Nuclear Engineering and Technology 49 (2017) 327—334

Available online at ScienceDirect

Nuclear Engineering and Technology

journal homepage: www.elsevier.com/locate/net

Original Article

Recent Insights from the International Common-Cause Failure Data Exchange Project

Albert Kreuser [a] *and Gunnar Johanson* [b,*]

[a] *Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH, Schwertnergasse 1, 50667, Cologne, Germany*
[b] *ÅF Industry, Frosundaleden 2, 16999, Stockholm, Sweden*

ARTICLE INFO

Article history:
Received 16 December 2016
Received in revised form
16 January 2017
Accepted 16 January 2017
Available online 9 February 2017

Keywords:
ICDE
OECD/NEA
CCF
PSA
Experience feedback

ABSTRACT

Common-cause failure (CCF) events can significantly impact the availability of safety systems of nuclear power plants. For this reason, the International Common Cause Data Exchange (ICDE) project was initiated by several countries in 1994. Since 1997 it has been operated within the Organisation for Economic Co-operation and Development (OECD)/ Nuclear Energy Agency (NEA) framework and has successfully been operated over six consecutive terms (the current term being 2015–2017). The ICDE project allows multiple countries to collaborate and exchange CCF data to enhance the quality of risk analyses, which include CCF modeling. As CCF events are typically rare, most countries do not experience enough CCF events to perform meaningful analyses. Data combined from several countries, however, have yielded sufficient data for more rigorous analyses. The ICDE project has meanwhile published 11 reports on the collection and analysis of CCF events of specific component types (centrifugal pumps, emergency diesel generators, motor operated valves, safety and relief valves, check valves, circuit breakers, level measurement, control rod drive assemblies, and heat exchangers) and two topical reports. This paper presents recent activities and lessons learnt from the data collection and the results of topical analysis on emergency diesel generator CCF impacting entire exposed population.

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 being collected and analyzed in most countries. A serious obstacle to the use of national qualitative and quantitative data collection by other countries is that the criteria and interpretations applied in the collection and analysis of events and data differ among 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 in which the events were observed.

To overcome these obstacles, preparation for the International Common Cause Data Exchange (ICDE) project was initiated in August 1994. Since April 1998, the OECD/NEA has formally operated the project. The current Phase VII has an

---

* *Corresponding author.*
E-mail address: gunnar.johanson@afconsult.com (G. Johanson).

http://dx.doi.org/10.1016/j.net.2017.01.012

agreement period that covers the years 2015–2018. The member countries under the Phase VII Agreement of OECD/NEA and the organizations representing them in the project are as follows: Canada (CNSC), Czech Republic (UJV), Finland (STUK), France (IRSN), Germany (GRS), Japan (NRA), Korea (KAERI), Spain (CSN), Sweden (SSM), Switzerland (ENSI), and the United States (NRC).

The objective of this paper is to provide generic information about ICDE activities and the lessons learnt from recent analysis of CCF events in the ICDE database.

2. ICDE objectives and operating structure

The objectives of the ICDE project (denoted later as the Project) are as follows: (1) to provide a framework for multinational co-operation; (2) to collect and analyze CCF events over a long term so as to better understand such events, their causes, and their prevention; (3) to generate qualitative insight into the root causes of CCF events, which can then be used to derive approaches or mechanisms for their prevention or for mitigation of their consequences; (4) to establish a mechanism for efficient gathering of feedback on experience gained in connection with CCF phenomena, including the development of defenses against the occurrence of such phenomena, such as indicators for risk-based inspections; and (5) to record event attributes to facilitate quantification of CCF frequencies when so decided by the member countries of the Project.

The ICDE Steering Group controls the Project with assistance from the NEA project secretary and the operating agent. The operating agent is responsible for the database and for consistency analysis. The NEA Secretariat is responsible for administering the project on behalf of the OECD.

Running an international project requires funding and consequently the participating countries yearly make an agreed ICDE contribution to the NEA for reimbursement of the costs of the operating agent and the OECD NEA Secretariat. In addition, each participant bears all other costs, such as those for data collection and national analysis, associated with participation in the Project. These costs are generally much higher than the costs of running the operating agent. Moreover, the in-kind principle is followed in the data exchange: each country gets the dataset corresponding to its own data sent to the operating agent. Thus, just participating and paying the fees does not lead to directly receiving any data without a member's own data collection and submittal effort.

The Steering Group meets twice a year on average. Its responsibilities include the following types of decisions: to secure the financial (by approval of budget and accounts) and technical resources necessary to carry out the project, to nominate the ICDE project chairman, to define the information flow (public information and confidentiality), to approve the accession of new members, to nominate project task leaders (lead countries) and key persons for the Steering Group tasks, to define the priority of the task activities, to monitor the development of the project and task activities, to monitor the work of the operating agent and quality assurance, and to prepare the 3-year legal agreement “terms and conditions” for project operation. ICDE experience indicates that such legal agreements completed by internal operating rules and summary presentations are vital prerequisites of mutual understanding and constitute a functioning framework for long-term internal co-operation with many countries involved.

Data collection and analysis have to be organized at the national level. In most countries, data exchange is carried out through regulatory bodies. They often delegate this to other organizations, since arriving at the information required by the ICDE requires access to plant maintenance data. That data are normally proprietary. Consequently, the ICDE database is available only to signatory organizations and is restricted by proprietary rights. The only way to obtain access to the working material is to actively take part in the data exchange.

OECD/NEA is responsible for administering the project according to OECD rules. This means secretarial and administrative services. Issuing publicly available ICDE reports, calling for member contributions/fees, paying expenses incurred in connection with operating agent activities, and keeping the financial accounts of the Project are examples of these activities. NEA appoints the project secretary from among its administrators.

To assure consistency of the data contributed by the national coordinators, the project operates through an operating agent. The operating agent verifies whether the information provided by members complies with the ICDE coding guidelines. Jointly with the national coordinators, it also verifies the correctness of the data included in the database. In addition, the operating agent operates, and develops if necessary, the ICDE databank. ÅF Industry (previously ES Konsult) in Sweden is currently running the operating agent.

3. Technical scope of ICDE activities

3.1. *ICDE operation*

The ICDE operates with a clear separation of the collection and analysis activities. The analysis results mostly in qualitative CCF information. This information may be used for the assessment of (1) the effectiveness of defenses against CCF events and (2) the importance of CCF events in the Probabilistic Safety Analysis (PSA) framework. Qualitative insights into CCF events generated are made public as Committee on Safety of Nuclear Installation (CSNI) reports. The member countries are free to use the data in their quantitative and PSA-related analyses.

It is intended to include in ICDE the key components of the main safety systems. The data collection and qualitative analysis result in a quality-assured database with consistency verification performed within the project. The responsibilities of participants in terms of technical work, document control, and quality assurance procedures, as well as in all other matters dealing with work procedures, are described in the special ICDE Quality Assurance Program and the ICDE operating procedures.

ICDE activity defines the formats for collection of CCF events in order to achieve a consistent database. This task includes the development and revision of a set of coding guidelines describing the classification, methods, and documentation requirements necessary for the ICDE database(s). Based on the generic guidelines, component-specific guidelines are developed for all analyzed component types as the Project progresses. These guidelines are made publicly available as a CSNI technical note [1].

3.2. *Definition of common-cause events*

A CCF event is 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.

ICDE data collection also includes potential CCF events, or ICDE events, that include impairment of two or more components (with respect to performing a specific function), which exists over a relevant time interval and is the direct result of a shared cause.

3.3. *ICDE reporting*

The ICDE Steering Group prepares publicly available reports containing insights and conclusions from the analysis performed whenever major steps (i.e., analysis of a dataset for a certain component type such as check valves) of the Project have been completed. The ICDE Steering Group assists the appointed lead person in reviewing the reports. Following this, an external review is provided by the NEA CSNI. ICDE reporting also includes submitting papers to suitable international conferences such as Probabilistic Safety Assessment & Management conference (PSAM) and PSA, and to journals. The intention is to make the lessons learnt known to the large nuclear safety audience.

The ICDE time schedules define the milestones of data collection tasks for each analyzed component group. The time schedule is reassessed and revised at each ICDE Steering Group meeting. The work starts with drafting the guidelines, getting comments, collecting trial data, approving the guidelines, carrying out data exchange, resolving the remaining problem cases, and reporting.

Generally, it takes between 1.5 years and 2 years from the first guideline draft to commence the data exchange itself. Furthermore, from that point it takes about 2–3 years for approving the final report. Thereafter, new exchange rounds (database updating) are possible.

The database contains general information about event attributes such as root cause, coupling factor, detection method, and corrective action taken. As for the current Phase VII (June 2016), data analysis and exchange have been performed for centrifugal pumps, emergency diesel generators (EDG), motor-operated valves (MOV), safety relief valves (SRV), check valves (ChV), batteries, level measurements, switching devices and circuit breakers, control rod drive assemblies (CRDA), and heat exchangers (Hx). In addition, first round data collection has been performed on fans and main steam isolation valves (MSIV), and has been started for digital instrumentation and control equipment (Digital I&C).

3.4. *Published ICDE component reports*

Public final reports for centrifugal pumps, diesel generators, motor-operated valves, safety and relief valves, check valves, batteries, level measurements, switching devices and circuit breakers, control rod drive assemblies, and heat exchangers have been issued in the NEA CSNI series [2–13] (see also: http://www.nea.fr/html/nsd/docs/indexcsni.html).

Guidelines for fans, main steam isolation valves, and digital instrumentation and control equipment have been approved; those for inverters and cross-component CCF (asymmetric faults) are almost finalized. In addition, an updated report on centrifugal pumps has been issued [11].

By June 2016, 1,421 ICDE events, i.e., events involving at least incipient common-cause characteristics, had been analyzed and reported. The total number of event records collected in the database for the analyzed component types is 1,742. The breakdown into the various components is shown in Table 1. Special emphasis is given to 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." The third column shows the numbers of events in which each redundant component failed completely due to the same cause and within a short time interval.

Table 1 – Number of ICDE events.

Component	No. of events in component report	No. of ICDE events with complete CCF in component report	No. of events in database (June 2016)	Data amount change since component report (%)
Centrifugal pumps	353^{i2} (125^{i1})	42^{i2} (19^{i1})	391	11
Diesels	224^{i3} (106^{i1})	23^{i2} (17^{i1})	229	2
MOVs	86	5	170	98
SRVs	149	14	271	82
Check valves	94	7	116	23
Batteries	50	3	77	54
Breakers	104	6	107	3
Level measurement	146	6	154	5
Heat exchangers	46	4	55	20
CRDA	169	—	172	2
MSIV	—	—	10	—
Fans	—	—	32	—
Digital I&C	—	—	4	—
Inverters	—	—	—	—
Cross-component CCF	—	—	—	—
Total	1,421	110	1,788	26%

CCF, common-cause failure; i1, Issue 1; i2, Issue 2; i3, Issue 2 ongoing, not published; ICDE, International Common Cause Data Exchange.

Events are further analyzed and categorized according to the ICDE failure analysis guidelines.

3.5. *ICDE data status*

ICDE observation overview across all ICDE components can be summarized by the following figures. Fig. 1 illustrates the overall ICDE observation by presenting the total number of events per year together with the total number of group years observed (per year). The participating countries are gradually extending the data with more observation time and events.

The frequency of observing an ICDE event in an observed population (CCF component group) is approximately 0.015/y (or <2E–6/h). This low frequency in itself justifies an international collaboration on this issue. Fig. 2 shows the data collection progress, i.e., when the data have been synchronized and exchanged, and how the database has been expanded with new components and data exchanges over the years.

4. Lessons learnt

Lessons learnt cover lessons about reporting of project results as well as technical insights from topical analysis of ICDE data. This experience has been collected in a failure analysis guide that is applied when a new component report is produced or if a new topical report is prepared. This section presents an overview of the guide and recent or ongoing applications.

4.1. *Failure analysis guideline*

When analyzing events, the approach to perform a failure analysis by examining failure mechanism categories, failure

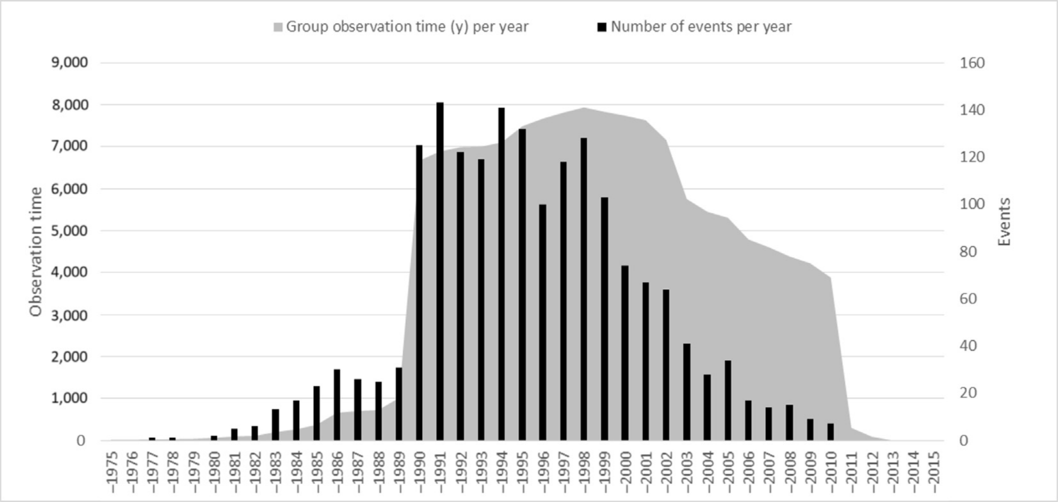

Fig. 1 – ICDE observation overview. ICDE, International Common Cause Data Exchange.

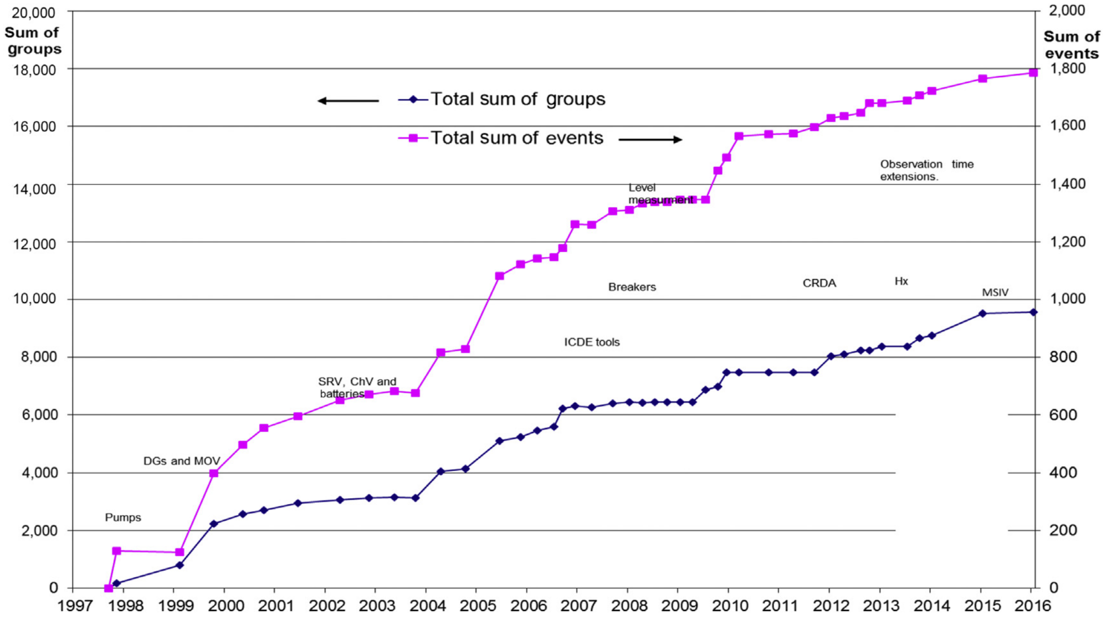

Fig. 2 – ICDE data collection progress. ICDE, International Common Cause Data Exchange.

mechanism subcategories, and failure cause categories, and their correlations, was proved to be very successful. Evaluations following this concept have revealed insights that would otherwise not have become evident. By incorporating failure analysis fields in the ICDE database, this assessment is as transparent as any other assessment being performed. The development of failure analysis provides the following: (1) appropriate transparency and reproducibility between component reports and the database. It is further expected that the opportunity to find new perspectives and to engage in new development of data analysis will increase as the database content is extended with failure analysis; (2) additional aspects when conducting workshops; and (3) detailed analyses of failure mechanisms that will provide valuable insights for improving defenses against the occurrence of CCF events.

An approach has been developed to perform failure analysis focused on failure mechanisms. Failure mechanisms should be considered as consequences of the failure cause. Therefore, the following steps should be performed in chronological order when performing a failure analysis. (1) Describe the failure mechanism in a few words. The failure mechanism is a history describing the observed events and influences leading to a given failure. Aspects of the failure mechanism could be deviation or degradation or a chain of consequences. (2) Specify the failure mechanism category. A failure mechanism category is a group of similar failure mechanism subcategories, e.g., for diesels, the failure mechanism category "engine damage or problems" has the following failure mechanism subcategories: (i) "Starting air or air supply valve/distributor damage" ; (ii) "(Potential) damage of rotating or stationary parts (bearings, crankcase, high pressure in crankcase, etc.)"; (iii) "Combustion chamber problems (e.g., cylinder, piston, fuel injection nozzle, and pump damage)"; (iv) "Coupling (between engine and generator) damage" (v) "Combustion/charging air problems (e.g., air intake and turbocharger damage)"; and (vi) "Other, for example, faulty operator actions or maintenance errors". (3) Specify the failure mechanism subcategory. Failure mechanism subcategories are coded component-type-specific observed faults or nonconformities that have led to an ICDE event. (4) Specify the failure cause category. Failure cause categories are potential deficiencies in operation or in design, construction, and manufacturing that made it possible for a CCF event to occur.

A list of the failure mechanism descriptions can be an easy, and yet efficient, way to summarize the type of failures for a certain scope of events.

4.2. *Topical reports*

Topical analyses have been performed or are under preparation for a number of topics: (1) External factors [14] (2015, 43 events); (2) Diesels all affected [15] (completed, to be published); (3) Plant modifications (ongoing, 54 events); (4) Improving testing (ongoing, 32 events); (5) Multi-unit events (ongoing, 99 multi-unit events); and (6) Pre-initiator human failure ICDE events (proposed for 2017).

In this paper, the recently completed topical analysis report on "diesels all affected" is discussed in detail, and the objectives and scope of the ongoing analysis is presented.

4.3. *Topical analysis on diesels all affected*

4.3.1. *Overview*

This topical analysis was completed in the ICDE steering group, and the report is to be published. The report summarizes the workshop results and presents an overview of the exchange of CCF data among several countries on diesel failures impacting entire exposed populations, the so-called "all affected" diesel failures. "All affected" diesel failures involve events in which all diesels in an exposed population failed or were degraded or showed an incipient impairment due the same cause.

The workshop format included the following types of questions. (1) If the event is not a complete CCF: (i) Can you identify any actual defenses that prevented all components from failing? and (ii) Can you identify any areas of improvement in order to prevent the event from happening again? (2) If the event is a complete CCF: Can you identify any possible defenses or areas of improvement that could have prevented all components from failing?

The most common answer to the question "what have or could have prevented all components from failing" was that the failure slowly developed over time and was therefore detected before all components failed. This indicates that there is a good chance that diesel failures can be detected "in time."

It was also established that specifying the failure mechanism was a good start in the analysis process. The failure mechanism describes the observed event and the influences leading to a given failure.

Table 2 is taken from the ICDE workshop report on diesels impacting entire exposed population, in which examples of concluded failure mechanisms for "complete CCF" are listed.

In addition, for a better general view, the mechanisms in the report were sorted by relevant mechanism groups (derived from the root cause codes).

The ICDE failure analysis guideline will be published as a new appendix in the coming update of the ICDE general coding guidelines.

4.3.2. *Areas of improvement and preventions for all effected events*

Six categories of improvement are defined in Table 3. The events were reviewed to determine where the improvement categories proposed in the workshop format could be applied. Each event could be assigned to multiple improvement categories. This resulted in 135 events with one selected category, 46 events with two to four selected categories, and seven events with no selected categories.

In Table 3, it can be seen that the most commonly assigned category was "maintenance or testing of component" (34%). Many of these events involve improper reinstallations or reassemblies after testing/maintenance. For example, in one event, the governors were incorrectly replaced after testing/maintenance.

Suitable prevention of this kind of failure would mean improved test/maintenance procedures, which would include checks after completion of test/maintenance. Approximately 15% of the events were concluded with this type of prevention.

Table 2 – Failure mechanism descriptions.

Failure mechanism examples for "complete CCFs"	Mechanism group
Cracks in numerous relay sockets were induced by vibrations in the EDG rooms, resulting in failure of diesel load control. Essential Service Water (ESW) strainers were deformed, allowing fish to plug ESW components External corrosion occurred on cooling pipes due to penetration of rain water because of a non-leak-proof EDG building. Lockout relay of both EDG output breakers were found sticking (not tripping when required). Mechanical fatigue caused pin rupture in pumps that provide fuel to diesels. Short circuits in 2 diodes in the rectifier bridge caused a protective fuse to blow, which caused the engine of the EDG to speed during a surveillance test.	Hardware
A repair work at a reactor protection system cubicle caused a spurious signal that started the EDGs. EDGs stopped when the signal disappeared. An erroneous test procedure led to the operator to lock the automatic start-up of both EDGs, which was not according to the technical specification requirements. An error in the test procedure led to not allowing the automatic start of EDG during tests of turbine-driven emergency power supply. Improper switch position—the inhibit keys for under voltage protection were in place & the sensor channels for both vital buses were bypassed. Incorrect installation of the flow control valves was due to procedural inadequacies, inattention to detail, & inadequate skills. Pollution of the air supply due to sandblasting outside the Diesel building	Human

Table 3 – Distribution of identified improvement categories.

Improvement category	No. of events	%
(1) Design of system or site	15	8.3
(2) Design of component	51	28.2
(3) Surveillance of component	15	8.3
(4) Maintenance or testing of component	61	33.7
(5) Operation of component	10	5.5
(6) Management system of plant	29	16.0
Total	181	100.0

Within this improvement category, the following additional noteworthy insights have been established: (1) when planning maintenance activities and procedures, the function of ancillary equipment has to be taken into account; (2) for events that include clogging of oil filters, one preventive action could be to add "oil filter nonclogging verification" to the periodic test procedure, which consists of pressure drop measurement; (3) increased redundancy of the level measurements in diesel fuel tanks combined with staggered testing can detect LM failures such as miscalibration; and (4) the improvement category "design of component" was common among the events (28%). Improper design of different piece parts such as cooling pipes, three-way valves (gap rod/valve), and exhaust damper linkage seems to be a problem for many events.

Among the 29 events (16%) that were assigned to the "management system of plant," improved quality assurance of the vendor was pointed out several times. Regarding one event, better instructions about the screwing torque of lock-nuts for the three-way valve from the manufacturer would have prevented the event from happening (the lock-nut was not tightened enough). This implies that not only "QA of vendor" involves quality assurance of the actual product, but also the product information delivered together with the product must be sufficient.

Examples of events assigned to the category "design of system or site" are, accordingly, design errors such as corrosion in cooling pipes due to penetration of rain water because of a non-leak-proof EDG building or an inadequately vibration-tolerant design leading to cracks in the cooling system. Regarding building design, it is important to implement state-of-the-art practices to handle possible weather phenomena such as rain water.

One example of an event assigned to the category "surveillance of component" is a blockage in heat exchanger tubes (primarily corrosion nodules) and unusually high oil consumption, which led to low oil level and stopping of the engine. Monitoring the flow in cooling pipes, oil consumption, and also diesel fuel supply can be appropriate steps of improvements for these types of events. However, with an increasing number of monitors and alarms in the control room, the risk of overlooking important alarms should be considered.

One example of an event assigned to the category "operation of component" is overheating of diesel due to dirt deposition on the heat exchanger due to a high iron content of well water. In the concerned plant, it is possible to use river or well water depending on circumstances, and, with regard to this event, operation with river water could have prevented the event from happening. One lesson learnt from this event is that controlling the water chemistry of the cooling water is important.

The most common answer (23%) to the question "what prevented, or could have prevented, all components from failing" was that failure slowly developed over time and was therefore detected before all components failed.

For one event (welding within another room activated the fire suppression system in the common basement under the diesel rooms in which cables are installed), it was concluded that consequent spatial separation of redundancies, including ancillary equipment (cables in this case), would have resulted in a less substantial event. Another preventive action for the same event would have been to seal possible fume transfer routes (wall penetrations) during maintenance activities.

Another noteworthy comment is that only one event was concluded as “nothing happened because the problem was detected by failure in another unit at the same site.” This indicates the importance of informing other units and plants when an event has occurred, as a preventive action.

Twenty-five percent of the events were left without any answer to this workshop question.

4.4. *Ongoing topical analyses*

4.4.1. *Plant modifications (ongoing, 54 events)*

The objective is to study events in which failures occurred due to modifications in systems, components, or procedures.

The selected CCF events are of a wide variety but have one common denominator, i.e., modification. The types of modifications of interest were design modifications of components and systems, modification of settings, backfitting of components with new or modified designs, and replacement of components with those of identical design. In addition, events that occurred due to modified test procedures are included.

4.4.2. *Improving testing (ongoing, 32 events)*

The objective is to study events in which no fault state or impairment could be detected in normal recurrent tests because the scope of the tests was insufficient or no appropriate tests existed.

The aim is to find recommendations on how to improve testing to reduce detection times and the risk of events occurring.

The aspects of inadequacy in the testing procedures concern the following: (1) lack of appropriate testing procedures; (2) validity and extent of tests (e.g., include all operating modes and emergency conditions); (3) updating testing procedures after modifications; (4) processes to ensure completeness and quality of tests (consistency between operating rules and maintenance tests); (5) use of adequate testing equipment; and (6) check of calibration instruments and settings.

4.4.3. *Multi-unit events, (ongoing, 99 multi-unit events)*

The objective is to study events that occurred at multiple plants at the same site, in which multi-unit dependency existed between the events.

Most of the events are site events occurring within 1 year. Moreover, eight of the multi-unit event groups are multisite events.

It is aimed at identifying actual defenses that prevented all components from failing, possible defenses to prevent events from happening again, and candidates for PSA site modeling.

Three event groups were assessed as candidates for PSA site modeling. The first candidate shared safety systems between two units. For this event, the system design, in combination with water passing a nonreturn valve, led to warming of the suction legs of both the emergency boiler feed pumps. The second candidate shared two diesels between two units. For this event, air was trapped in the governor compensation system, which caused vibrations and resulted in operation in a degraded state. The final candidate had multi-unit dependency through a shared connection, i.e., connected supply lines (same piping), and during maintenance activities, both trains of both units were affected.

4.4.4. *Pre-initiator human failure ICDE events (proposed for 2017)*

The goal of the workshop will be to review operational plant experience and possibly find defenses against human failure events (HFEs). Analysis for pre-initiator HFEs will include the following: (1) identify activities/actions resulting in dependent pre-initiator HFEs and (2) identify involved performance-shaping factors for the specific dependent pre-initiator HFEs.

5. Discussion

It can be said that the ICDE has changed the view of CCFs a great deal. For instance, determination of the fact that the most common cause of complete CCFs seems to be human action as a part of operation or design, rather than manufacturing deficiencies, would not have been possible without deep plant data collection and combination of information from many sources.

Maybe the most important generic lesson is that it is worth forming specialized data exchange projects such as ICDE. This, however, requires first the will of several countries to form a critical mass by combining their operating experience efforts; second, national efforts to collect lower-level data than those made publicly available as Licensing Event Reports or Incident Reporting System reports; third, the forming of a legal framework to protect this proprietary data; and, fourth, a long-term commitment to consistently continue and develop the activity.

OECD/NEA and ÅF industry, as the operating agent, have provided the means to run the international dimension of the ICDE; however, national efforts are the key to the success of any project that relies on operating experience. The success of the ICDE has given birth to several similar types of projects, among which are the CODAP for pipe failure events and the OECD-FIRE for nuclear power plant fire events.

More information about ICDE may be obtained by visiting the CSNI report site (http://home.nea.fr/html/nsd/docs/indexcsni.html) or the operating agent website (https://projectportal.afconsult.com/ProjectPortal/icde), or by contacting the responsible OECD administrator.

Conflicts of interest

The authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript

REFERENCES

[1] Nuclear Energy Agency Committee on the Safety of Nuclear Installations, ICDE General Coding Guidelines, NEA/CSNI/R(2004)4, Jan 2004.

[2] Nuclear Energy Agency Committee on the Safety of Nuclear Installations, Collection and Analysis of Common-cause Failure of Centrifugal Pumps, NEA/CSNI/R(99)2, Sep 1999.

[3] Nuclear Energy Agency Committee on the Safety of Nuclear Installations, Collection and Analysis of Common-cause Failure of Emergency Diesel Generators, NEA/CSNI/R(2000)20, May 2000.

[4] Nuclear Energy Agency Committee on the Safety of Nuclear Installations, Collection and Analysis of Common-cause Failure of Motor-operated Valves, NEA/CSNI/R(2001)10, Feb 2001.

[5] Nuclear Energy Agency Committee on the Safety of Nuclear Installations, Collection and Analysis of Common-cause Failure of Safety Valves and Relief Valves, NEA/CSNI/R(2002)19, Oct 2002.

[6] Nuclear Energy Agency Committee on the Safety of Nuclear Installations, Collection and Analysis of Common-cause Failure of Check Valves, NEA/CSNI/R(2003)15, Feb 2003.

[7] Nuclear Energy Agency Committee on the Safety of Nuclear Installations, Collection and Analysis of Common-cause Failure of Batteries, NEA/CSNI/R(2003)19, Sep 2003.

[8] Nuclear Energy Agency Committee on the Safety of Nuclear Installations, Proceedings of ICDE Workshop on the Qualitative and Quantitative Use of ICDE Data, NEA/CSNI/R(2001)8, Nov 2002.

[9] Nuclear Energy Agency Committee on the Safety of Nuclear Installations, Collection and Analysis of Common-cause Failure of Switching Devices and Circuit Breakers, NEA/CSNI/R(2008)01, Oct 2007.

[10] Nuclear Energy Agency Committee on the Safety of Nuclear Installations, Collection and Analysis of Common-cause Failure of Level Measurement Components, NEA/CSNI/R(2008)8, Jul 2008.

[11] Nuclear Energy Agency Committee on the Safety of Nuclear Installations, Collection and Analysis of Common-cause Failure of Centrifugal Pumps, NEA/CSNI/R(2013)2, Jun 2013.

[12] Nuclear Energy Agency Committee on the Safety of Nuclear Installations, Collection and Analysis of Common-cause Failure of Control Rod Drive Assemblies, NEA/CSNI/R(2013)4, Jun 2013.

[13] Nuclear Energy Agency Committee on the Safety of Nuclear Installations, Collection and Analysis of Common-cause Failure of Heat Exchangers, NEA/CSNI/R(2015)11, Aug 2015.

[14] Nuclear Energy Agency Committee on the Safety of Nuclear Installations, ICDE Workshop—Collection and Analysis of Common-cause Failures Due to External Factors, NEA/CSNI/R(2015)17, Oct 2015.

[15] Nuclear Energy Agency Committee on the Safety of Nuclear Installations, ICDE Workshop—Collection and Analysis of Emergency Diesel Generator Common-cause Failures Impacting Entire Exposed Population, NEA/CSNI/R(2017)8.