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Use of NEA Database Projects Operating Experience Data for Probabilistic Safety Assessment

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NUCLEAR ENERGY AGENCY
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

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Committee on the Safety of Nuclear Installations (CSNI)

The Committee on the Safety of Nuclear Installations (CSNI) addresses Nuclear Energy Agency (NEA) programmes and activities that support maintaining and advancing the scientific and technical knowledge base of the safety of nuclear installations.

The Committee constitutes a forum for the exchange of technical information and for collaboration between organisations, which can contribute, from their respective backgrounds in research, development and engineering, to its activities. It has regard to the exchange of information between member countries and safety R&D programmes of various sizes in order to keep all member countries involved in and abreast of developments in technical safety matters.

The Committee reviews the state of knowledge on important topics of nuclear safety science and techniques and of safety assessments, and ensures that operating experience is appropriately accounted for in its activities. It initiates and conducts programmes identified by these reviews and assessments in order to confirm safety, overcome discrepancies, develop improvements and reach consensus on technical issues of common interest. It promotes the co-ordination of work in different member countries that serve to maintain and enhance competence in nuclear safety matters, including the establishment of joint undertakings (e.g. joint research and data projects), and assists in the feedback of the results to participating organisations. The Committee ensures that valuable end-products of the technical reviews and analyses are provided to members in a timely manner, and made publicly available when appropriate, to support broader nuclear safety.

The Committee focuses primarily on the safety aspects of existing power reactors, other nuclear installations and new power reactors; it also considers the safety implications of scientific and technical developments of future reactor technologies and designs. Further, the scope for the Committee includes human and organisational research activities and technical developments that affect nuclear safety.

Foreword

The main challenge identified in the Committee on the Safety of Nuclear Installations (CSNI) and Committee on Nuclear Regulatory Activities (CNRA) joint Strategic Plan (NEA/CSNI/R[2011]1) is the safe operation of current, new and advanced nuclear facilities. As described in the Strategic Plan, this challenge is being addressed, in part, by utilising operating experience, research and analytical tools (such as the PSA). Accurate and complete operating experience data is needed to ensure that PSA results realistically represent as-built and as-operated nuclear power plants and provide useful and meaningful insights. In response to this challenge, and based on needs expressed by a number of member countries, in 2011 the Working Group on Risk Assessment (WGRISK) initiated a task to investigate the use of OECD database project products in PSAs. In 2017, a follow-on activity was started to address within a common workshop new developments in the following database projects with a direct connection to PSA:

- the International Common-cause Failure Data Exchange (ICDE) project;
- the Fire Incidents Record Exchange (FIRE) project;
- the Component Operational Experience, Degradation and Ageing Programme (CODAP) project.

These NEA database projects can, in principle, support the collection and analysis of data that is highly relevant to PSA, particularly in the areas of material degradation and ageing, common-cause failures, fire risk, and digital instrumentation and control systems. All of the projects collect qualitative information that can be useful in the development and review of PSA models. Moreover, several of these projects include specific objectives to support quantification activities.

The main objectives of this task were the following:

- Identification and characterisation of the current uses of NEA database project products and data in support of PSAs. In this context, the term “products” refers to data analysis results, technical reports and other project outputs.
- Identification and characterisation of technical and programmatic characteristics that either support or impede the use of products from the database projects in PSA. This includes an assessment of which PSA parameters could be potentially estimated from the various database project products and gaps between available product information and PSA data needs.
- Identification of recommendations for enhancing the usefulness of database project products and the co-ordination between WGRISK and the database projects.

This work represents the collective effort of the task group, whose participants all provided time and knowledge towards its production. The core task group for this WGRISK activity on the use of the NEA database products was comprised of representatives from the different WGRISK and database project member countries. The individuals listed in the table below represented their respective organisations and countries as members of the core task group, which was responsible for: 1) activity planning; 2) administration of task surveys, questionnaires and an international workshop; and 3) development of this final report. The NEA Secretariat wishes to thank these experts.

Name	**Organisation**	**Country**
Jovica Riznic (Chair of CODAP)	Canadian Nuclear Safety Commission (CNSC)	Canada
Benjamin Brück (Chair of ICDE)	Gesellschaft für Anlagen- und Reaktorsicherheit (GRS)	Germany
Marina Röwekamp (Task Leader and Chair of WGRISK and FIRE)	Gesellschaft für Anlagen- und Reaktorsicherheit (GRS)	Germany
Andreas Werner (Operating Agent of FIRE)	Safety Assessment Consulting (SAC)	Germany
Wolfgang Werner (Operating Agent of FIRE)	Safety Assessment Consulting (SAC)	Germany
Gunnar Johanson (Operating Agent of ICDE)	AFRY	Sweden
Bengt Lydell (Operating Agent of CODAP)	Sigma-Phase Inc.	United States

The NEA administrators responsible for this WGRISK activity were Markus Beilmann, Diego Escrig Forano, Olli Nevander and Andrew White.

This document was approved by the Committee on the Safety of Nuclear Installations (CSNI) at its 67th session on 4-5 June 2020 and prepared for publication by the NEA Secretariat.

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List of abbreviations and acronyms

ABWR	Advanced boiling water reactor
AGR	Advanced gas-cooled reactor
ANS	American Nuclear Society
ANVS	Autoriteit Nucleaire Veiligheid en Stralingsbescherming (Netherlands)
AP1000	Advanced power reactor 1 000 MWe
APR1400	Advanced power reactor 1 400 MWe
ASME	American Society of Mechanical Engineers
ASEP	Accident Sequence Evaluation Program
Bel V	Belgian TSO, part of the regulatory body FANC
BSL	Basic safety level
BSO	Basic safety objective
BWR	Boiling water reactor
CAPS	CSNI activity proposal sheet (NEA)
CCCG	Common cause component group
CCDP	Conditional core damage probability
CCF	Common-cause failure
CDF	Core damage frequency
CNID	Constrained non-informative distribution
CNRA	Committee on Nuclear Regulatory Activities (NEA)
CNSC	Canadian Nuclear Safety Commission
CODAP	Component Operational Experience, Degradation and Ageing Programme (NEA)
COG	CANDU owners group (Canada)
COMPSIS	Computer-based system important to safety (NEA)
CSN	Consejo de Seguridad Nuclear (Nuclear Safety Council, Spain)
CSNI	Committee on the Safety of Nuclear Installations (NEA)
DMA	Degradation mechanism analysis
EBS	Equivalent break size
EDF	Electricité de France
ENSI	Eidgenössisches Nuklearsicherheitsinspektorat (Swiss Federal Nuclear Safety Inspectorate)
EOP	Emergency operating procedures
EPR	European pressurised reactor or evolutionary power reactor

EPRI	Electric Power Research Institute (United States)
FANC	Federal Agency for Nuclear Control (Belgium)
FDF	Fuel damage frequency
FEDB	Fire events data base
FIRE	Fire Incidents Records Exchange (NEA)
FP	Full power
GDA	Generic design assessment
GRS	Gesellschaft für Anlagen- und Reaktorsicherheit (Germany)
HDPE	High-density polyethylene
HEAF	High energy arcing fault
HELB	High energy line break
HFE	Human failure events
HTGR	High-temperature gas-cooled reactors
IAEA	International Atomic Energy Agency
ICDE	International Common-cause Failure Data Exchange (NEA)
IDPSA	Integrated deterministic probabilistic safety assessment
IE	Initiating event
IF	Internal flooding
IGSCC	Intergranular stress corrosion cracking
INES	International nuclear event scale
INPO	Institute of Nuclear Power Operations
IPSART	International probabilistic safety assessment review team
IRS	Incident reporting system
IRSN	Institut de Radioprotection et de Sûreté Nucléaire (Institute for Radiological Protection and Nuclear Safety, France)
ISI	In-service inspection
I&C	Instrumentation and control
KAERI	Korea Atomic Energy Research Institute
KINS	Korea Institute of Nuclear Safety
LER	Licensee event report
LOCA	Loss of coolant accident
LOOP	Loss of offsite power
LPSD	Low power and shutdown
LTO	Long-term operation
LWR	Light water reactor
MB	Management Board

MCR	Main control room
MELB	Moderate-energy line break
MUPSA	Multi-Unit PSA
NC	National co-ordinator
NDE	Non-destructive examination
NEA	Nuclear Energy Agency
NRA	Nuclear Regulatory Authority (Japan)
OA	Operating agent
OE	Operating experience
OECD	Organisation for Economic Co-operation and Development
ONR	Office for Nuclear Regulation (United Kingdom)
OPDE	Piping failure data exchange
OPEX	Operating experience
PEO	Plant extended period of operation
PFM	Probabilistic fracture mechanics
PHWR	Pressurised heavy water reactors
POS	Plant operating state
PRA	Probabilistic risk assessment
PRG	Project review group
PSA	Probabilistic safety assessment
PRIME	Propagation d’un incendie pour des scénarios multi-locaux élémentaires (“fire propagation in elementary, multi-room scenarios”)
PSR	Periodic safety review
PWR	Pressurised water reactor
QHO	Quantitative health objective
QI	Quality index
RIDM	Risk-informed decision-making
RIM	Reliability and integrity management
RI-ISI	Risk-informed in-service inspection
RPVH	Reactor pressure vessel head
RR	Reactor recirculation
ry	Reactor year
R&D	Research and development
SAC	Safety assessment consulting
SAMGs	Severe accident management guidelines
SBO	Station blackout

SCAP	Stress corrosion cracking and cable ageing project
SD	Significance determination
SFP	Spent fuel pool
SQL	Structured query language
SSCs	Structures, systems and components
SSM	Swedish Radiation Safety Authority
STUK	Radiation and Nuclear Safety Authority (Finland)
TSO	Technical safety organisation
UHS	Ultimate heat sink
UJV Řež	Ústav Jaderného Výzkumu (Czechia)
USNRC	United States Nuclear Regulatory Commission
WGAMA	Working Group on Analysis and Management of Accidents (NEA)
WGEV	Working Group on External Events (NEA)
WGHOF	Working Group on Human and Organisational Factors (NEA)
WGIAGE	Working Group on Integrity and Ageing of Components and Structures (NEA)
WGOE	Working Group on Operating Experience (NEA)
WGRISK	Working Group on Risk Assessment (NEA)
WGSAR	Working Group on the Safety of Advanced Reactors (NEA)

Executive summary

Background

The main objective of the Working Group on Risk Assessment (WGRISK) of the Nuclear Energy Agency (NEA) Committee on the Safety of Nuclear Installations (CSNI) is to advance understanding of the probabilistic safety assessment (PSA) and to enhance its use in improving the safety of nuclear installations, in both design and operation, as well as to increase regulatory effectiveness through risk-informed approaches. Because of its disciplined, integrated and systematic approach, the PSA[1] is considered a necessary complement to traditional deterministic safety analysis.

As noted in the Joint CSNI/CNRA Strategic Plan and Mandates (NEA, 2019), the safe operation of current, new and advanced nuclear facilities is a key challenge for nuclear regulators and technical safety organisations. As described in the Strategic Plan, this challenge is being addressed in part by utilising operating experience, research and analytical tools (such as the PSA). Accurate and complete operating experience data is needed to ensure that PSA results realistically represent as-built and as-operated nuclear power plants and to provide useful and meaningful insights.

The NEA joint database projects and information exchange programmes enable interested countries, on a cost-sharing basis, to pursue research or share data with respect to particular areas or problems. There are three joint NEA database projects with direct relevance to PSA activities:

- International Common-cause Failure Data Exchange (ICDE) ;
- Fire Incidents Record Exchange (FIRE);
- Component Operational Experience, Degradation and Ageing Programme (CODAP).

These database projects can, in principle, support the collection and analysis of data that is highly relevant to the PSA, particularly in the areas of material degradation and ageing, common-cause failures, fire risk, and digital instrumentation and control systems. All of these projects collect qualitative information that can be useful in the development and review of PSA models. Moreover, several of these projects include specific objectives to support quantification activities. However, in the past, WGRISK participants, particularly those that are not part of the database projects, have made little use of the database project products. To address this challenge and based on the needs expressed by a number of participating countries, the WGRISK initiated a task in 2011 on the "use of OECD data project products in probabilistic safety assessment" in NEA member countries. This task was co-ordinated with representatives from the ICDE, FIRE, OPDE[2]/CODAP, and COMPSIS and benefitted greatly from the perspectives offered by the database project members.

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[1] In this report the abbreviations PRA (probabilistic risk assessment) and PSA (probabilistic safety assessment) are used synonymously.

[2] The OECD/NEA project OPDE (OECD piping failure data exchange) was a predecessor to CODAP.

As a follow-on activity, in 2017 the WGRISK initiated the task on the "use of OECD database project products in probabilistic safety assessment". This task was carried out jointly with representatives from the database projects ICDE, FIRE and CODAP.

Objectives

The NEA joint database projects represent mature data collection efforts with substantial support from the NEA membership. These projects have endeavoured to ensure that data collection activities have a high level of completeness and quality. This has resulted in the development of project-specific programmatic requirements intended to ensure quality. However, there remain some challenges when attempting to apply database project products to PSA activities (e.g. data completeness and exposure information needed to calculate PSA parameters). As such, data applicability and completeness should be fully assessed prior to applying database project products to a specific application. Despite these challenges, a number of NEA members have developed experience in applying ICDE, FIRE and CODAP data to PSA initiatives. Examples include common-cause failure (CCF) parameter estimation, fire occurrence and suppression frequency calculations and estimations of piping rupture frequencies. Overall, the database projects represent a valuable NEA activity, particularly for member states with a limited number of nuclear installations and limited operating experience.

Task approach

The WGRISK activity on the use of NEA database project products in PSAs was completed by means of an international workshop organised jointly by WGRISK and the three database projects. The ICDE and FIRE database projects used specific survey questionnaires sent to their participants to demonstrate the values of the databases as well as to identify related topical areas of interest for PSA use of database project products. The CODAP project organised a one-day workshop to discuss database applications. This workshop was held in conjunction with its spring 2018 working group meeting.

The workshop by WGRISK and the three joint database projects following the preparatory work inside the database projects consisted of eight presentations from ICDE, FIRE and CODAP as well as from PSA practitioners using products from the database projects for their PSA-related work. The purposes of the workshop were to:

- Identify, update, characterise and share current uses of NEA database project products and data in support of nuclear power plants PSA. In this context, the term "products" refers to data analysis results, technical reports and other project outputs.
- In collaboration with the NEA database projects, identify and characterise new operating experience data needs for PSAs.
- Demonstrate the value of the NEA database project products to PSAs and continue to strengthen the co-ordination between database project activities and end users.

Task insights

This task identified a number of challenges and opportunities for further improvement:

- enhancing participation in database project activities;
- continuously improving operating experience data collection;
- increased sharing of data with national organisations from participating countries, including nuclear industry and standards organisations (as appropriate);
- considering new or changing data collection needs;

- considering success factors for the application of database project products to PSAs when developing new activities.

As a result of this task, several success factors for the use of database project products in PSA applications were identified. These factors include:

- The database project addresses issues important to safety and/or risk.
- The existence of validated methods for the application of data, in particular for PSA use.
- Sustained interest from multiple countries.
- Participant efforts to address completeness and comprehensiveness.
- Full understanding by participants of the project objectives, limitations and resource implications.
- Awareness within the broader PSA community of the projects.

Of the above-mentioned factors, data completeness and comprehensiveness have a strong effect on the suitability of the database project products to support specific safety applications (including PSAs). Therefore, in addition to maximising participation in data collection activities, a strong commitment from each database project member to ensuring complete and high quality data is essential for the ultimate success of a project. Additionally, a strong involvement of PSA practitioners in the identification of new database project activities would help to ensure their usefulness for future PSA applications.

General conclusions and recommendations

Based on the analysis of the key findings from the workshop, the core task group for this joint WGRISK, ICDE, FIRE and CODAP activity developed the following general conclusions with respect to the use of NEA database project products in PSAs:

- Enhancing participation in NEA database project activities:
    - The participating countries have to ensure the expected resource commitment associated with database project participation. Equally important is the equitable sharing of operating experience data among participating countries.
    - Collection and processing of operational data should take into account that these data can be applied to a broad spectrum of reactor facilities and other nuclear installations.
    - Experience from recent common database project activities in other NEA projects has demonstrated the value of benchmark exercises with limited scope that provide an opportunity to share selected data that try to apply these safety issues to be assessed by means of PSA-related problems. The results of such exercises being published and/or presented to a broader expert community will provide insights on improvements potentially needed in the data collection but may also promote the database project products.
- Continuously improving operating experience data collection efforts:
    - The significance of verifying data completeness and comprehensiveness on a regular basis needs to be emphasised.

  - With the database projects continuing to provide data in the long-term, a permanent knowledge transfer and management from experienced project participants to new ones is essential for ensuring consistent data collection, assessment and application.
  - To ensure data completeness as far as reasonably practicable, a potential use of other data sources (e.g. operational data from the International Atomic Energy Agency [IAEA] databases such as INES or IRS, or data collected by the NEA WGOE) should be investigated and the respective data, if needed for completeness, should be included in the NEA databases.
  - The means for sharing information and data across the database projects, particularly on events that may be associated with pertinent events across multiple database projects (e.g. pipe ruptures involving flammable fluids, CCFs of electrical components resulting in fires) should be investigated in more detail.
  - The best practices for the roles and responsibilities of the national co-ordinators (NCs) of databases should be identified in order to encourage information sharing within the participating countries.
- Increasing the sharing of data with national organisations, including nuclear industry and standards organisations (as appropriate):
  - Practical applications of database project data and the sharing of experience should be further encouraged.
  - For appropriate knowledge management, it is important that all publicly available documents, papers and other references be accessible through the database project websites.
  - The feedback mechanism that has already started between the broader PSA community and the database projects participants should be further improved.
- Consideration of new and changing data collection needs, for example: new builds and advanced power reactors, research, pilot and demonstration reactors, reactor units under decommissioning, risk aggregation from different plant operational states (POSs) as well as from internal and external hazards including hazard combinations, dependencies between multiple collocated units and radioactive sources (Site-Level PSA) at a given site, and human reliability analysis (HRA):
  - To cover the needs of the analysts, it is essential to provide feedback to project representatives for evaluation.
  - The data needs should be re-evaluated on a regular basis in light of project success factors and new (or changed) project needs proposed through the CSNI as appropriate.
- Considering success factors for the application of database project products to PSA when developing new activities.
- Periodic critical reviews of NEA database project data application to PSA issues by WGRISK participants (supported by the broader PSA community) together with database project participants aiming at:
  - closer co-operation with the NEA database projects to help update good practices and the project coding guidelines;

– the identification of future activities to enhance and extend existing analytical methods, models, tools and guidance.

NEA database project members should consider the above general recommendations and the issues and potential resolutions identified when planning future activities. CSNI and CNRA decision makers can support these efforts by:

- continuing to promote and support interactions between the NEA working groups (particularly WGRISK, Working Group on External Events [WGEV] and Working Group on Operating Experience [WGOE]) and the database projects;
- recognising the lengthy timescales and sustained commitment needed to ensure a successful database project and provide associated management support;
- identifying areas where additional, more reliable data would significantly support current or anticipated risk-informed decision-making applications.

The WGRISK and the NEA joint database projects should consider performing a task aimed at sharing the results and lessons learnt from these activities on a regular basis.

In addition, the CSNI and CNRA should:

- Consider sponsoring further joint working group(s) and/or data project(s) activities concerning lessons learnt from operational incidents.
- More generally, continue to support efforts to permanently increase interactions between WGRISK and relevant NEA joint database projects.
- Encourage and facilitate co-operation with other NEA projects and working groups as well as with the IAEA on related topics to address the challenges of PSA methods and data and associated risk-informed decision-making.
- Encourage institutions from participating countries to join the database projects in order to increase the amount of data available and their applicability.

1. Introduction

1.A. Background

The main objective of the Working Group on Risk Assessment (WGRISK) of the Organisation for Economic Co-operation and Development (OECD)/Nuclear Energy Agency (NEA) Committee on the Safety of Nuclear Installations (CSNI) is to advance the probabilistic safety assessment (PSA) understanding and to enhance its utilisation for improving the safety of nuclear installations. Due to its disciplined, integrated and systematic approach, PSA is currently considered as a necessary complement to traditional deterministic safety analysis. To accomplish this mission, WGRISK performs a number of activities to exchange information related to PSA between member countries´ experts. The main products of WGRISK are available to all NEA member countries and in several cases also to the public.

As described in the WGRISK integrated plan (NEA, 2019a), the WGRISK work programme includes a broad range of topics related to the PSA. The programme includes a mix of continuing activities (such as the WGRISK annual meeting for sharing risk-related information) and tasks involving specific PSA-related topics. These latter tasks are formally proposed by WGRISK and approved, as appropriate, by the CSNI.

Each WGRISK task is led by a core group of WGRISK participants whose home organisations have both needs and active (or at least planned) work programmes directly relevant to the topic and supported, as appropriate, by WGRISK participants outside of the core group. Moreover, it is appropriately scoped to avoid unnecessary duplication with other international activities and to enable satisfactory completion within realistic time and resource constraints.

The CSNI Operating Plan (NEA, 2017a) identifies a number of key challenges and supporting technical goals. Challenges include maintaining adequate nuclear skills and infrastructure and ensuring safe operation of existing, new and advanced nuclear power plants. The following CSNI technical challenges (and associated technical goals) have been addressed by the joint activity of WGRISK and the NEA database projects:

- adequate nuclear skills and infrastructure, in particular developing and maintaining databases in key areas;
- safe operation of current nuclear installations, identifying and assessing the impact of new technologies on the safety of existing nuclear installations, further reviewing and assessing the development of PSA methods and promoting further PSA applications, contributing to enhancing performance;
- safety in new nuclear installations, addressing the lack of experience base for new designs, equipment and material.

It is well understood that accurate and complete operating experience data are needed to ensure that PSA results realistically represent as-built and as-operated nuclear power plants and provide useful and meaningful insights. Several joint NEA database projects can, in principle, support the collection and analysis of data that are highly relevant to PSAs, particularly in the areas of material degradation and ageing, common-cause failures, fire risk and digital instrumentation and control systems. Currently, the following NEA database projects have direct relevance to PSA activities:

- International Common-cause Failure Data Exchange (ICDE);
- Fire Incidents Record Exchange (FIRE) project;

- Component Operational Experience, Degradation and Ageing Programme (CODAP).

All of these projects collect qualitative information that can be useful in the development and review of PSA models. Moreover, several of these projects include specific objectives to support quantification activities. However, in the past, WGRISK participants, particularly those not part of the database projects, have made little use of the database project products. To address this challenge, and based on needs expressed by a number of participating countries, WGRISK initiated in 2011 a task on the “use of OECD data project products in probabilistic safety assessment” in NEA member countries, documented in (NEA, 2014). As a follow-on activity, WGRISK initiated in 2017 together with the NEA databases ICDE, FIRE and CODAP a task on the “use of NEA database project products in probabilistic safety assessment”.

1.B. Objectives

In June 2017, the CSNI approved the WGRISK activity on the use of NEA database project products in probabilistic safety assessments[3]. The main objective of this task for WGRISK was to conduct a workshop in collaboration with the NEA joint database projects as a follow-up to the WGRISK(2011)1 activity, which had culminated in the publication of the report “Use of OECD/NEA Data Project Products in Probabilistic Safety Assessment” (NEA, 2014) in order to accomplish the following:

- Identify, update, characterise and share uses of NEA database project products and data in support of nuclear power plant PSAs. In this context, the term “products” refers to data analysis results, technical reports and other project outputs.
- In collaboration with NEA database projects, identify and characterise new operating experience data needs for PSAs.
- Demonstrate the value of database project products to PSAs and continue to strengthen the co-ordination between database project activities and end users.

To support this task, a core task group was formed that included representatives from all three database projects as well as from WGRISK. The core group worked in close co-ordination with WGRISK and database project members to ensure that diverse perspectives and views were adequately considered as task activities developed.

1.C. Target audience

This report is intended for a broad spectrum of individual experts and entities across the international nuclear community that have an interest in the assessment of risks attributable to potential concurrent accidents involving one or more co-located radiological sources at shared nuclear installations.

1.D. Report structure

The main report is organised into six chapters and is supported by five annexes:

- Chapter 1 – Introduction to the purpose of this task.
- Chapter 2 – General overview of the motivation and approach used for this task.

[3] The approved CSNI activity proposal sheet (CAPS) for this WGRISK activity is provided in Annex A to this report.

- Chapter 3 – Overview of the ICDE, FIRE and CODAP database projects. For each project, the scope and objectives, history, data collection methodology and quality assurance, project status, exemplary PSA applications and information related to project participation are provided.
- Chapter 4 – Findings of the common WGRISK and NEA database projects workshop, summarising the presentations and analysis of survey responses, including a discussion of data challenges and good practices. A discussion of enhancing project participation, new and changing data and analysis needs, database project success factors for PSA applications and a summary of key issues and potential resolutions.
- Chapter 5 – Summary of general conclusions and recommendations for further WGRISK activities following from these conclusions.
- Chapter 6 – References cited throughout the main report.
- Annex A – CSNI activity proposal sheet WGRISK(2017)1, "Use of NEA database project products in probabilistic safety assessment (PSA)" as approved by CSNI.
- Annex B – Workshop announcement.
- Annex C – Workshop programme.
- Annex D – Workshop papers and presentations.
- Annex E – Lists of publicly available documents from the NEA joint database projects.

2. Task approach

The Working Group on Risk Assessment (WGRISK) activity on the use of NEA database project products in probabilistic safety assessments (PSAs) has been completed through the following activities:

- development, distribution and completion of survey questionnaires in the database projects as far as feasible;
- a joint workshop by WGRISK and the database projects;
- analysis of survey questionnaire responses and workshop results;
- preparation of the final task report.

In performing the WGRISK activity, a task core group was formed that included representatives from all three database projects as well as from WGRISK. The core team worked in close co-ordination with WGRISK and database project participants to ensure that diverse perspectives and views were adequately considered.

The core group determined that at least for the International Common-cause Failure Data Exchange (ICDE) and the Fire Incidents Records Exchange (FIRE) projects, survey questionnaires would be appropriate to meet the objectives of the task and to prepare the common workshop of WGRISK and of the database projects. Both projects developed survey questionnaires specifically for their projects, which were discussed internally and finalised and circulated among participants in early 2018. Insights from the survey responses were presented and discussed at the joint workshop. In support of the WGRISK activity, the Component Operational Experience, Degradation and Ageing Programme (CODAP) project organised a one-day workshop addressing insights and lessons learnt from database applications. Again, these were presented and discussed within the joint WGRISK and databases workshop. From the surveys, various common issues, challenges and limitations, as well as some good practices and unique issues, could be identified.

Besides presentations given on the projects' enhanced structures and ongoing progress, several survey results were presented and discussed during the workshop in April 2018, resulting in some valuable conclusions and recommendations for the task. Moreover, the workshop also included open discussion periods for identifying approaches to further enhance participation in the database projects as well as emerging operating experience data needs.

After the April 2018 joint workshop, the core group members developed the final report. Because the knowledge management value of this task was well recognised by the task group, it was decided that the final report would include – as the report for the preceding task (NEA, 2014) – updated descriptions of the ICDE, FIRE and CODAP database projects. These project descriptions would serve as an important vehicle for providing an overview of the administration, content, quality, completeness as well as actual and potential future uses of database project products for PSAs.

3. NEA database projects overview

This chapter provides an overview of the background, history, scope and objectives, and data structure of the three NEA database projects, International Common-cause Failure Data Exchange (ICDE), Fire Incidents Records Exchange (FIRE) and Component Operational Experience, Degradation and Ageing Programme (CODAP). It also outlines some of the results and conclusions that are relevant to risk assessment.

From the point of view of project organisation and overall data collection framework, the NEA joint database projects ICDE, FIRE and CODAP share many similarities. All three joint database projects are organised under the auspices of the NEA Committee on the Safety of Nuclear Installations (CSNI). While there are many commonalities between the three projects, there are also some noteworthy working-level differences. It is important to recognise the unique intrinsic drivers that motivate project participation and the sharing of operating experience (OE) data. Both ICDE and FIRE have clear probabilistic safety assessment (PSA)-oriented objectives and the two projects provide products that are closely tied to the different national programmes for PSA. It may be argued that CODAP is no different than ICDE or FIRE relative to its PSA value-proposition. However, some subtle yet important differences exist regarding the "motivational drivers" for CODAP. Project participation is mainly motivated by an interest in the sharing of "selected" (or "representative") information on current and projected material problems facing the different passive component materials (e.g. carbon steels, low-alloy steels, nickel-base steels, stainless steels), including the sharing of experience with non-destructive examination (NDE) and in-service inspection (ISI). Therefore, it may be argued that in CODAP the technical support to the PSA community is not as important as that of providing a knowledgebase supporting the material science community.

The differences in the motivational drivers for the three database projects are expected, necessary and commendable. These differences also affect the way in which information is shared and in how the respective databases are populated and applied. By necessity, the PSA-oriented databases emphasise database completeness, comprehensiveness and quantification. PSA practitioners who consider using an NEA database product have certain expectations regarding not only the usefulness with respect to specific applications, but also the integrity of the results. Integrity in this case means that an analysis based on qualitative and quantitative data derived from a database can withstand a focused peer review process.

3.A. ICDE

The consistent use of redundant systems and components is one of the central principles in the design of nuclear power plants. For this reason, the safety significance of a failure of a single component, a so-called "independent failure", is in general low. In contrast, common-cause failures (CCFs), defined as 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", have the potential to cause entire safety functions to become unavailable. For this reason, CCFs have a significant impact on the safety of nuclear power plants, and operating experience (OPEX) is continuously screened for information regarding CCFs from nuclear power plants in many countries. A major goal of the ICDE data collection is to enable analysts to assess the impact of CCFs within the scope of PSAs and to develop precautionary measures against CCFs.

One of the major issues with these activities is that CCFs are rather rare events and thus the national operating experience is often not sufficient to obtain all the relevant insight. To overcome these obstacles, the ICDE database project was initiated in August 1994. The central element of the project is the database itself containing detailed descriptions of the CCF events that have been observed in the nuclear power plants of the participating countries.

The NEA has formally operated the project since April 1998. Phase 7 of the project finished at the end of 2018, while Phase 8 began in January 2019 and finished in December 2022. The participating countries under the Phase 8 Agreement of NEA and the organisations representing them in the project are the following: Canadian Nuclear Safety Commission (CNSC, Canada), Ústav Jaderného Výzkumu (UJV Řež, Czechia), Radiation and Nuclear Safety Authority (STUK, Finland), Institut de Radioprotection et de Sûreté Nucléaire (IRSN, France), Gesellschaft für Anlagen- und Reaktorsicherheit (GRS, Germany), Nuclear Regulatory Authority (NRA, Japan), Swedish Radiation Safety Authority (SSM, Sweden), Eidgenössisches Nuklearsicherheitsinspektorat (ENSI, Switzerland), and Nuclear Regulatory Commission (NRC, United States). The Korea Atomic Energy Research Institute (KAERI, Korea), Consejo de Seguridad Nuclear (CSN, Spain), and Office for Nuclear Regulation (ONR, United Kingdom) participated in some of the preceding project phases.

The ICDE meanwhile represents a mature database with a significant amount of data over a number of components. ICDE data being available to project participants can be used to support PSA quantification. Publicly available qualitative information can also inform the development of CCFs in PSAs, i.e. what to model and how to model them. In addition to supporting PSAs, a significant amount of qualitative insights can be gained from the data and publicly available reports that can be used to improve the defences against CCFs.

3.A.1. ICDE project scope and objectives

The objectives of the ICDE project as defined in the terms and conditions for the project's operation are the following:

- Collect and analyse CCF events over the long term to better understand such events, their causes and their prevention.
- Generate qualitative insights into the root causes of CCF events that can then be used to derive approaches or mechanisms for their prevention or for mitigating their consequences.
- Establish a mechanism for the efficient feedback of experience gained in connection with CCF phenomena, including the development of defences against their occurrence, such as indicators for risk-based inspections.
- Generate quantitative insights and record event attributes to facilitate quantification of CCF frequencies in the participating countries.
- Use ICDE data to estimate CCF parameters.

Thus, the scope of the project covers both qualitative and quantitative aspects. Moreover, both qualitative and quantitative information about CCF events is systematically collected.

3.A.2. ICDE data structure

The collection and processing of the operating experience from nuclear power plants varies considerably from country to country. This also applies to the aspect of CCFs. Therefore, the information which is available from nuclear power plants of the participating countries is rather inhomogeneous. To be able to make scientifically sound statements, however, a well-founded, uniform database is required. Thus, an obligatory data structure was developed and implemented. This structure is provided in detail in the “General Coding Guidelines” of the project (NEA 2019b) and based on two types of data elements:

- The first type of element is the “observed population record (OP record)”, representing a set of similar or identical components that are considered to have a potential for failure due to a common cause and which are in general equivalent to the Common Cause Component Group (CCCG) used in a PSA. For each component, the corresponding OP record contains a pre-structured textual description of the component, the system where it is installed, the manufacturer, etc. as well as statistical information such as the number of similar components, test intervals, the number of observed independent failures and the present observation time of the OP record. It does not contain any event-specific data. As of March 2019, the ICDE database comprises 9 621 OP records with 160 012 group years of observation time.
- The second type of element is the “ICDE event record”. Each ICDE event record is attached to an OP record and characterises one specific CCF event affecting that OP record. The ICDE event record contains a pre-structured narrative description of the event, its causes and consequences as well as the failure mechanism. Furthermore, it contains coded information, e.g. about the simultaneity of the failures (the so-called “time factor”), the mechanism that ties the multiple impairments together (called “coupling factor”), or the extent of damage to the components. Finally, statistical information such as the event date or the latent time of the failures are included in the ICDE event record. As of March 2019, the ICDE database comprises 1 815 ICDE event records.

3.A.3. ICDE project results

For more than 20 years, the ICDE project has provided a substantial contribution to understanding, assessing and reducing the risk from CCF in nuclear power plants. The ICDE project summary report (NEA, 2019b) presents details on project results that are briefly summarised here.

The ICDE database project covers the CCF-related operating experience of 320 nuclear power plant units from the participating countries with 275 000 MWel, representing ~ 63% of all nuclear power plant units and 70% of nuclear generating capacity worldwide. All relevant types of nuclear reactors are covered, with the ICDE participating countries counting 189 pressurised water reactors (PWRs), 75 boiling water reactors (BWRs), 22 pressurised heavy water reactors (PHWRs) and 34 advanced gas-cooled reactors (AGRs).

As shown in Table 1, the ICDE database comprises 1 815 CCF events and covers most of the safety relevant active component types which are used in nuclear power plants. In all, 161 CCF events are so-called “h”. These are events in which all components within one CCCG failed to perform their safety-related function.

Table 1. Number of CCF events in the ICDE database

Component Type	No. of CCF Events	No. of Complete CCFs
Centrifugal pump	401	51
Safety and relief valve	271	26
Diesel	238	26
Control rod drive assembly	173	3
Motor operated valve	172	9
Level measurement	154	7
Check valve	117	14
Breaker	110	8
Battery	77	5
Heat exchanger	55	4
Fan	32	3
Main steam isolation valve	10	3
Digital I&C	4	2
Inverter	1	1
Total	**1 815**	**162**

Source: FIRE project, first published in (Röwekamp and Brück, 2019).

Since the ICDE database contains a large amount of restricted (proprietary) information, it is only accessible to project participants. Yet, as long as the anonymity of the countries and/or nuclear power plants involved is ensured (i.e. no line data is provided), the project participants are free to use the data for any kind of qualitative or quantitative analysis.

In addition to the collection and preparation of CCF events for use by the individual project participants, workshops for the analysis of CCF events are held regularly within the framework of the ICDE project. The topics of these workshops are either component specific (e.g. CCFs of centrifugal pumps) or topic specific (e.g. external factors, diesels all affected, plant modifications, improving testing, multi-unit events, intersystem events). The results of the workshops are published as ICDE topical reports in the CSNI publication series (as provided in Annex E, see also CSNI website www.oecd-nea.org/nsd/docs/indexcsni.html).

Recent examples of activities performed by individual project members utilising information from the ICDE database is in the latest update of the C-book with CCF reliability data published by the Nordic PSA group in (Håkansson and Johanson, 2016) or qualitative CCF analysis with the focus on the development and implementation of precautionary measures against CCF published by (Brück et al., 2018).

3.B. FIRE database project

The FIRE database is another nuclear power plant operational events database operated under the auspices of the NEA. The need for this database emerged in the late 1990s when it became evident that the only international recording of fire events by the international recording system (IRS) was not suitable for specific analysis and use in risk assessment. In this respect, only dedicated databases allow for “topic focused” lessons learnt as well as for quantitative analysis.

The purpose of this database project is to provide a platform for multiple countries to collaborate and exchange fire data, to enhance the knowledge of fire phenomena and improve the quality of risk assessments that require fire-related data and knowledge.

3.B.1. FIRE project scope and objectives

The objectives of the NEA FIRE project as defined according to the terms and conditions of the project are as follows:

- Collect fire event experience (by international exchange) in an appropriate format in a quality-assured and consistent database.
- Collect and analyse fire events over the long term to better understand such events and their causes, and to encourage their prevention.
- Generate qualitative insights into the apparent and root causes of fire events to derive approaches or mechanisms for their prevention and to mitigate their consequences.
- Establish a mechanism for efficient operational feedback on fire event experience including the development of policies of prevention, such as indicators for risk-informed and performance-based inspections.
- Record characteristics of fire events to facilitate fire risk analysis, including quantification of fire frequencies.

The FIRE database project does not only cover qualitative aspects but also serves as a data source for fire PSA.

3.B.2. FIRE database overview

As of January 2019, the FIRE database covers more than 500 fire events from 14 participating countries (Belgium, Canada, Czechia, Finland, France, Germany, Japan, Korea, the Netherlands, Spain, Sweden, Switzerland, the United Kingdom and the United States) representing more than 9 080 years of observation for different phases of the operational plant lifetime.

The FIRE database can be used:

- to identify all types of events and scenarios to be included in PSA models, ensuring that all mechanisms are accounted for;
- to support fire PSAs with real data from nuclear power plant operating experience, particularly to evaluate fire occurrence frequencies;
- to compare national fire event data from participating countries with the accumulated international data.

Recent applications focus on calculations of generic fire occurrence frequencies relevant for fire PSAs (room type-specific occurrence frequencies by buildings as well as component specific ones), the significance of event combinations including fires, the high energy arcing fault (HEAF) induced fire events as non-negligible PSA contributor, and apparent causes of fire events.

3.B.3. FIRE data structure

For the organisation and structure of the FIRE database project, the project participants agreed, as a general rule, that the data provided by individual countries remain the property of the original owners, but the project participants have the right to access the data and to perform analytical activities with them. Each participating country nominates a so-called national co-ordinator (NC), an individual who serves as the single point of contact for the respective country, approves the data collected from nuclear power plants in that country and is the only person with unrestricted access to the database.

To recognise the support from the plant operators providing the data and to increase the value of the database for the participating countries, an anonymised version of the FIRE database was also prepared and made available for users (analysts from the nuclear installations having provided data and their consultant supporting analysis, from technical safety organisations [TSOs], and from the regulatory bodies involved in safety assessments) in participating countries. It should be noted that the NC is obliged to distribute the anonymous user version of the database, particularly to those organisations that provided the original raw data.

In this encrypted user version, the nuclear power plant from which the data originated is encoded. Nevertheless, it is possible to use the data, for example for general statistics. Since high quality data are essential for usability and comparability in the database, specific guidelines and boundary conditions exist for the exact coding of the data. The compliance with the corresponding coding guideline (CG) (NEA, 2019c), which are regularly improved by the project participants, is the responsibility of the NC, who is supported in this aspect by the operating agent (OA) of the FIRE project. Other responsibilities of the OA include analytical activities as well as the maintenance and constant improvement of the usability of the database.

Two parallel systems are used in the FIRE database project. A web-interface is provided through the NEA for participating countries to enter data. The data to be entered cover more general aspects of each reactor facility included in the database, such as: the reactor type, whether the reactor is part of a multiple reactor site, whether there are other nuclear sources present on site, the start and end of commercial operation, the end of post-commercial operation safe shutdown, the start and end of decommissioning, and the start and end of fire events observed and for which data is entered into the database. Moreover, for each year, operating and shutdown periods have to be distinguished. This information is needed to create fire frequencies for different reactor types and different plant operational states (POSs). To enable the analyst to calculate fire frequencies depending on the type of room where the fire occurred or for different types of fire sources (components), the various room types and numbers of components present per plant unit are coded.

For each fire event coded, a variety of data are coded. These range from more general event data, including a narrative description of the event, to data on the fire ignition, the fire location, the type of ignition, the causes, the fire’s detection, and information on the fire’s suppression. Last but not least, information is compiled on the functional consequences of the fire event and the corrective actions taken. Details can be found in (NEA, 2019c).

From the web interface, the OA creates annual user versions as a MS ACCESS® database with advanced search functions and tools for statistical analysis.

3.B.4. FIRE database project results

An important result of the FIRE database project is that it allows analysts performing safety assessments for nuclear power plants to consider in their assessments quality-assured information on the operating experience with fires in such installations in other countries. This helps to better understand these events and their apparent as well as root causes. The experience feedback again can help prevent fires in nuclear installations and/or mitigate their effects on nuclear safety.

Applications of qualitative operating experience feedback from the FIRE database in participating countries or from the statistical use of fire event data collected for the purpose of quantitative risk assessments have indicated that the generic information from this database provides an added value for risk-informed performance-based decision-making. In particular, for specific types of fire events, such as HEAF-induced fires (for details see NEA, 2013a) or various types of event combinations of fires and other events (see the results summarised in NEA, 2016), the need for in-depth analyses has been recognised and nuclear standards have been or are being updated accordingly on an international and, as far as necessary, a national basis.

The FIRE database contains more than 500 quality-assured event records can support fire PSAs by providing generic fire occurrence frequencies as prior information if the plant-specific or national fire event data are insufficient for a reliable and meaningful statistical use. Another result of the consistent fire event coding is that all the events in the database can be mapped to three types of generic event tree sequences: FET-T, representing the generic fire event tree with the time-dependent sequence of actions to successfully suppress and mitigate the fire event; FET-D, covering details of fire detection and alarm; and FET-S, providing details on fire suppression. Guidance on this mapping is given in Appendix D of the FIRE CG (NEA, 2019c).

3.C. CODAP project

The CODAP international collaboration has its origins in the piping reliability research and development (R&D) sponsored by the Swedish Nuclear Power Inspectorate (SKI, now the Swedish Radiation Safety Authority, SSM) in the early 1990s and in response to the so-called 1992 “Barsebäck-2 strainer event”. The Swedish regulatory and industry response to the strainer event involved the establishment of R&D efforts that focused on physical phenomena associated with containment sump clogging issues, pipe break debris generation, debris transport and a technical basis for more realistic loss of coolant accident (LOCA) frequency assessment. The latter aspect of this broad R&D effort consisted in part of a five-year programme to explore the viability of establishing an international database on the operating experience with piping in commercial nuclear power plants. An underlying objective was to investigate different technical options and possibilities for deriving pipe failure rates and rupture frequencies on the basis of operating experience data as an alternative to, for example, probabilistic fracture mechanics (PFM). The R&D programme culminated in an international piping reliability seminar in the fall of 1997 (SKI, 1997a) and the completion of a plant-specific LOCA frequency assessment pilot study in 1998 (Lydell, 1999).

An outcome of the R&D was a decision by SKI to transfer the pipe failure database including the lessons learnt (SKI, 1995), (SKI, 1997b) to an international co-operative effort under the auspices of the NEA. After a series of information exchange and planning meetings organised by the NEA in September 2000 and April 2001, the “OECD pipe failure data exchange project” (OPDE) was officially launched in May 2002 (NEA, 2021).

In June 2006, Japan provided a voluntary financial contribution to the NEA to support a collaborative research within the “Stress corrosion cracking and cable ageing project” (SCAP). The SCAP was formally launched in June 2006 and officially closed with an international workshop held in Tokyo in May 2010. The majority of the member organisations of the two projects (OPDE and SCAP) were the same and it became clear that some of the lessons learnt and the knowledge database developed with the SCAP could be integrated in the OPDE.

With an initial focus on piping systems and components upon completion of the 3rd term (May 2011), the scope of the OPDE project was expanded to also address the reactor pressure vessel and internals as well as some other metallic passive components that are susceptible to environmental degradation. In recognition of the expanded scope, the OPDE project review group (PRG) decided on a transition of the OPDE to a new, expanded CODAP.

Currently in its third term (2018-2020), the CODAP project's participating countries and territories are: Canada, Czechia, Finland, France, Germany, Japan, Korea, the Netherlands, the Slovak Republic, Spain, Switzerland, Chinese Taipei and the United States.

3.C.1. CODAP project scope and organisation

The objectives of the NEA CODAP project as defined according to the terms and conditions of the project are as follows:

- Collect and analyse information on passive metallic and high-density polyethylene (HDPE) component degradation and failures to promote a better understanding of underlying causes, impact on operations and safety and prevention.
- Analyse the information collected in the event database to develop topical reports on degradation mechanisms.
- Develop and implement an enhanced web-based event database that supports the creation of standard and custom reports on certain aspects of the database content. Building on the experience with the existing web-based event database, the new development will address user-friendliness, improved database structure and analysis tools that enable advanced statistical analyses of the database content.
- Provide ageing management programmes support that addresses current operability determination practices, performance of new materials in the field (e.g. dual-certification stainless steels, super-austenitic stainless steels, Alloy 690, Alloy 52/152), and commendable practices of licence renewal and long-term operation.
- Facilitate the exchange of the existing and future information among the participating organisations as a way to improve the quality of decisions made about components material degradation, ageing management and operability determination. The CODAP database and other relevant information collected will be used for applications of service experience data, with an emphasis on observed trends and patterns, past and current degradation mechanism mitigation practices, and risk characterisation of passive component failure events.

The CODAP management board (MB) is the "custodian" of the database and is responsible for its maintenance and the data access rules. The selection of events of interest and all data submissions are made in accordance with the operating procedures and annual work plans. The respective MB member is ultimately responsible for ensuring an equitable exchange of operating experience data. From the point of view of practical applications of the CODAP database, the MB is also responsible for the completeness of the database, i.e. capturing all significant and relevant data from the operating experience. The role of the CODAP OA is to ensure the consistency of the operating experience data contributed by the NCs. The CODAP OA verifies whether the event information provided by the NCs complies with the CG.

3.C.2 CODAP database structure

CODAP is a web-based structured query language (SQL) database, which facilitates data input, search and query routines as well as data export to a local computer. When executing the data export function, the online version creates a "failure data" file in extensible markup language (XML)-format for import to a local computer. This allows for the file to be converted into Microsoft® or any other relational database program. Necessitated by many different combinations of component types, materials, operating environments and degradation mechanisms, it is a complex database structure consisting of 62 database fields and more than 800 database filters (or key words).

The CODAP terms and conditions contain statements on the use of data within and outside the CODAP project and on the handling of proprietary information. The event database is a restricted database and its access is limited to participating organisations that provide input data.

3.C.3. CODAP database application example

In the following, an example of an application of CODAP data is provided which resulted from work sponsored by the Nordic PSA group (NPSAG). Based on technical discussions and seminars within the frame of the NPSAG planned activities for R&D, a formal decision to launch a project to develop a piping reliability parameter handbook for use by PSA practitioners was made in 2005. Project phase I (2005-2007) consisted of the following tasks:

- Review of pipe failure databases and identification of technical features recognised as important to the statistical estimation processes that are considered for use in the development of the handbook. This element of the planning effort addressed the question "from where can piping component operating experience data be obtained?"
- Review of methods for piping reliability parameter estimation.
- Development, distribution and evaluation of a questionnaire addressing user requirements on the planned R-book (content, including level of detail and updating philosophy). Input from the international PSA community was sought.
- Development, distribution and evaluation of a questionnaire addressing the availability and access to piping exposure term data (piping system design information including weld counts and pipe length information organised by system, size, material, process medium, safety classification).
- Detailed work plan for the R-book development (phase II), including cost, schedule, quality assurance and selection of analysis techniques and tools. All calculations were to be performed in a Microsoft EXCEL workbook format with R-DAT and Oracle Crystal Ball add-in programs for Bayesian update and uncertainty analysis, respectively.

Phase II of the project was launched through a workshop in mid-2008 that included a demonstration of the analysis techniques and tools to be used in the development of the first edition of the R-book and a discussion of the project schedule. The technical scope was narrowed from an "all-encompassing" scope to a focus on the American Society of Mechanical Engineers (ASME) III Code Class 1 and 2 systems in Nordic BWR and PWR plants, for a total of 26 different systems. A first edition of the R-book was issued in 2011.

Only an electronic version of the R-book has been issued. It consists of a password protected CD with the project files structured as follows:

- Summary report (as a Microsoft Word file and as a PDF file); NPSAG report 04-007:01 (Swaling, 2010), (Swaling and Olsson, 2011): This report summarises the data processing routines: from extracting event population data from the OPDE database, via definition of relevant exposure term data (i.e. the "number of reactor-operating-years that produced a certain event population" times the number of welds susceptible to a certain degradation mechanism), to the definition of calculation case and to the execution of a certain calculation.
- Theory manual: This document contains an overview of the general calculation format, including a technical basis for how to define exposure terms specific to a certain calculation case, e.g. pipe failure in BWR reactor recirculation (RR) piping susceptible to intergranular stress corrosion cracking (IGSCC) or failure of dissimilar-metal RR piping welds.
- For each of the 26 systems a file folder with the following system-specific computer files.
- Text file (WORD and PDF formats) summarising the underlying degradation mechanism analysis (DMA results), input data (event population data and corresponding exposure term data), results summary and a discussion on how to use the R-data results.
- Data processing and results summary; Microsoft Excel files.
- Oracle Crystal Ball® reports (Microsoft Excel files) for each calculation case; depending on system, up to 24 individual Excel files): These "reports" enable a user to not only reproduce a certain application but also to perform different types of sensitivity analyses depending on an intended application.

The total file size is approximately 90 MB (compressed archive format), which is made up from a total of 96 independent as well as related files. All piping reliability calculations are based on operating experience data as of the end of 2007.

The three sponsoring utility organisations have used the R-book in the development of plant-specific LOCA frequencies. In 2015 a "R-book light version" was made available to non-sponsoring organisations. A questionnaire was distributed to current and potential future users to obtain feedback on the content, usefulness and technical relevance. In a few instances a user noted that the R-book does not contain any quantitative information on a specific degradation mechanism, piping configuration or system. In other words, there are some lingering questions about the completeness of the source data. It also raises a technical question on how to estimate the reliability of a system for which the operating experience data is zero events. Could "zero" be a true statement about the actual operating experience or is it due to database incompleteness? In any case, the methodology does support the zero-failure case.

Since CODAP is a restricted database, it took great deal of effort to reach a consensus among the CODAP project participants on how to make the data available to the nuclear safety community at large. In response to a request by the NPSAG, a non-confidential version of the event database was prepared and released for project-specific applications. This non-confidential version was derived by removing all references, including attached files, as well as by removing narratives and all plant identity information. The non-confidential version was based on the 2007 version of the OPDE database.

3.C.4. CODAP project results

Apart from recognising the intrinsic value of exchanging operating experience data and related root cause analysis results and insights, an important motivation for supporting the international collaboration originally was related to the emerging trend towards the development and implementation of risk-informed in-service inspection (RI-ISI) programmes. An area of specific interest at the time (2002) was concerned with the technical basis for performing pipe failure probability analysis in support of RI-ISI programme development. Since the project initiation in 2002, the synergies between a comprehensive database such as CODAP and the development of enhanced passive component reliability models have been explored in multiple database application projects.

As summarised in Table 2, the CODAP project has collected a significant event population. In addition to safety class 1 through 3 and certain balance-of-plant (e.g. high energy piping systems within the turbine building), the event population includes selected fire water system pipe failures and pipe failures affecting multiple trains of safety-related piping systems. Hence, the CODAP database includes events of interest for the ICDE and FIRE database projects.

Table 2. Number of events in the CODAP event database

Component type	No. Events involving structural degradation	No. Events involving major structural failure (e.g. pipe rupture)
Piping		
Safety Class 1 (ASME III Code Class 1) – all component types and pipe sizes)	1 278	11
Safety Class 2 (ASME III Code Class 2) – all component types and pipe sizes)	1 018	33
Safety Class 3 (ASME III Code Class 3) – all component types and pipe sizes)	1 068	63
Non-Safety – balance-of-plant piping	640	196
Selected non-piping passive metallic components		
PWR reactor pressure vessel head penetration (RPVH)	170	0
PWR pressuriser heater sleeve	64	0
BWR core shroud weld	57	0
Cast austenitic stainless steel valve body (multiple system applications)	42	0
PWR baffle former bolt	21	0
PWR control rod drive thermal sleeve	5	1
Total no. of events:	4 363	304
Total event population:	4 667	

Source: CODAP project

In addition to the development of the web-based event database, the CODAP project has produced a series of topical reports. These provide high-level summaries of trends and patterns in metallic material performance in different operating environments and for different time periods. Since 2010 the following topical reports have been published on the CSNI website (www.oecd-nea.org/nsd/docs/indexcsni.html, see also Annex E):

- 2011 – "Technical Basis for Commendable Practices on Ageing Management: Stress Corrosion Cracking Mechanisms", produced by the SCAP Working Group with extensive input from the OPDE Project.
- 2014 – "Flow Accelerated Corrosion (FAC) of Carbon Steel and Low Alloy Steel Piping in Commercial Nuclear Power Plants", first CODAP Topical Report.
- 2015 – "Operating Experience Insights into Pipe Failures in Electro-Hydraulic Control (EHC) and Instrument Air (IA) Systems", second CODAP Topical Report.
- 2017 – "Operating Experience Insights into Pressure Boundary Component Reliability and Integrity Management (RIM)", third CODAP Topical Report.
- 2018 – "Operating Experience Insights into Below Ground Piping at Nuclear Power Plants", fourth CODAP Topical Report.
- 2019 – "Basic Principles of Collecting and Evaluating Operating Experience Data on Metallic Passive Components", fifth CODAP Topical Report.
- 2022 – "A Review of the Post-1998 Experience with Thermal Fatigue in Heavy Water and Light Water Reactor Piping Components", sixth CODAP Topical Report.

A topical report on material degradation operating experience during commercial nuclear power plants' extended period of operation (PEO) and long-term operation (LTO) has been finalised with publication expected in the first quarter of 2021.

4. Workshop findings

This chapter summarises the insights gained by the participants of the joint Working Group on Risk Assessment (WGRISK) and NEA databases workshop. The most important overall questions to be answered by the workshop were:

- Can the NEA databases be used to support risk-informed decision-making (RIDM), and what may improve their usefulness for RIDM?
- Is there additional information that could be collected to improve the use of the NEA databases for probabilistic safety assessments (PSAs)?
- What are potential other applications for the NEA databases to support risk assessments?
- Are there new data needs to support PSAs?

4.A. Observations and findings from the International Common-cause Failure Data Exchange (ICDE) project

The ICDE project conducted a survey among project participants on how information on common-cause failure (CCF) was collected and used from both qualitative and quantitative points of view. From this survey, the following insights could be gained and were presented (see Annex D) during the workshop:

- There is no uniform procedure among the project participants for carrying out a PSA. This concerns almost all aspects of a PSA, e.g. the calculation of CCF reliability data, the determination of the spectrum of initiating events, the modelling of the plant systems as well as the software tools used.
- For the calculation of reliability data, some countries use only their own national operating experience, some use calculated data from other countries and some use both. In some cases, data from the ICDE project is used to supplement the available operating experience.
- The most common way to use information from the ICDE database in the participating countries is to gain qualitative insights about CCF failure mechanisms from the events that were observed by the other project participants. For example:
  - Coding guidelines and failure analysis guidelines: ICDE Coding Guideline and United States Nuclear Regulatory Commission (USNRC) coding guideline are used in the process of CCF data analysis.
  - New system design and in-plant procedures: this knowledge is used for new system design and in-plant procedures.
  - Identify CCF mechanisms: constant analyses of the ICDE and IRS databases to identify CCF mechanisms which have not been observed in their own operating experience yet.
  - Accuracy of CCF modelling: during updates of the reliability data, the ICDE database is used to verify the accuracy of CCF modelling for selected components.
  - Source of information regarding possible CCF mechanisms: ICDE data are used as a source of information regarding possible CCF mechanisms involving a given component type and for the scope of components for which CCF have to be considered.

– New CCF mechanisms: international operating experience is periodically consulted for identifying new CCF mechanisms.

– Research examples: the international operating experience is only used for some exemplary research.

4.B. Observations and findings from the Fire Incidents Records Exchange (FIRE) project

In the following, the main observations and findings from the FIRE database project as discussed in the common workshop are provided.

4.B.1. FIRE database project survey

The following questions were covered in the survey of the FIRE database project when preparing the workshop:

1. Are probabilistic fire risk analyses (fire PSAs) used in the regulatory process (e.g. periodic safety reviews, other applications) and to what extent?

   (Possibly relevant aspects: Level 1, 2, 3 PSA, use of operating experience, precursor analysis of events)

2. What data sources are used in your country for a fire PSA?

   (Potentially relevant aspects: operating experience, models, data availability, quantitative use and application of OECD FIRE data)

3. What type of data do you need specifically in the frame of a fire PSA?

   (Potentially relevant aspects: fire sources [combustibles, ignition sources], data for fire frequencies [location or component specific frequencies], detection, suppression)

4. Which data from the OECD FIRE do you use already or intend to use in future for a fire PSA in your country?

5. How often you update data needed for a fire PSA?

6. Use of international operating experience (in particular, from the OECD FIRE database) for fire risk assessment:

   a) How is the international operating experience with fire events used in the development of the PSA plant model and to what extent?

   b) Are there other areas where international operating experience from fire events (e.g. from the OECD FIRE database) is used?

7. Fire PSA models/software

   a) What PSA-related software is used to perform a fire PSA? Is the PSA software standard or something special in addition?

   b) Are detailed fire simulations performed in the frame of a fire PSA, and if yes, by which codes?

   c) Do you have specific requests to the FIRE database with respect to modelling and fire simulations for a fire PSA? If yes, specify these.

Regarding the survey results, the following insights were gained:

Fire PSAs to be carried out and used for risk-informed decision-making represent the state of the art in participating countries. However, the scope is different. While a Level 1 fire PSA is required in all countries, and in a majority of these every five or ten years, a Level 2 fire PSA is not yet in the scope of all FIRE countries. A Level 3 PSA is voluntary in most countries and has been carried out so far for only a few reactors. The applications of a probabilistic risk assessment are manifold: depending on the principally applicable requirements for precursor analysis in the countries, precursor analyses are performed and used as an important analytical tool for operating experience feedback supporting modelling activities. Some countries use it as well for risk monitoring; with the regulatory decision-making trending more and more to a risk-informed performance-based approach, probabilistic fire safety analyses gain more attraction in the licensing and supervisory processes. As an example, significance estimations (e.g. for fire compartments or cells) are being carried out on a case by case basis.

Although incipient fires do occur with a non-negligible frequency and therefore are considered in the design of nuclear power plants, the plant or reactor unit specific number of more severe fires affecting nuclear safety is still low for a majority of reactor units in operation. A statistically meaningful probabilistic assessment needs a solid and sound basis. Therefore, for many plants, in addition to plants and/or reactor unit specific fire event occurrence data, generic data are needed to reduce stochastic uncertainties. A broad majority of FIRE participating country institutions apply generic fire event data in addition to plant-specific ones. In this context, generic data such as from NUREG/CR-6850, NUREG-2169, or Electric Power Research Institute (EPRI) reports, and from the United States fire events data base (FEDB) and the nuclear insurers database (NEIL database) are applied. In the fire PSA of nuclear power plants in some participating countries, such as Belgium, Finland, Germany and the United States, generic data from the FIRE database are also applied for comparisons.

On a national level, some generic data are also applied, such as the X-Book containing fire events from Finland and Sweden. In several countries, plant or site specific data are used in fire PSAs. Typical examples are ignition source frequencies and reliability data, mainly for active fire protection features. Depending on the level of detail of the PSA, other data sources are considered, such as available information on transient fires and the corresponding ignition frequencies.

Based on the data already being applied, analysts from the FIRE participating countries have clearly indicated a need for further data to be collected, shared between experts from different countries and discussed to extend the database applicable to fire PSAs for existing nuclear power stations in operation or for sites with reactors no longer being operated, as well as for the design and operation of new builds. The following types of data have been identified in this context:

- Fire occurrence frequencies: Depending on the approach used within the fire PSA for a plant being analysed, fire frequencies specifically obtained for different types of rooms of fire ignition (fire compartments) per building being investigated or fire source (component of ignition) are needed. In this context, it is essential that for similar types of components operated under comparable conditions (e.g. batteries) with similar inspection and maintenance strategies, even in very different types of reactors or installations, generic frequencies can be applied with a high level of confidence.

- Data with respect to fire detection and suppression: Plant- and/or site-specific operating experience should typically be available for nuclear power plants after having started operation. However, the database for a plant, for which analyses are being carried out, may not be sufficient. To reduce uncertainties as much as possible in the probabilistic analyses, generic data collected for characterising fire detection and suppression, including human reliability data, should be used. An exchange of fire protection systems and equipment performance data (including actuation times, fire brigade action success times, etc.) could be a valuable means to improve fire event trees. However, this task is challenging as this level of detail is not yet provided for most of the fire event sequences recorded in the FIRE database. Moreover, as far as applicable, generic data for the technical reliability of active fire detection and suppression means can be used in the fire-specific event trees. The collection of such data is as challenging as it is time consuming and requires harmonised assessment criteria for failure estimations. Therefore, a joint international effort for generating reliability data specifically for active fire protection features might be beneficial to help reduce the individual effort and, at the same time, decrease the uncertainties in the values being applied.
- Other data: In a majority of FIRE participating countries, a lack of data on cable characterisation, location and routing has been observed. Even if international experimental efforts (e.g. the NEA PRISME fire experiments [NEA, 2017b]) contribute to further reducing this gap, this is still one of the most urgent challenges, since cable fires represent a non-negligible contribution to the damage states in fire PSAs. Other data areas where still more precise information is needed for fire PSAs in several nuclear power plants are fire load and ignition source data, specific data on PSA components as well as building and room and/or area specific geometric data and time dependent data on the ventilation conditions. Due to the non-negligible number of at least incipient fires due to hot work, more information for adequately modelling such fires including the respective procedures in fire PSAs is needed. It might be valuable to carry out a corresponding task within the FIRE database project for better characterising hot work fires within fire PSAs. In addition, there is an interest in collecting more data on spurious or faulty actuation of fire protection systems as well as on main control room (MCR) evacuation in case of fire for application within PSAs.

Some types of data collected in the FIRE database are already being used for fire PSAs in some participating countries, while other countries have not yet applied such data but intend to use them as soon as the data collection is mature enough to generate statistically meaningful data. This is particularly valid for room as well as for component type specific fire frequencies. Fire frequencies can at least be generated for different types of reactors and plant operational phases in those participating countries reporting all fire events without specific reporting criteria and thresholds for clearly defined observation periods. Fire frequency data, if not directly applied as prior information in case of insufficient data for a plant under investigation, are often used in several participating countries for comparison and widely used for operating experience feedback.

In some countries, generic event tree data, including a mapping to fire detection and suppression or other data regarding the individual fire event sequences, are or will be used in the near future. As mentioned before, one of the challenges in fire PSAs which still exist the lack of data related to fire detection and suppression. The need for generic data was clearly identified; in this context, it was stated that more suitable international data complementing national data would be useful for risk assessments.

While in a broad majority of FIRE participating countries the data for fire PSAs are regularly updated, typically every five to ten years in the frame of periodic safety reviews (PSRs), only in some countries do such data updates also take place on a "typical regulatory" request, such as in case of plant modifications, when new data are available, as a result of e.g. an international probabilistic safety assessment review team (IPSART) mission, when new methodologies for assessment are available, or on a case by case basis.

Internationally available operating experience, in particular from the FIRE database, is used for different purposes of fire risk assessment. Typically, it represents the basis for Bayesian updates. In some countries, a general use of (international) operating experience feedback in the frame of PSAs is mandatory for comparison to national operating experience. Interest in the use of the FIRE project information for different purposes differs between countries. As an example, there is a strong interest from utilities or regulatory bodies in some countries in the experience with specific types of fire events such as combinations of fires and other hazards, MCR fires, or high energy arcing fault (HEAF) induced fires.

With the increasing maturity of fire PSAs, the PSA-related software for performing fire PSAs has also advanced. Various codes with different levels of detail for specifically modelling fire event sequences and consequences are available worldwide and can be adapted to or coupled with standard PSA software. More and more detailed fire simulations are performed with such codes (more simple zone models as well as highly complex three-dimensional fluid dynamics codes) in the frame of fire risk assessments. So far, it is still difficult for fire modellers and PSA analysts to meet their needs for event specific information required for fire simulations with the FIRE database project. For example, for validation and verification or benchmarking of fire simulation codes, more detailed and precise information is needed, particularly on cable fires, electric cabinet fires or transient fires recorded in the database. This would either require providing additional information from the plant operator where an event to be investigated occurred or to generally extend the information in the database to non-event specific plant data (e.g. room geometry, ventilation conditions), which is difficult to obtain and requires at least some collaboration with the licensees on specific events, particularly regarding fire propagation, transient fire growth, heat release rate, etc. A common activity between the NEA experimental PRISME project and the FIRE database project, in which a cable fire benchmark exercise is performed considering a corresponding cable fire event recorded in the database, is ongoing and has demonstrated the above mentioned challenges.

4.B.2. Generic findings from the FIRE database project at the workshop

Various observations and findings from the work of the organisations participating in the FIRE database project were highlighted in the workshop. These have partly already resulted in database improvements. The major observations and findings from the FIRE database project as discussed in the common workshop are provided below.

With respect to generic fire occurrence frequencies relevant mainly to fire PSAs, the findings revealed valuable products from the FIRE database, but also indicated a few challenges:

- Well-defined observation times sub-divided into the different plant operational states (POSs) – full power operation as well as low power and shutdown states, including the post-commercial operation safe shutdown phase, but also covering the construction and decommissioning phases – are available for all reactors in the database.
- The time periods, for which all fire events from a country have been reported to the database according to the nationally applicable reporting criteria, are also provided.

- In principle, for those buildings listed in the FIRE CG (NEA, 2019c), the respective numbers of rooms of different types as also listed in (NEA, 2019c) have been counted for those reactor units included in the database. The corresponding data sheet which needs to be filled in is provided in Figure 1. Some data are still missing but will be provided during phase 6 of the project. As a result, generic room type specific fire frequencies can be principally generated for various buildings based on the average numbers of the respective rooms; see examples for pressurised water reactors (PWR) in Figure 2 and Figure 3. These are statistically relevant at least for reactors from those countries reporting all events (not only those being reportable to given national criteria). One important challenge is that the amount of statistically relevant data is not yet very high; more data are needed. On a national basis, room based fire frequencies can, however, be generated for nearly all countries.

Figure 1. Tables to collect the number of rooms of different types for different building for each nuclear power plant in the FIRE database

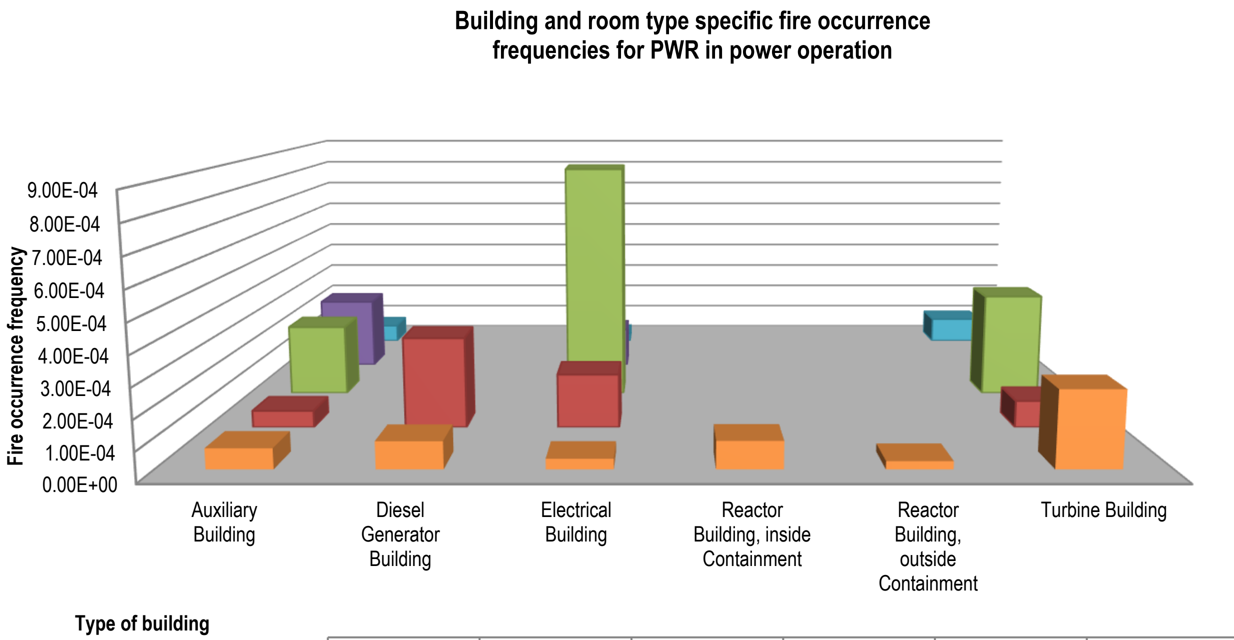
OECD FIRE Database – No. of Rooms per Building Plant ID: Date:

Room Type	Cable rooms		Room for electrical control equipment incl. MCR	Switchgear room	Battery rooms	Room for ventilation	Room for off-gas equipment	Process room	Staircase / corridor	Office	Workshop	Storage rooms			Diesel generator room	Transformer room / bunker	H_2 cylinder bunker	Other room	**Total**
Building	Cable spreading room	Other cable room										for nuclear waste	for other waste	for combustibles					
Reactor Building																			
Containment																			
Outside Containment																			
Electrical Building																			
Auxiliary Building																			
Turbine Building																			
Diesel Generator Building																			
Intake Building																			
Spent Fuel Building																			
Independent Emergency Building																			
Workshop Building																			
Other building																			
Total																			

Note: Definitions of rooms and buildings, see OECD FIRE Coding Guideline 2017:02, par. 3.2.3 and 3.2.4

Source: FIRE project, workshop meeting

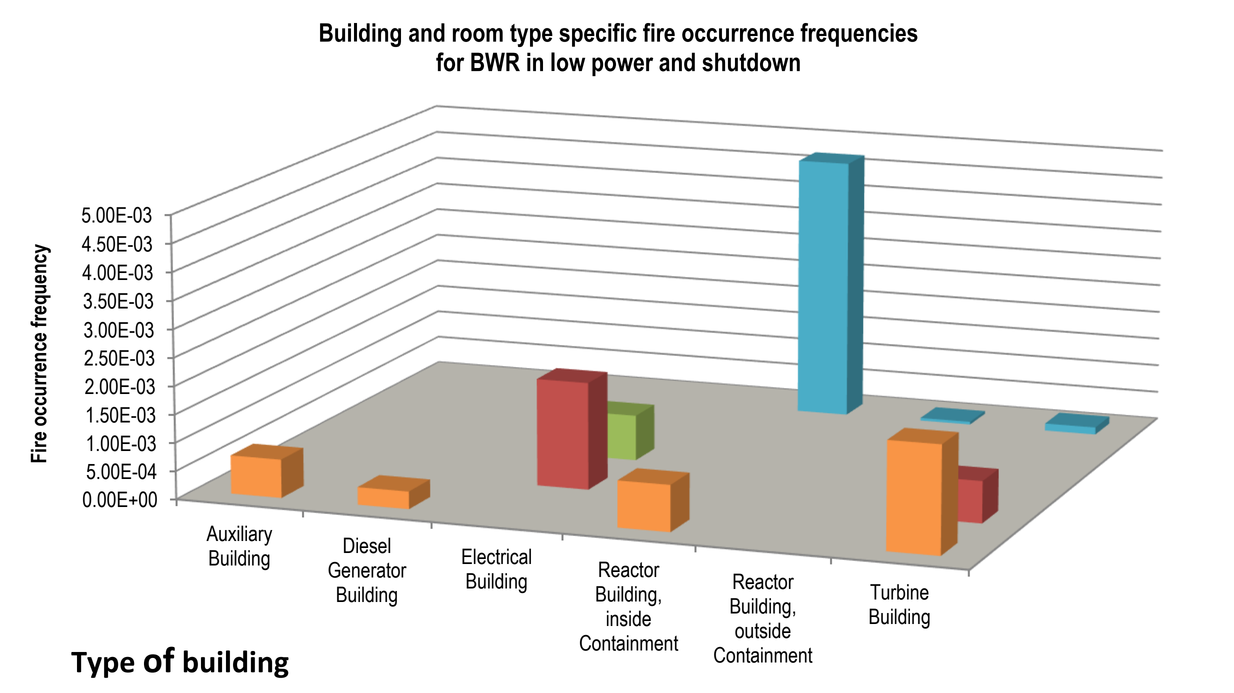
Figure 2. Fire frequencies per room and building for PWR type reactors during power operation



	Auxiliary Building	Diesel Generator Building	Electrical Building	Reactor Building, inside Containment	Reactor Building, outside Containment	Turbine Building
Process room	6.90E-05	9.20E-05	3.50E-05	9.30E-05	2.70E-05	2.60E-04
Room for electrical control equipment	5.90E-05	3.20E-04	1.90E-04			9.50E-05
Switchgear room	2.60E-04		8.70E-04			3.80E-04
Room for ventilation	2.70E-04		1.50E-04			
Other type of room	6.90E-05		3.30E-05			1.00E-04

Source: FIRE project, workshop meeting.

Figure 3. Fire frequencies per room and building for PWR type reactors during low power and shutdown states



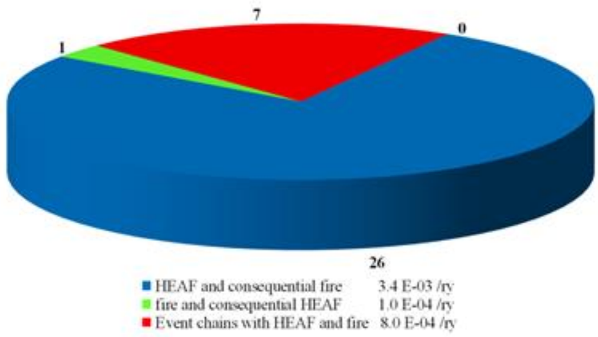
	Auxiliary Building	Diesel Generator Building	Electrical Building	Reactor Building, inside Containment	Reactor Building, outside Containment	Turbine Building
Process room	6.80E-04	3.10E-04		8.20E-04		1.90E-03
Room for electrical control equipment			1.90E-03			7.40E-04
Switchgear room			8.10E-04			
Room for ventilation						
Other type of room				4.70E-03	4.90E-05	1.30E-04

Source: FIRE project, workshop meeting.

- For the generation of fire source-specific fire occurrence frequencies, a similar template table is available that is derived from the FIRE CG (NEA, 2019c) to collect for each reactor unit in the database the number of components where a fire can ignite. The component counting is not yet complete as it requires a non-negligible effort to be supported by plant operators. Generic component specific ignition frequencies can therefore so far only be generated for selected components. However, a comparison with national data from fire PSAs is in principle possible. The main challenge here is the fire frequencies for cables, which are difficult to derive. For cable fire frequencies, information is needed on cables by segments or by length. Efforts to close that gap have been started based, as a starting point, on cable data collected in one FIRE participating country for fire PSAs. The frequencies were calculated by the length of cable, which was derived either from nuclear power plant cable databases in place or counted approximately room by room where the cables are routed in the respective nuclear power plant unit. One additional challenge the task participants recognised is that for in-depth modelling of cable fire scenarios in fire PSAs, data that are needed for cable fire simulations (e.g. cable materials, burning rate) must be provided.

- Analyses of event combinations of fires and other anticipated events collected in the database have clearly indicated that fires induced by HEAF represent an important contributor to the overall risk of a nuclear power plant (cf. figure 4). In total, 62 HEAF-induced fires – 33 of them representing event combinations shown in figure 4 – have resulted in an occurrence frequency of 7 E-03/ry. For nuclear power plants during power operation, the occurrence frequency is 6.6 E-03/ry (44 events), while for plants in low power and shutdown states (18 events) the frequency is 9.2 E-03/ry.

Figure 4. Contribution of event combinations of HEAF and fire events



Source: FIRE project, workshop meeting.

Several needs for improving the use of FIRE data for PSAs have also been identified. Although some details from the operating experience are collected in the database to model fire detection and suppression within the fire specific event trees, more details on the time sequences are necessary, such as fire detection and alarm times and information on the start and end of fire suppression.

The participants in the FIRE database project have made the observation that there is a need to find out more details on the apparent causes of fire events in nuclear power plants in order to improve fire safety. This may help not only to better prevent fires but also to gain more insight into their root causes. A corresponding activity has been started. In a first step, a rough trend analysis was conducted with respect to the most common apparent causes of fire events recorded in the FIRE database. For a statistically meaningful analysis the investigation was limited to:

- those 290 events from PWRs, BWRs and PHWRs in FIRE participating countries reporting all fires without any reporting thresholds or exclusion criteria, representing an operating experience of nearly 30% of the whole observation times in the database;
- fire events with known POS at the time of fire occurrence, in order to gain insight into their safety significance.

Some major causes have been identified and analysed, such as electrical causes (hot shorts, shorts to ground, HEAF, electrical overheating), mechanical overheating, lubricant and hydrogen fires, and fires due to hot work. However, it was only possible to identify the cause without doubts for less than 170 events. The results of this first trend analysis provide further suggestions for detailed analyses.

Apparent cause categories with non-negligible contributions from human error or deficiencies in procedures are interesting because understanding their causes may help prevent future events. Such categories include electrical or mechanical overheating. For these, fire ignition frequencies could possibly be reduced by improved operating and maintenance procedures and enhanced training. Other significant categories of apparent causes are hot work, where strengthening of rules for maintenance and repair work and for handling of transient material might decrease ignition frequencies, and HEAF-induced fire events, whose occurrence can be reduced through improvements in quality controls, maintenance procedures and training, in addition to technical enhancements.

The analysis of apparent causes of fire events in the database demonstrated that it is possible to identify potential precursor events. Moreover, insights can be gained on possible backfitting measures and their effect on the fire-specific core and/or fuel damage frequencies. However, one finding is that more detailed investigations into the root causes of fire events are needed. In this context, it is challenging that the root cause coding is not yet complete and exhaustive, requiring improved analyses to reduce uncertainties and increase the level of confidence with respect to the analytical results.

The following main challenges with respect to fire event data have been identified in the frame of the task:

- Cable fires are still challenging and need further investigation. In particular, for cable fire frequencies, information is needed on either cable by cable segments or by cable length.
- For in-depth modelling of cable fire scenarios in fire PSAs, data that is needed for cable fire simulations (e.g. cable materials, burning rate) need to be provided.
- To analyse the apparent as well as the root causes of fire events recorded in the FIRE database, more detailed information is needed, such as detail on the different causes and the number of root causes of each type per event.
- To model fire detection and suppression in the fire-specific event trees, more details on the time sequences are needed. This covers fire detection and alarm times, time periods until fire suppression is started, in particular by the fire brigade, and the time when the fire is extinguished.
- Moreover, more reliability data (technical as well as human) are needed for application in the event and fault trees of fire PSAs.

4.C. Observations and findings from the CODAP database project

In April 2018 the CODAP management board (MB) distributed a questionnaire and arranged a CODAP mini-workshop to address the use of the CODAP database in participating countries. The main results of this activity were as follows:

- Public domain CODAP topical reports are distributed within the corresponding participating organisation and made available to operators that support the database project by providing event information. Furthermore, Eidgenössisches Nuklearsicherheitsinspektorat (ENSI) via its annual regulatory safety research summary report (“Erfahrungs- und Forschungsbericht”) informs about the activities of the CODAP project. However, the management board has not yet implemented any formal processes for the dissemination and evaluation of the conclusions and recommendations that are presented in the topical reports.

- Encouraging participating organisations to provide operating experience (OPEX) data in an equitable manner continues to be a challenge for the successful operation of the CODAP project. However, the active and continued collection and evaluation of passive component OPEX nevertheless is an essential task of ageing management programme reviews, periodic safety reviews and licence renewals. A lack of resources has been mentioned as a key bottleneck in ensuring an active data submission effort, which in turn affects the completeness and comprehensiveness of the database. In addition, it was identified that reporting requirements in participating countries could be enhanced to facilitate information sharing from licence reports and their integration in the CODAP database.
- It was mentioned that in addition to qualitative insight reports, the CODAP database could in future be used for quantitative insight reports if more events with detailed information were to be submitted to the database. It is envisaged that such reports would generate high-level statistics of passive component failures organised by component types and degradation mechanisms that would be of use to PSA practitioners. In order to provide a link to the database using a Bayesian update process, the constrained non-informative distribution (CNID) method may be used.

In conclusion, it shall be reminded that providing support for different kinds of applications is a continuous target of the CODAP database development. The CODAP project actively supports proposals to arrange an international benchmark exercise concerning the use of operating experience data to quantify piping reliability parameters for input to a standard problem application; e.g. a risk-informed operability determination. The benchmark could be concerned with a uniquely defined component boundary that has been known to be susceptible to degradation. The benchmark participants would then be asked to quantify a reliability metric (e.g. annual frequency of a through-wall crack producing a certain mass flow rate), including explicit consideration of uncertainty.

The R-book project is one of many examples of the NEA database project products' applications. Collectively, these many applications have demonstrated that collecting and analysing operating experience data is highly relevant to PSAs, particularly in the areas of material degradation and ageing (CODAP), common-cause failures (ICDE), and fire risk (FIRE). In contrast to CODAP, ICDE and FIRE include specific objectives to support quantification activities. As demonstrated by the R-book project, CODAP not only needs to provide complete sets of event population data, it also needs to include extensive exposure term data to address plant-to-plant and nation-to-nation variability with respect to piping system design information (e.g. material type, routing, weld type, weld populations, dimensional data, methods of fabrication). Therefore, in the execution of the R-book project, CODAP was one of several sources of information required to facilitate data processing and analysis.

To better support future PSA applications of CODAP it is recommended that the CODAP MB address the following technical challenges:

- Reaching a consensus on how to make the restricted CODAP database available to PSA practitioners and in a form that enables PSA practitioners to process and analyse the operating experience data in an effective way.
- Continuing the work to develop PSA-oriented database application guidelines and associated methodology.
- Consideration of possibilities for an international benchmark exercise concerning the use of operating experience data to quantify piping reliability parameters for input to a standard problem application; e.g. risk-informed operability determination.

- Data completeness: In its past and current forms, CODAP has a strong US centric basis (about 70% of the operating experience data). An action for the third term (2018-2020) of the project is to put in place operating procedures and processes whereby future national data submissions are commensurate with the number of operating reactors.
- From the point of view of PSAs, CODAP is lacking exposure term data. Such information is readily available, for example, via in-service inspection (ISI) programme plan databases and should be incorporated in the database. This is essential for applications.
- An open-ended question concerns how to update database applications as new operating experience data becomes available. Sweden withdrew from CODAP at the end of the first term. A hypothetical question relates to how the Nordic PSA group (NPSAG) would pursue a future R-book update project should such a need be identified.
- In its communications with nuclear industry organisation it is incumbent upon the CODAP MB to clearly state all relevant disclaimers regarding the database completeness and comprehensiveness as well as the status of data submission (frequency and extent).
- There is a possible “dichotomy” in the way the R-book project evolved. That is, on the one hand a “de-contented” database project product was used in developing a proprietary application project product. On the other hand, PSA practitioners need complete data to estimate certain input parameters to meet PSA standard requirements. Whenever a question arises about data incompleteness such as “why is system ‘X’ not represented in the database?” it becomes essential that such user feedback reach the CODAP MB.
- Whenever a PSA application is completed the CODAP MB should solicit, document and evaluate database user feedback as a means for making improvements where needed.
- In re-designing the CODAP IT architecture, the CODAP MB should evaluate the different options for PSA user access to the database, including facilities for interrogating the database and preparing calculation data input.
- Current reporting requirements in participating countries should be revisited and enhanced to allow easier data collection and inclusion in various database projects. This is particularly important for staff of regulatory agencies to stay current with the operating experience of the existing fleet of nuclear power plants.

5. Conclusions and recommendations

Based on its analysis of the key findings documented in chapter 4, the core task group for the joint activity between the Working Group on Risk Assessment (WGRISK) and the database projects developed some general conclusions with respect to the use of database products in probabilistic safety assessments (PSAs). This chapter summarises these conclusions and provides recommendations for further WGRISK activities that could follow from them.

5.A. General conclusions

The joint workshop held by the NEA database projects and WGRISK provided some new insight into the use of the database products for PSAs, from the perspective of participants in both WGRISK and the database projects. The following conclusions have been drawn:

The NEA databases are sufficiently mature to support risk-informed decision making. However, it is obvious that some limitations and challenges exist. It is therefore important to continue to extend the data collection in the longer term in a consistent and quality-assured manner. Moreover, additional countries should be encouraged to join these projects in order to further extend the data and improve their usefulness.

Proposals to extend the data with more detailed and precise information, as well as through additional data sources, have been provided and will be discussed by the participants of the database projects. Such extensions, including cross-cutting topics between, for example, the International Common-cause Failure Data Exchange (ICDE) and the Fire Incidents Records Exchange (FIRE) databases on common-cause failures of active fire protection features may attract new countries to these projects. An additional thought is to extend the data collection to the decommissioning phase or to research and demonstration reactors.

Moreover, some applications of the database products, such as operating experience feedback or root cause analysis, can further support risk assessment.

The database projects are open for new participants according to the rules and regulations of the NEA. More information about the NEA database projects ICDE, FIRE and Component Operational Experience, Degradation and Ageing Programme (CODAP) can be obtained from the Committee on the Safety of Nuclear Installations (CSNI) website (www.oecd-nea.org/jointproj/) or by contacting the NEA Secretariat.

5.B. Recommendations to WGRISK

Recognising that a variety of PSA and risk-related activities are underway in participating countries and international organisations, WGRISK should consider carrying out a future task aimed at sharing on a regular basis the results, lessons learnt and challenges from the NEA database project activities. Such a task should be co-ordinated between WGRISK and the ongoing NEA joint projects as well as with other NEA working groups, which would likely provide useful perspectives. Examples of other NEA working groups to co-ordinate with include:

- Working Group on External Events (WGEV);
- Working Group on Human and Organisational Factors (WGHOF);

- Working Group on Integrity and Ageing of Components and Structures (WGIAGE);
- Working Group on Operating Experience (WGOE).

5.C. Recommendations to the database projects

The ICDE project allows multiple countries to collaborate and exchange common-cause failure (CCF) data to enhance the quality of risk analyses, which include CCF modelling. CCF events are typically rare, therefore 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 data collection provides a structure and basis for component-specific quantification of CCF rates and probabilities. A quantitative application example with use of ICDE data has been performed.

The ICDE project has published reports on collection and analysis of CCF events of specific component types and topical reports. What can be said is 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 (including maintenance and testing) or design, rather than manufacturing deficiencies, would not have been possible without deep plant data collection and combining information from many sources.

Several analyses are ongoing in parallel in the ICDE database project. The qualitative analyses will continue and result in insights and lessons learnt about the collected data. This work is part of one of the objectives of the ICDE to generate qualitative insights into CCF events to prevent them or mitigate their consequences.

Future components and issues for topical analysis are continuously discussed by the project participants. The list of topics to focus upon is open and new topics can always be suggested. Recent or ongoing topical analyses are intersystem dependencies and pre-initiator human failure events (HFEs). Other interesting topics that have been up for discussion are safety culture and grease/lubrication issues. In general, a focused topical failure analysis can improve the search for CCF defences and decrease the occurrence of CCF events.

Maybe the most important generic lesson is that it is worth forming specialised data exchange projects like the ICDE. This, however, requires first the will of several countries to form a critical mass by combining their operating experience efforts; second, it requires national efforts to collect and code the data at a more detailed level than those made publicly available as licensee event reports (LERs) or reports from the international reporting system for operating experience (IRS); third, it requires the forming of a legal framework to protect this proprietary data and, fourth, a long-term commitment to consistently continue and develop the activity.

One of the major objectives of the data collection in the FIRE database project is to provide different types of data which can be used mainly as generic prior information for fire risk assessments if the plant-specific data and, in some cases, also the generic data available on a national basis are insufficient. It is therefore recommended to further increase the number of quality-assured event records with more precise information on the event sequences and the boundary conditions of the events. The gaps which still exist should be closed to enable the analysts to use more of the data for future analysis. Extensions of the database capturing fires also in research, pilot, and demonstrating reactor facilities as well as fires during reactor decommissioning phases have been identified as beneficial. As fires remain a significant issue for all types of nuclear installations, even after the end of commercial plant operation or in nuclear embarking countries, it is important to encourage institutions from more countries, including Electric Power Research Institute (EPRI), to join the FIRE database project to increase the value of the data for PSA applications.

The CODAP database project has collected and evaluated a significant volume of operating experience data on passive component material degradation and failure. Since its establishment in 2002 (through the piping failure data exchange [OPDE] project), the issue of equitable data exchange among participating organisations has been at the forefront of the annual work planning activity. The project still faces challenges in ensuring data submittals that are representative of the many different material degradation issues that arise in any given calendar year.

CODAP relies on the voluntary and equitable exchange of operating experience data. In its present form the database content is influenced by three factors:

1. differing national event reporting requirements and routines;
2. extent of (i.e. more/less/no) data exchange participation;
3. differing national codes and standards.

There are challenges in obtaining and evaluating the relevant operating experience. Mainly this is due to two factors: a) degraded conditions that are discovered during in-service inspections are typically not documented per abnormal occurrence reporting or licensee event reporting routines; and b) associated flaw evaluation reports and NDE results tend to be classified as restricted or proprietary information.

The role of the NEA databases such as CODAP is to support applications. Therefore, CODAP should re-focus its attention on making the database more application-oriented. There are four application areas to consider:

- information tool for regulatory site inspectors to help identify relevant material degradation scenarios at plants of similar or like designs;
- information tool for evaluating the effectiveness of in-service inspection programmes and technologies;
- information tool for evaluating the effectiveness of ageing management programmes;
- data source for PSAs.

Collecting and analysing material degradation data is technically challenging and resource intensive. Modernising the CODAP infrastructure is key to instilling a deeper interest in and committing adequate resources to the continued data exchange. The “CODAP infrastructure” entails the web interface and related software tools to facilitate data exchange and data analysis. Plans are in place for various software upgrades to be developed and implemented in the near term. Continued software development should be encouraged to modernise the CODAP database web interface. National regulatory bodies should provide sufficient resources (time and staff) to ensure the most effective data submission, which in turn affects the completeness, comprehensiveness and usefulness of the database. The current reporting requirements in participating countries could be enhanced to facilitate information sharing from licence reports and their integration in the CODAP database.

As a general conclusion, applicable to all three NEA database projects, it is recommended that all the publicly available documents, papers and other references be made more easily accessible through the websites of WGRISK and the database project websites. Annex E includes a list of publications by the database projects sharing information for PSA use.

5.D. Recommendations to CSNI and CNRA

The PSA provides a useful perspective on operating experience, as indicated by accident precursor analysis programmes in several participating countries, as well as by a past WGOE activity on precursors to the Fukushima Daiichi reactor accidents. The NEA databases provide highly valuable information from the operating experience that can be directly or indirectly used to support risk-informed decision making. However, the database projects do not provide guidance on how to apply the data recorded by them in probabilistic risk analysis. This remains the responsibility of the participating countries.

The CSNI and the CNRA should therefore:

- consider sponsoring further joint working group(s) and/or database project(s) activities concerning lessons learnt from operational incidents;
- more generally, continue to support efforts to permanently increase interactions between the WGRISK and the NEA joint database projects;
- encourage and facilitate co-operation with other NEA projects and working groups as well as with the IAEA on related topics to address the challenges of PSA methods and data and associated risk-informed decision making.
- encourage institutions from participating countries to join the database projects in order to increase the amount of data available and their applicability.

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Annex A: CAPS WGRISK (2017)1

Annexes A-D can be found on the NEA website at the following address: https://www.oecd-nea.org/psa-database-annexes.

Annex B: Workshop announcement

Annexes A-D can be found on the NEA website at the following address: https://www.oecd-nea.org/psa-database-annexes.

Annex C: Workshop programme

Annexes A-D can be found on the NEA website at the following address: https://www.oecd-nea.org/psa-database-annexes.

Annex D: Workshop papers and presentations

Annexes A-D can be found on the NEA website at the following address: https://www.oecd-nea.org/psa-database-annexes.

Annex E: Lists of publicly available documents from the OECD/NEA joint database projects

WGRISK and database publications

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