation

This group comprises all ICDE events that involve human errors, expressed by a human error related root cause, or a human error related coupling factor. Note that, following this definition, events with hardware related root causes are included in this group if human errors have created the conditions for multiple components to be affected by a shared cause, i.e. if the coupling factor is human error related. Three failure cause categories have been identified as being important in this group:

A1 Absence/insufficiency of testing/ re-qualification after repair/modification/back fitting.

A2 Deficient/incomplete procedures for testing/maintenance, insufficient work controls.

A3 Human performance error during maintenance/testing

Deficiencies in design, construction, manufacturing

This group comprises all events with hardware related root cause and hardware related coupling factor. Thus, an event is only included, for example, in category D (design deficiency) if the root cause is coded as "design", combined with any hardware related coupling factor, or if the coupling factor is coded as "hardware design" or "system design", combined with any hardware related root cause. Two failure cause categories have been defined for this group:

D1 Deficiencies are corrected by hardware related actions

D2 Deficiencies are corrected by procedure related actions

Two categories of hardware related failures, D1 and D2, are introduced because there are situations with no clear-cut borderline between human error aspects and hardware failure aspects. Specification of adequate maintenance procedures including maintenance intervals is part of the design of any technical component. If violation by the operator of such specifications causes a failure there clearly is human error involvement. If failures occur despite the observance by the operator of maintenance specifications the cause of such failures would be viewed as design error, because the influence of, for example, mechanical or chemical wear had been misjudged by the designer. Finally, there is the situation that a plant has been in operation for an extended period of time, like most of the plants included in the ICDE data collection, but the operator has failed to adapt maintenance procedures to operating experience that suggests more stringent standards. Events falling in the categories "Deficiencies in design, construction, maintenance", but with procedure related corrective actions could have resulted from such situations. Unfortunately, most event descriptions do not provide sufficient detail to definitively conclude whether these events should be assigned to the category "Deficiencies in operation", or to category "Deficiencies in design, construction, maintenance", as presently done.

7.4 Technical Fault Aspects

The main technical faults are identified, their significance to the dominant failure symptom/failure cause combinations is shown in the assessment matrix.

7.5 Assessment matrix

The matrix "Relationship among failure symptoms and failure cause categories" shown by table 7.5.1 forms the basis for interpreting the collected data.

The failure symptom categories as defined in section 7.2 are assigned to the columns of the matrix, the failure cause categories as defined in section 7.3 are assigned to the rows of the matrix.

The matrix entries show the number of ICDE events having been reported for each of the failure symptom/failure cause combinations. Additionally, technical fault aspects are addressed by showing *(in italic print)* the contributions of significant technical faults to the dominant failure symptom/failure cause combinations.

Table 7.5.1 Relationship of failure symptoms/failure cause categories, SRVs.

	Failure symptoms				
Failure cause categories	B1 Valve or pilot valve movement is impeded by deposits of dirt, oxidation products, missing lubrication, bonding, damaged o-rings, etc. or valve is leaking due to disk/seat surface degradation.	B2 Valve does not open or close, or opens inadvertently or too slowly due to misalignment of switches, wrong manual valve setting, torque switch misadjustment, wrong setpoint, control equipment failure, etc.	B3 Valve or pilot valve movement is impeded by loose/broken/ degraded screws, bolts, hinges, bushings, seals, degraded diaphragm, bent internals, etc.	B4 others	Total
Deficiencies in operation	11	72	9	1	93
A1 Absence/insufficiency of testing/ re-qualification after repair/modification/backfitting	-	4	2	-	6
A2 Deficient/incomplete procedures for testing/maintenance, insufficient work control	11 *mech. Wear: 10*	61 *control circuit failure: 19* *mech. misadjustment: 17* *mech. wear: 11*	2	1	75
A3 Human performance error during maintenance/test		7	5		12
Deficiencies in design , manufacturing, construction	20	22	13	1	56
D1 Hardware related "corrective actions taken"	9 *mech. Wear: 4* *unsuited parameter of medium: 5*	*10* *mech. wear: 3* *control circuit failure: 3*	7	1	27
D2 Procedure related "corrective actions taken"	11 *mech. Wear: 6*	*12* *mech. wear: 6* *control circuit failure: 2*	6	-	29
Total	31	94	22	2	149

7.6 Statistics of complete CCFs

Table 7.6.1 presents the statistics of the reported complete CCFs (complete failure of all components of a redundant system), identifying the degree of redundancy of the affected system as well as the event scenarios.

Table 7.6.1 Scenarios for complete CCFs of SRVs

Failure cause category	**Complete CCFs**					
	CC	CCC	CCCC	8-fold	10-fold	all
Deficiencies in operation						
A1 Absence/insufficiency of testing/ re-qualification after repair/modification/backfitting	1					**1**
A2 Deficient/incomplete procedures for testing/maintenance, insufficient work control	-	-			1	**1**
A3 Human performance error during maintenance/test	2	1		1		**4**
Deficiencies in design and/or construction						
D1 Hardware related "corrective actions taken"	2		1			**3**
D2 Procedure related "corrective actions taken"	4	1				**5**
Total	**9**	**2**	**1**	**1**	**1**	**14**

8. SUMMARY

One-hundred-forty-nine ICDE events reported in the SRV data collection are included in the evaluation. The following observations are made:

8.1 Dominant failure symptom categories.

B2 "Valve does not open or close, or opens inadvertently or too slowly due to misalignment of switches, wrong manual valve setting, torque switch misadjustment, wrong setpoint, control equipment failure, etc." accounts for 63% of the failure symptom categories.

B1 "Valve or pilot valve movement is impeded by deposits of dirt, oxidation products, missing lubrication, bonding, damaged o-rings, etc. or valve is leaking due to disk/seat surface degradation" accounts for 21% of the failure symptom categories.

B3 "Valve or pilot valve movement is impeded by loose/broken/degraded screws, bolts, hinges, bushings, seals, degraded diaphragm, bent internals, etc." accounts for 15% of the failure symptom categories

8.2 Dominant failure cause categories.

A2 Deficient/incomplete procedures for testing/maintenance, insufficient work control account for 50% of the failure cause categories.

D2 Deficiencies in design, construction, manufacturing corrected by procedure related actions account for 20% of the failure cause categories.

D1 Deficiencies in design, construction, manufacturing corrected by hardware related actions account for 18% of the failure cause categories.

A3 Human performance errors during maintenance/testing account for 8% of the failure cause categories.

8.3 Human error involvement

Human error involvement is high: "Deficiencies in operation", accounts for 62.4 % of the failure cause categories. For all events reported in these categories improvements or additions to procedures, mostly for testing and maintenance, have been taken by the licensees.

For Failure cause category D2 (19.4 %) procedure related corrective actions have been taken, suggesting that the licensees believed that recurrence of the reported events could best be made more unlikely by improved procedures.

This leaves only 18.1 % of the events as being caused by hardware problems and being corrected by hardware measures.

8.4 Technical fault aspects

Mechanical wear (35%) missing control signals (18%) and incorrect mechanical adjustment of valve mechanism (15%) are dominant.

It appears that a significant portion of these three technical faults could have been avoided by better test/maintenance strategies.

8.5 Complete CCF events

There are 14 complete CCF events (9% of the of the included 149 events).

Five complete CCF events evidently involve human error, 5 more are suspected to also involve human influence, as the licensee chose changes to test/maintenance procedures as corrective action (presumably shorter test or maintenance intervals).

Only 3 complete CCF events are purely hardware related.

The number of reported complete CCF events decreases strongly with increasing degree of redundancy of the systems.

8.6 Conclusions

For 82% of the ICDE events and 78% of the complete CCFs the potential exists for reduction of their occurrence rate by improving procedures and operator training.

Better indications in the control room and unambiguous local identification of valves could also help to reduce the occurrence rate of ICDE events.

9. REFERENCES

1. OECD/NEA's web site: http://www.nea.fr. ICDE project documentation, 1995-1998.

2. ICDE Coding Guidelines (NEA/SEN/SIN/WG1(98)3).

3. Marshall, F. M., D. M. Rasmuson, and A. Mosleh, 1998. *Common Cause Failure Data Collection and Analysis System, Volume 1—Overview*, U.S. Nuclear Regulatory Commission, NUREG/CR-6268, INEEL/EXT-97-00696, June.