ICDE Project – Brief presentation of an international collaboration on collecting and analysing CCF events

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ABSTRACT: This paper presents a summary of the International Common Cause Data Exchange project (ICDE), which is operating under the umbrella of the OECD/NEA. This project was established to encourage multilateral co-operation in the collection and analysis of data relating to common cause failure (CCF) events. IRSN and GRS actively take part in this project since its beginning and support it substantially. The ICDE operates with a clear separation of the collection and analysis activities. In the first stage of the project, emphasis has been put on the collection activities. The data collection and qualitative analysis result in qualitative CCF information that can be used for the assessment of the effectiveness of defences against CCF events and of the importance of CCF events in the PSA framework. The qualitative insights on CCF events generated by the task force are made available to CSNI countries through external reporting. Up to now, data analysis and exchange have been performed for Centrifugal Pumps, Diesel Generators, Motor-operated Valves, Safety Relief Valves, Check Valves and Batteries. Final reports for Centrifugal Pumps, Diesel Generators, Motor-operated valves and Safety Relief Valves have been published. The information presented in this paper is property of countries participating in ICDE project. Members' countries participating are: Canada (CNSC), Finland (STUK), France (IRSN), Germany (GRS), Japan (NUPEC), Korea (KAERI), Spain (CSN), Sweden (SKI), Switzerland (HSK), United Kingdom (NII), United States (NRC).

1 INTRODUCTION

Common-cause-failure (CCF) events can significantly impact the availability of safety systems of nuclear power plants. In recognition of this, CCF data are systematically collected and analysed in several countries. A serious obstacle to the use of national qualitative and quantitative data collections by other countries is that the criteria and interpretations applied in the collection and analysis of events and data differ among the various countries. A further impediment is that descriptions of reported events and their root causes and coupling factors, which are important to the assessment of the events, are usually written in the native language of the countries where the events were observed.

To overcome these obstacles, the preparation for the international common-cause data exchange (ICDE) project was initiated in August of 1994. Since April 1998, the OECD/NEA has formally operated the project under the coordination of the Committee on the Safety of Nuclear Installations (CSNI). The Phase II with an agreement period covered years 2000-2002 and phase III cover the period 2002-2005.

This paper is based on a draft of the general presentation of ICDE project, which was initially prepared by Clearinghouse and the OCDE/NEA Secretariat Mr. P. PYY.

2 OBJECTIVE AND SCOPE

The objective with the ICDE activity is to provide a framework for a multinational co-operation:

- to collect and analyze CCF events over 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 in connection with CCF phenomena, including the development of defenses against their occurrence, such as indicators for risk based inspections; and
- to record event attributes to facilitate quantification of CCF frequencies when so decided by the Project Working Group.

The ICDE operates with a clear separation of the collection and analysis activities. In the first stage of the project, emphasis has been put on the collection activities. The data collection and qualitative analysis result in qualitative CCF information that can be used for the assessment of the effectiveness of defences against CCF events and of the importance of CCF events in the PSA framework. The qualitative insights on CCF events generated by the task force are being made available to CSNI countries through external reporting.

Signatory countries can use the information content in the database to generate their own quantitative CCF parameters. An international co-operation for quantification of CCFs may be separately established in future, if the participating organisations wish to do so.

3 ICDE ORGANISATION

The ICDE Steering Group (SG) controls the project and their responsibilities include the following types of decisions: secure the financial (approval of budget and accounts) and technical resources necessary to carry out the project, nominate the ICDE project chairman, define the information flow (public information and confidentiality), approve the admittance of new members, nominate project task leaders (lead countries) and key persons for the Steering Group tasks, define the priority of the task activities, monitor the development of the project and task activities, monitor the work of the clearinghouse and quality assurance and prepare the legal agreement for project operation. The SG meets twice a year on average.

In most countries the data exchange is carried out through the regulatory bodies, with the possibility to delegate it to other organisations. The ICDE database is available for signatory organisations. The only possibility to get access to the working material is to actively take part in the data exchange.

Member countries, which form the Steering Group under the Phase III Agreement of OECD/NEA and the organisations representing them in the project, are: Canada (CNSC), Finland (STUK), France (IRSN), Germany (GRS), Japan (NUPEC), Korea (KAERI), Spain (CSN), Sweden (SKI), Switzerland (HSK), United Kingdom (NII), United States (NRC).

The steering group is assisted by the OECD/NEA project secretary and the Clearinghouse. OECD/NEA is responsible for administering the project according to OECD rules. This means secretarial and administrative services in connection with the funding of the Project such as calling for contributions, paying expenses incurred in connection with the Clearing House and keeping the financial accounts of the Project. The Clearinghouse is responsible for the database and consistency analysis in particular the Clearinghouse verifies whether the information provided by the national co-ordinators complies with the ICDE Coding Guidelines. It also verifies the correctness of the data included in the database jointly with the national co-ordinator who has provided such data. In addition the Clearinghouse operates the databank.

Project Quality Assurance: The responsibilities of participants in technical work, document control and quality assurance procedures as well as all other matters dealing with work procedures are described in the ICDE Quality Assurance Programme.

4 TECHNICAL SCOPE OF THE ICDE ACTIVITIES

It is intended to include in ICDE the key components of the main safety systems. The data collection and qualitative analysis shall result in quality assured data recorded in databases with consistency verification performed within the project. The ICDE activity defines the formats for collection of CCF event experience in a quality assured and consistent database. This task includes the development of a set of coding guidelines describing the methods and documentation requirements necessary for the development of the ICDE databases.

In the context of the ICDE data collection it is envisaged to collect all possible events of interest, including both complete and potential CCF events. To include all events of interest an “ICDE event” is defined as follows: “Impairment of two or more components (with respect to performing a specific function) that exists over a relevant time interval and is the direct result of a shared cause.

Possible attributes of impairment are: complete failure of the component to perform its function, degraded ability of the component to perform its function and incipient failure of the component. The relevant time interval is defined as two pertinent inspection periods (for the particular impairment) or, if unknown, a scheduled outage period.

The ICDE Steering Group prepares publicly available reports containing insights and conclusions from the analysis performed whenever major steps of the Project have been completed. The ICDE Steering Group assists the appointed lead person in reviewing the Project report. Otherwise the work follows the quality assurance plans and external review is provided by CSNI/WGOE and CSNI in sequence.

5 DATA COLLECTION GUIDELINES

Data collection guidelines (Refs. 1 and 2) have been developed during the project and are continually revised. They describe the methods and documentation requirements necessary for the development of the ICDE databases and reports. The format for data collection is described in the generic coding guideline and in the component specific guidelines. Component specific guidelines are developed, for all analysed component types as the ICDE plans evolve, defining: the observed population to be used for the collection, the common cause component group (CCCG), component boundaries etc. The documentation consists of Descriptions, Format, Agreements, Definitions, Directory, Guides, Codes, Procedures etc.

6 SYNTHESIS OF DATA COLLECTED

Data analysis and exchange have been performed for Centrifugal Pumps, Diesel Generators, Motor-operated Valves, Safety Relief Valves, Check Valves and Batteries. The breakdown into the various components is shown in Table 1. Special emphasis is given on CCF events in which each component fails completely due to the same cause and within a short time interval. These events are called “Complete CCF”.

Table 1 : Number of reported ICDE events and ICDE events with complete CCF

Component	ICDE events	ICDE events with complete CCF
Centrifugal pumps	125	19
Emergency diesel generators	106	17
Motor operated valves	86	5
Safety and relief valves	149	14
Check valves	94	7
Total	560	62

The database contains general information about event attributes like root cause, coupling factor, detection method and corrective action taken.
The working group, consisting of the members of the Steering Group and Specialists in CCF analysis, presents qualitative insights on CCF events in its external reporting. The ICDE prepares reports containing conclusions on the analysis performed whenever major steps of the Project have been completed. The ICDE Steering group assists the appointed lead persons in reviewing the Project reports.
Final reports for Centrifugal Pumps, Diesel Generators, Motor Operated Valves and Safety Relief Valves have been published. IRSN and GRS jointly took the lead for preparing the report about Motor Operated Valves. The following paragraphs provide a brief overview on major insights from qualitative analysis of the ICDE database.

6.1 Collection and Analysis of Common-cause Failures of Centrifugal Pumps

This study examined 125 events in the International CCF Data Exchange (ICDE) database (Ref 3). Organisations from Finland, France, Germany, Sweden, Switzerland and the United States have contributed data to this first data exchange. 125 ICDE events, among them 19 with complete CCF, were reported from 84 plants (60 PWR plants and 24 BWR plants).
The table 2 provides statistical summaries of several important characteristics of the received data. Classification of root causes, coupling factors and corrective actions for events with complete failure showed following distributions:

- root causes: 70% human actions and procedural deficiencies, 20% hardware related,
- coupling factors : 66% operational, 33% hardware related,
- corrective actions taken: more than 70% administrative/procedure controls, maintenance, operation and testing practices.

Most of the events leading to complete failure involve human error; they could be corrected by better procedures and control/maintenance practices.

Table 2 : Summary statistics of centrifugal pump data

Event reports received	Affecting group size				Total
	2	3	4	others	
ICDE events	40	29	41	15	125
Failure to run	24	15	25	7	71
Failure to start	16	14	16	8	54
Stand-by systems	39	17	15	-	71
Operational systems, also intermittent	1	12	26	15	54
Complete CCFs[1]	14	3	2	-	19
Failure to run	4	-	1	-	5
Failure to start	10	3	1	-	14
Stand-by systems	14	1	1	-	16
Operational systems, also intermittent	-	2	1	-	3
Common-cause component group records[2]	396	163	171	63	793

6.2 Collection and Analysis of Common-Cause Failures of Emergency Diesel Generators (EDG)

This study examined 106 events in the International CCF Data Exchange database by tabulating the data and observing trends (Ref. 4). Once trends were identified, individual events were reviewed for insights.

CCF data for the EDG component have been collected. Organisations from Finland, France, Germany, Sweden, Switzerland, United Kingdom and the United States contributed data to this data exchange. Events were reported from pressurized water reactors, boiling water reactors, Magnox, and AGR. Table 3 summarises, by failure mode, the EDG CCF events used in this study. In this table a subclass of non-complete CCF is introduced as “almost-complete” CCF events. Examples of events that would be termed *almost-complete* are those events in which all but one of the components are completely failed and one component is degraded, all components are completely failed but the time between failures is greater than an inspection interval.

Table 3 : Summary statistics of emergency diesel generator data.

Event reports received	Total	Degree of Failure Observed	
		Almost-Complete	Complete
ICDE events failure modes			
Failure to run	61	10	5
Failure to start	45	11	12
Total	106	21	17

The largest set of *complete* failures (62 percent) occurs in the fail-to-start group.

The most likely root cause is design, manufacture, or construction inadequacy (43 percent). Most of the *complete* design faults are in the instrumentation and control subsystem, which contributes a significant portion of its CCFs to the fail-to-start mode. It should be noted that the design category

[1] All components of CCCGs completely failed

[2] Number of sets of CCCGs (CCCG is a set of identical components in a system, performing the same function)

includes events that were faults of the initial design as well as modifications made subsequent to the original installation. These are powerful mechanisms to introduce CCF to a piece of equipment.
Hardware is the dominant coupling factor (55 percent) and design modification is the most common possible corrective action (26 percent). These are consistent with design being the dominant root cause.
The instrumentation and control subsystem is especially vulnerable to CCF from the human factor, due to the complexity and the function of instrumentation and control. Procedures, maintenance, and operations all contribute to this root cause.
The distribution of CCF events by the CCCG size of the event indicates that the largest contributors are from CCCG sizes two and four. These are consistent with the distribution of the installed CCCGs. Over 70 percent of *complete* CCF events are in CCCG size two systems.
Testing is the primary way to detect CCF failures. The most common failure detected by inspection is leakage of a minor nature.
Cooling, engine, and fuel oil are most likely to result in fail-to-run. Instrumentation and control, output breaker, and starting are most likely to result in a fail-to-start. This does not shift significantly between all CCFs and *complete* CCFs. Cooling and engine become much less significant and the instrumentation and control and fuel oil become much more significant. The instrumentation and control contribution is consistent with the nature of that system since it controls the shutdown and control of the EDG. Therefore, small errors can propagate into *complete* failures of the EDG component. This subsystem has experienced many design modifications.

6.3 Collection and Analysis of Common-Cause Failures of Motor Operated Valves

This study examined 87 events in the International CCF Data Exchange (ICDE) database by tabulating the data and observing trends (Ref. 5). Once trends were identified, individual events were reviewed for insights.
CCF data for the MOV component have been collected. Organisations from Finland, France, Germany, Sweden, Switzerland and the United States contributed data to this data exchange. ICDE events were reported from pressurised water reactors and boiling water reactors.
Table 4 summarizes, by failure mode, the MOV 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. Due to the low number (5) of observed complete CCF events no further detailed statistical analysis of this particular subclass of ICDE events is done in this study. A further subclass of ICDE events are partial CCF events having at least two completely failed components, not including the complete CCF events. This subclass contains 19 events.
Regarding the coded failure modes, there seems to be no rigid borderline between “failure to close” and “internal leakage” events. Looking at the verbal event descriptions, some of the “failure to close” events might also have been coded as “internal leakage” events and vice versa.
Testing is the dominant mode for detecting common cause failures. The used term “test” summarized all kind of tests like tests during annual overhauls, tests during operation, and unscheduled tests.
The report contains a further grouping according to a decision tree that shows the distribution of the same events further refined by kind of human and technical failures. The analysis shows that more than 50 % of the events could be assigned either to human error categories or to technical fault categories. For about 30% of the events, both human errors and technical faults have been identified.
There are errors in design calculations that caused false stroke forces. Wear is another widespread effect. The subcomponent “limit switch” caused also a substantial amount of CCF. Locking out failures during maintenance actions were also conspicuous. Selection of unsuited service media (mostly lubricants), the selection of improper materials, and assembly faults was less significant.

Table 4 : Summary statistics of MOV data.

Event reports received	Total	Degree of Failure Observed	
		Partial	Complete
ICDE events failure modes			
Failure to open	38	11	3
Failure to close	34	7	1
External leakage	1	0	1
Internal leakage	9	0	0
No failure mode coded	4	1	0
Total	86	19	5

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

CCF data for safety and relief valves have been collected by organisations from Finland, France, Germany, Sweden, Spain, United Kingdom and the United States (Ref. 6). One hundred forty nine (149) ICDE events were reported from pressurized water reactors, boiling water reactors, Magnox, and AGR. Table 5 summarises, by failure mode, the SV/RV ICDE events used in this study.

Table 5 : Summary statistics of SRV data

Event reports received	Total	Degree of Failure Observed
		Complete
ICDE events failure modes		
Failure to open	104	11
Failure to close	31	3
Inadvertent opening	11	0
Other	3	0
Total	149	14

There are 14 complete CCF events (9% 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. 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.

6.5 Collection and Analysis of Common-Cause Failures of Check Valves

This study examines 94 check valves (CV) events reported in the ICDE database by tabulating the data and observing trends (Ref. 7). As part of this study, most of these events were reviewed in more detail and characterized by failure cause and failure symptom categories.

Table 6 summarizes, by failure mode and degree of failure, the reported ICDE events. Seven of the reported ICDE events are complete CCF events. A further subclass of ICDE events are partial CCF events having at least two components completely failed, not including the complete CCF events. In comparison to the number of the complete CCF events the number of partial CCF events is more than three times higher. From Table 6 it is obvious that the most common failure mode of CVs is “failure to close”. This result is in line with the experience gained from the assessment of independent failures of CVs.

The remaining sixty-four ICDE events are CCF events in which less than two components failed completely. All other components of the observed group have the impairment attribute “degraded ability” or “incipient failure” or were not affected. However more than 75% of the ICDE events are assigned to the shared cause factor category “high”.

Table 6 : Summary statistics of CV data

Event reports received	Total	Degree observed of Failure	
		Partial	Complete
ICDE events failure modes			
Failure to Open	17	11	2
Failure to Close	36	11	5
External Leaking	4	0	0
Failure to Remain Closed/Internal Leaking	35	1	0
No proper interpretation	2	0	0
Total	94	23	7

88 of the 94 reported ICDE events were reviewed in some more detail with respect to failure causes, failure symptoms and failure mechanism. All events classified with a low “shared cause factor” were screened out.

The most common failure mode of CVs is “failure to close” (includes internal leaking). Deficiencies in operation are responsible for about 50% of the failure causes, mainly due to “deficient maintenance procedures”. In several cases test and maintenance intervals were too long, preventing detection of the failure mechanism in time. The other 50% of failure causes are design, construction, manufacturing deficiencies, mainly due to “deficiencies in design of hardware”.

Two failure symptoms have been identified to be dominant; valve movement impeded by deposition of dirt or oxidation products and valve leakage due to disk/seat surface degradation. Other failure symptoms are disk/seat misalignment and problems with loose or broken piece parts. The dominant failure mechanism are mechanical wear, (in particular disk/seat surface degradation causing the valve to leak), and chemical wear (in particular corrosion products impeding valve movement).

6.6 Generic Insights from Data Collected in the ICDE Project

Main causes for complete CCF and principal scenarios of complete CCF events

ICDE events are categorised in the two categories (1) operation related human error involvement and (2) design, manufacturing and construction deficiencies.
Operations related human error involvement means that the failure is either

- Caused by human actions, maintenance or procedural problems as described by the root cause
- Or that the influences that created the conditions for multiple components to be failed result from maintenance or operations procedure deficiencies, as described by the coupling factor.

Table 7 presents the summary of complete CCFs with operation related human error involvement and their principal failure cause categories.
The remaining design, manufacturing and construction related deficiencies are dominated by problems related to design of hardware. Manufacturing and construction related deficiencies are not significant in the presented statistics.

Table 7 : Summary of complete CCFs with operation related human error involvement and principal failure cause categories

Failure cause categories	Complete CCF				
	CC	CCC	CCCC	5-10 fold	All
absence/insufficiency of testing after maintenance/repair/backfitting work (mostly undetected misalignment)	5	3	2	1	11
operator error due to deficient/ incomplete procedures for testing/ maintenance, insufficient work control	15	2	6	1	24
operator error of commission (wrong valve manoeuvring, wrong switch/ breaker positioning)	5	2	1	1	9
total (second number: all complete CCFs)	25⊂ 39 (64%)	7⊂ 10 (70%)	9⊂ 10 (90%)	3⊂ 3 (100%)	44⊂ 62 (71%)

7 IRSN-GRS COOPERATION ON ICDE DATA BASE USES

Cooperation is under way between IRSN and GRS. Within this framework, a comparison between German and French approaches for collecting and processing data is envisaged. An initial action has been defined with regard to assessing the impact of common cause failures in relation to the probabilistic safety evaluation. This action consists in comparing French and German data processing taking a single case: common cause failure probabilities of diesel generators.

8 CONCLUSIONS

The analysis of the ICDE events provided a baseline set of parameters, which were subsequently re-arranged into groups representing important failure causes. Several high level findings are listed below:

- For complete CCFs the relative share of human error involvement increases with the number of redundant components, but the frequency of occurrence of complete CCF sharply decreases with the number of redundant components.
- In essence: the higher the degree of redundancy of a system, the more it takes human action to fail the system.
- High redundancy is an effective defence against *complete* CCF. However, complete CCF cannot be excluded by high redundancy.
- Deficiency and incompleteness of procedures together with insufficient work control prove to be the most prominent cause for complete CCF.
- During re-qualification: human errors and organisational problems like deficient documentation and communication are important causes for complete CCF. Valves and electrical equipment were identified as particularly vulnerable to re-qualification errors.
- Third in importance: operator errors of commission, i.e. the operator incorrectly applies a correct procedure.

Main areas for improvement

- Scrutinising existing operation, maintenance and testing procedures for deficiencies creating the potential for CCF of redundant systems.
- Ensuring comprehensive work control.
- Comprehensively prescribing the steps of testing required in the re-qualification of components or systems after maintenance, repair or backfitting work.
- Intensifying operator training, introducing ergonomically better designs, introducing more key locks.

9 REFERENCES

1. ICDE General Coding Guidelines. NEA/CSNI/R(2002)5
2. ICDE Project General Coding Guidelines and Component Coding Guidelines for Centrifugal pumps, Motor Operated Valves, Emergency Diesel Generators, Safety Valves/Relief Valves, Check Valves and Batteries. NEA/CSNI/R (Draft October 2002)
3. W. Werner, G. Johanson: NEA/CSNI/R(99)2 ICDE Project Report on Collection and Analysis of Common-cause Failure of Centrifugal Pumps, 2000-02-29.
4. T. E. Wierman, D. M. Rasmuson, F. M. Marshall: NEA/CSNI/R(2000)20 ICDE Project Report on Collection and Analysis of Emergency Diesel Generators. 2001-02-19
5. A. Kreuser, V. Schulze and J. Tirira: NEA/CSNI/R(2001)10 ICDE Project Report on Collection and Analysis of Common-Cause Failures of Motor Operated Valves, 2001-07-27
6. E. Jonsson, G. Johanson, J. Pesonen, K. Jänkälä, and W. Werner: NEA/CSNI/R(2002)19 ICDE Report on Collection and Analysis on Safety and Relief Valves, 2002-10-03
7. K. Theiss, Ph. Hessell and W. Werner: NEA/CSNI/R (Draft September 2002) ICDE Project Report on Collection and Analysis of Common-Cause Failures of Check Valves. Final draft to be issued as CSNI report in 2003