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NUCLEAR ENERGY AGENCY
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

NEA/CSNI/R(2009)6
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FIRE Project Report: "Collection and Analysis of Fire Events (2002-2008) - First Applications and Expected Further Developments"

June 2009

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of 30 democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

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NUCLEAR ENERGY AGENCY

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

The mission of the NEA is:

– to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as

– to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information.

The NEA Data Bank provides nuclear data and computer program services for participating countries. In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

The NEA Committee on the Safety of Nuclear Installations (CSNI) is an international committee made up of senior scientists and engineers, with broad responsibilities for safety technology and research programmes, and representatives from regulatory authorities. It was set up in 1973 to develop and co-ordinate the activities of the NEA concerning the technical aspects of the design, construction and operation of nuclear installations insofar as they affect the safety of such installations.

The committee's purpose is to foster international co-operation in nuclear safety amongst the OECD member countries. The CSNI's main tasks are to exchange technical information and to promote collaboration between research, development, engineering and regulatory organisations; to review operating experience and the state of knowledge on selected topics of nuclear safety technology and safety assessment; to initiate and conduct programmes to overcome discrepancies, develop improvements and research consensus on technical issues; to promote the coordination of work that serve maintaining competence in the nuclear safety matters, including the establishment of joint undertakings.

The committee shall focus primarily on existing power reactors and other nuclear installations; it shall also consider the safety implications of scientific and technical developments of new reactor designs.

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

PREFACE

After the CSNI State-of-the-Art Report on level-1 PSA methodology [CSNI/R(92)18] was published, a study on fire risk assessment was started by PWG5 (now WGRISK), which resulted in the international workshop on fire risk assessment held from 29 June to 2 July 1999 in Helsinki, Finland and in a State of the Art report on "*Fire risk analysis, fire simulation, fire spreading and impact of smoke and heat on instrumentation electronics*" [CSNI/R(99)27] issued in March 2000. In 2000, the Committee on the Safety of Nuclear Installations (CSNI) of the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (hereinafter referred to as the "OECD/NEA") approved the establishment of an OECD/NEA Fire Incident Records Exchange Project on collection of data on fire events at nuclear power plants. This Project was finally established in 2002.

The objectives of the OECD-FIRE Project are to:

(a) Collect fire event experience (by international exchange) in an appropriate format in a quality-assured and consistent database (the "OECD-FIRE database");

(b) Collect and analyse fire events over the long term so as to better understand such events and their causes, and to encourage their prevention;

(c) Generate qualitative insights into the root causes of fire events in order to derive approaches or mechanisms for their prevention and to mitigate their consequences;

(d) Establish a mechanism for efficient operation feedback on fire event experience including the development of policies of prevention, such as indicators for risk-informed and performance-based inspections; and

(e) Record characteristics of fire events in order to facilitate fire risk analysis, including quantification of fire frequencies.

After more than six years of event data collection (343 events at the date of the publication of this report) it is now possible to derive relevant information for fire safety analysis, which is presented in this report. Although first applications with respect to Fire PSA are possible on a more general level, it will be important to collect as many events as possible in the future to enlarge the data base and to encourage additional participation of organisations from other OECD Member States to support the OECD FIRE Database Project.

ACKNOWLEDGEMENTS

The preparation of this reports benefited from the contributions of each National Co-ordinators of the OECD FIRE Project. Special acknowledgements are due to W. Werner for the statistical analysis and to M. Röwekamp, Chair of the FIRE Project Review Group, for the entire review of the report.

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EXECUTIVE SUMMARY

Background

Fire Hazard Analyses (FHA) and Probabilistic Fire Safety Analyses (Fire PSA) have shown that fire may be an important contributor to core damage and plant damage states. Yet, realistic modelling of fire scenarios is difficult due to the scarcity of reliable data for fire analysis. In an attempt to improve the situation, the CSNI issued a State-of-the-Art Report on level-1 PSA methodology [CSNI/R(92)18] and a study on fire risk assessment was started by the CSNI/WGRISK (formerly PWG5). In 1996, a Task Group was established to review the status and maturity of methods used in fire risk assessment for operating nuclear power plants. This group concluded in 2000 that "*The shortage of fire analysis data is one of the major deficiencies in the present fire risk assessment*." Based on these conclusions, several OECD member countries have agreed to establish the International Fire Data Exchange Project (OECD FIRE) under the umbrella of the CSNI to encourage multilateral co-operation in the collection and analysis of data related to fire events in nuclear power plants. The Project was formally launched in January 2003 for a three-year period with nine countries, which was followed by a four years term with the addition of three further countries. It is anticipated that a new term for the project will start in 2010.

Objective of the work

The objectives of the OECD FIRE Project include the establishment of a framework for multi-national co-operation in sharing event information useful to fire risk assessment. The primary activity was to define the format for collecting fire event experience in a quality assured and consistent database. In the course of the Project improvement of fire record event attributes was made to facilitate quantification of fire frequencies and fire risk analysis. The permanent activity is to collect and analyse fire events over the long term so as to better understand such events, their causes, and their prevention. The Database thus obtained allows generating qualitative insights into the root causes of fire events which can then be used to derive approaches or mechanisms for their prevention or for mitigating their consequences. Amongst the applications of the Database is the possibility for member countries to establish a mechanism for the efficient feedback of experience gained in connection with fire events, including the development of defenses against their occurrence, such as improvements of the existing national as well as international reporting systems and indicators for risk based inspections.

Description of the work

Applicable to commercial nuclear power plants only, the OECD FIRE Project exchanges fire events data covering all plant operational modes including construction and decommissioning phases. Currently, the Database contains 344 fire events, most of them quality assured. The events are from the period from the early 1980ies to 2008, with the bulk of the events in the period of the mid 1990ies to end of 2007. Although the reporting of events is not exhaustive, the Database provides a good platform for starting the analytical phase

Results and their significance

Important observations from the statistical evaluation can be summarised as follows: Fires are most likely to occur in process rooms, the origin of approximately one third of the events in the Database was the turbine building. The latter is in accordance with observations from international event databases such as IRS and INES.

With regard to fire detection and suppression, the availability of an adequate amount of suitable fire detectors and appropriate manual fire fighting capabilities is essential. A large majority of the fires could be confirmed within a very short time period (minutes). Only a minority of fires was suppressed by automatically actuated fixed extinguishing systems; in more than 75 % of the events, manual fire fighting means were involved in the successful fire suppression. The share of self-extinguished fires and of fires terminated by fire source isolation is also significant. Finally it could be concluded that events associated with long suppression times are more likely to cause severe fire effects than those with short suppression times, and they are correlated with the need for several attacks by different means of fire suppression.

Conclusions and recommendations

Although the data are inhomogeneous due to the differing reporting thresholds and criteria in the Project member states, the OECD FIRE Database provides qualitative insights into the root causes of incipient fires and the time dependent fire development. First national applications of the Database have shown the importance of detailed fire event descriptions providing broader insights beyond the information in the coded fields.

Although first applications with respect to Fire PSA are possible on a more general level, it will be important to collect as many events as possible in the future to enlarge the database by a continuous and consistent reporting of events by the Project members and to encourage additional OECD Member States to support the OECD FIRE Database Project for achieving better corroborated data for PSA use. The human factor in the fire event sequence has to be investigated in more detail. Indications of the positive effects of human intervention on fire extinguishing can already be found in the existing Database.

The database is becoming large enough to use it how to estimate room based fire initiator frequencies from information contained in the OECD FIRE database. Appendix D contains a detailed proposal how to estimate room based fire initiator frequencies from information contained in the OECD FIRE database.

One of the main questions which could be answered by the Database is how fires can propagate from the initial fire compartment to other compartments, even if there are protective means available for prevention of fire spreading.

The coding of events has to reflect as far as feasible the needs of the analysts. Therefore the Coding Guidelines are continuously improved and enhanced to meet these requirements. Improvements in the Database structure and a more consistent and exhaustive reporting to the Database will give the possibility to provide a high lev4el of information.

Data collection is continuing. Data flow of approx. 30 events per year is expected, as can be extrapolated from operating experience (about two thirds during power operation and one third during non-full power operating conditions).

Project members express the hope that this report will encourage additional participation of organisations from other OECD Member States to support the OECD FIRE Database Project.

1. PROJECT BACKGROUND

The OECD FIRE Database is one of the five nuclear power plants (NPP) operational events databases currently developed under the umbrella of the OECD/NEA. The need for such database has emerged in the late 1990s when it became evident that the International Recording System (IRS) could not allow for specific analysis and use in risk assessment. In this respect only dedicated databases allow for "topic focused" lessons learned as well as for quantitative analysis and eventually determination of initiator frequencies.

Fire Hazard Analyses (FHA) and Probabilistic Fire Safety Analyses (Fire PSA) have shown that fire may be an important contributor to core damage and plant damage states, particularly for older NPP. Yet, realistic modelling of fire scenarios is difficult due to the scarcity of reliable data for fire analysis.

In an attempt to improve the situation, the CSNI issued a State-of-the-Art Report on level-1 PSA methodology [CSNI/R(92)18] and a study on fire risk assessment was started by the CSNI/WGRISK (formerly PWG5). In 1996, a Task Group was established to review the status and maturity of methods used in fire risk assessment for operating nuclear power plants. The Task Group issued a questionnaire in May 1997 to all nuclear power generating OECD countries. The Summary Report [1] of this activity was published in March 2000. One of its concluding remarks was as follows:

"The shortage of fire analysis data is one of the major deficiencies in the present fire risk assessment. In order to facilitate the situation, it would be highly important to establish an international fire analysis data bank, similar to that set up by OECD for the CCF data collection and processing system (ICDE/CCF data bank at OECD). Such a data bank would provide fire event data on real fire cases, incipient fires (e.g. smoldering) detected/extinguished before development, dangerous or threatening situations, reliability data on fire protection measures, and the unavailability of fire fighting systems, for example, due to component failures or operational errors."

Based on the above concluding remarks, several OECD member countries have agreed to establish the International Fire Data Exchange Project (OECD FIRE) to encourage multilateral co-operation in the collection and analysis of data related to fire events in nuclear power plants. During its 2000 annual meeting, CSNI formally approved the carrying out of this Project. The Project was formally launched in January 2003, initially joined by 9 countries. At the end of the first term (December 2005), a second term was agreed on, ending after December 2009. Currently, twelve OECD member countries have signed the OECD FIRE agreement (Canada, Czech Republic, Finland, France, Germany, Japan, Korea, The Netherlands, Spain, Sweden, Switzerland and United States).

The operation of the project is described in detail in the Operating Procedures [2]. In particular, the responsibilities of the participants, the funding and the distribution of the Database are addressed. The Project is managed by a Project Review Group composed of National Coordinators (NC) of the participating countries, who have full responsibilities to take decisions for the Project. Funding is provided by each country and the Operating Agent (OA) ensures the quality assurance (QA) and the operation of the Database.

Applicable to commercial nuclear power plants only, the OECD FIRE Project exchanges fire events data covering all plant operational modes including construction and decommissioning phases.

Currently, the Database contains 344 fire events, the majority of these being quality assured, for the others quality assurance (QA) pending. The events are from the period from the early 1980ies to 2008, with the bulk of the events in the period of the mid 1990ies to end of 2007. Although the reporting of events is not exhaustive, the Database provides a good platform for starting the analytical phase.

Data collection is continuing. Data flow approx. 30 events per year is expected, as can be extrapolated from operating experience (about two thirds during power operation and one third during non-full power operating conditions).

2. PURPOSE AND SCOPE OF THE PROJECT

Improving the safety of nuclear power plants by better accounting for feedback from operating experience and by providing common resources for analytical work in the frame of deterministic and probabilistic assessments is the main objective of the OECD FIRE Project. To fulfill this objective, the Project includes the establishment of a framework for a multi-national co-operation in fire data collection and analysis. The objectives of the OECD FIRE project are:

- to collect fire event experience by international exchange in an appropriate format in a quality assured and consistent database (the "OECD FIRE Database");
- to collect and analyse fire events over the long-term so as to better understand such events and their causes, and to encourage their prevention;
- to generate qualitative insights into the root causes of fire events in order to examine:
    - approaches or mechanisms for their prevention and mitigation of their consequences
    - fire causes
    - new dependencies as a result of fires having occurred
- to establish statistics based on the Database contents for e.g. identifying repeating causes, fire mechanisms, etc.;
- to support member countries to establish more effective national fire event reporting practices;
- to establish a mechanism for the efficient operational feedback on fire event experience including the development of policies of prevention, such as indicators for risk informed and performance based inspections; and
- to record characteristics of fire events in order to facilitate fire risk analysis, including quantification of fire frequencies.

The Database is envisioned to be used to

- support model development, validation, etc.;
- identify all types of events and scenarios for inclusion in PSA models ensure that all mechanisms are accounted for;
- support fire PSAs by real data;
- compare fire event data from member states with the accumulated international data collected within the OECD FIRE Database.

With emphasis on data validity and data quality, OECD FIRE Coding Guidelines [3] have been developed (see also Appendix A) for collecting and classifying fire event data to ensure consistent interpretations and applications. The Operating Procedures [2] and the Quality Assurance Manual [4] complete the Project documentation. This task of document elaboration has been an important part of the first phase of the Project (2003 - 2005).

Fire data have been continuously delivered to the OECD FIRE Project since January 2003. The first data collection concerned the observation period from 1 January 2001 to 31 December 2002. The first data collection had several objectives:

- to confirm and, if necessary, improve the design and attributes of the OECD FIRE Database;
- to confirm and, if necessary, improve the Coding Guidelines against data;
- to test routines for further data collection.

Since 2004, and based on the feedback from the first years stable routines for reporting and quality assurance [4] are in place.

One challenge in setting up an international database is to ensure a consistent reporting level between countries in order to capture all events fulfilling the objectives of the project. Regulatory and utilities' reporting levels are different between member countries (e.g., did the fire or did it not affect safety equipment, different duration thresholds, etc.), and, in addition, the reporting criteria may have changed with time. For events from the past, the Database includes for reference the evolution with time of reporting levels. For future events, one objective of the first three years phase was to define a project reporting level, which will account for the countries' policies while correctly addressing the technical objectives of the project.

Fire events considered in the OECD FIRE Database are defined as follows [3]:

- Any process of combustion characterised by the emission of heat accompanied by (open) flame or smoke or both, or
- Rapid combustion spreading in an uncontrolled manner in time and space.

Note:

This includes incipient fires as well as fully developed fires. Fires shall be included in the Database if they are relevant to safety and also if the same type of fire has the potential to be relevant/significant for safety under different boundary conditions (such as different ventilation conditions, other plant operating states (POS), same components affected in other locations, etc.). Explosions not resulting in an open flame shall be excluded.

3. STRUCTURE OF THE DATABASE

3.1 Reported events

The reporting of fires is limited to nuclear power plants. Fires at research reactors, nuclear waste storage facilities, etc. are excluded. The reporting includes all plant internal fires on-site (inside and outside buildings) as well as plant external fires if these have the potential to impact nuclear safety. The reporting shall include fires in all operation modes, also fires during construction and decommissioning.

3.2 Description of OECD FIRE events

The OECD FIRE event is described by the narrative event description and a number of coded descriptive fields with attributes selectable from predefined menus. The source of information normally is the narrative event description; the entries in the coded fields are derived from the narrative event description. The classification of the fire event through coded attributes provides the possibility to search for and identify specific fire events of interest in the OECD FIRE Database for a wide range of applications. Details are provided in Appendix B.

3.3 Relevance indices

Relevance indices are implemented to characterise the quality of fire event reports collected in the OECD FIRE Project. The rationale to introduce relevance indices is twofold:

- The Operating Agent wants to have a mechanism that allows filtering out issues in the reports for which more information must be sought.
- The user desires to have knowledge of the completeness of the information in the Database and of the degree of confidence he can put in the information in the Database if he wants to analyse data for various purposes.

The relevance indices essentially are “completeness indices”, i.e. they measure how complete and detailed the reported information is and by what kind of references it is supported.

3.4 Fire event analysis support data

Fire event analysis requires supporting data that are stored in two database support modules. These are:

- The *Reporting Threshold Module* defines thresholds for reporting fire events to authorities by the utilities. If collected fire data are to be used for statistical purposes it is essential to know the reporting routines applied in the various countries. Essentially, there are two different reporting threshold levels:

  - **LER level fires:**
    The Licensee Event Report (LER) level is normally defined in the technical specifications. Several different definitions exist, depending on member country and date of the fire event. In some member countries a fire event will be reported as a LER if it had affected a safety component. Other LER definitions are based on the duration of the fire.
  - **All fires:**
    Some OECD FIRE member countries have access to all fire reports. This fact also has to be documented in the reporting threshold module.

- The *Fire Brigade Organisation Module* contains the general description of on-site and off-site fire brigade organisation. Distance between plant and off-site fire brigade stations as well as off-site fire brigade response time are provided. Changes over time in the organisation can be addressed in the Database.

3.5 Further improvements to the database

Experience with the OECD FIRE Database in its current form suggests improvements that would enable more detailed analyses of fire events. This would entail revisions of the Coding Guidelines and corresponding changes of the Database coding and structure, as well as substantial re-coding work. Such improvements are envisaged to be implemented in the next phase of the project. They are described in Section 8 Conclusions.

4. CONTENTS AND BASIC STATISTICS

4.1 Database contents

Fire data have been continuously delivered to the OECD FIRE Project. Today, data collection is a continuing process and stable routines for reporting and quality assurance are in place.

Currently, the Database contains 344 fire events, the majority of these being quality assured, for the remaining ones QA pending. The events are from the period early 1980ies to 2008, with the bulk of the events in the period from the mid 1990ies to 2007. Although the reporting of events is not exhaustive, the OECD FIRE Database provides already a good platform for starting with analysis work.

One challenge in setting up an international database is to ensure a consistent reporting level between countries in order to capture all events fulfilling the objectives of the project. Regulatory and utilities' reporting levels are different between member countries. The respective information is collected in the Reporting Threshold Module of the Database (see section 3.4).

4.2 Statistics

This Section presents statistics on selected important features of all the data collected up to the end of 2008 in the OECD FIRE Database. The statistics are mostly not exhaustive, i.e. the presented numbers do not add up to 100 % because only the more important features are included in the presentation of statistical results, or because relevant information is missing for some events, or because the thresholds for reporting events to the Database vary between member countries.

Figure 1 shows the statistics of time from first alarm to confirmation of the fire, i.e. verification of the occurrence of a fire and identification of its location. As can be seen 70 % of the fires were confirmed within two minutes after the alarm, most of them within one minute. On the other hand 15 % of the fires needed more than five minutes to be confirmed. For 10 out of 344 events the time to confirmation is unknown. There is no conspicuous correlation between time to confirmation and the severity of consequences of fires.

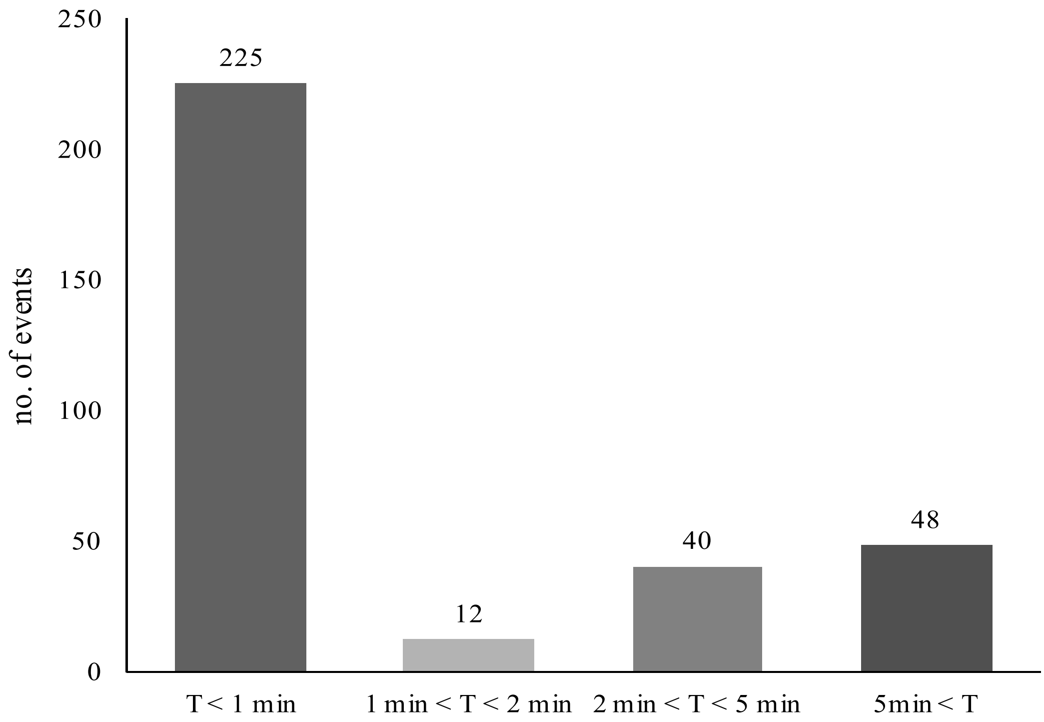


Figure 1: Time T to fire confirmation of for all reported events

Figure 2 shows the time from the first alarm to the suppression of the fires for all events with known suppression time. There is a steady decrease of the times to suppression. Only 11 % of the fires needed suppression times in excess of one hour. Some of these were transformer fires that needed long extinguishing times because of the large amounts of hot metal. The number of reports with unknown suppression time is large.

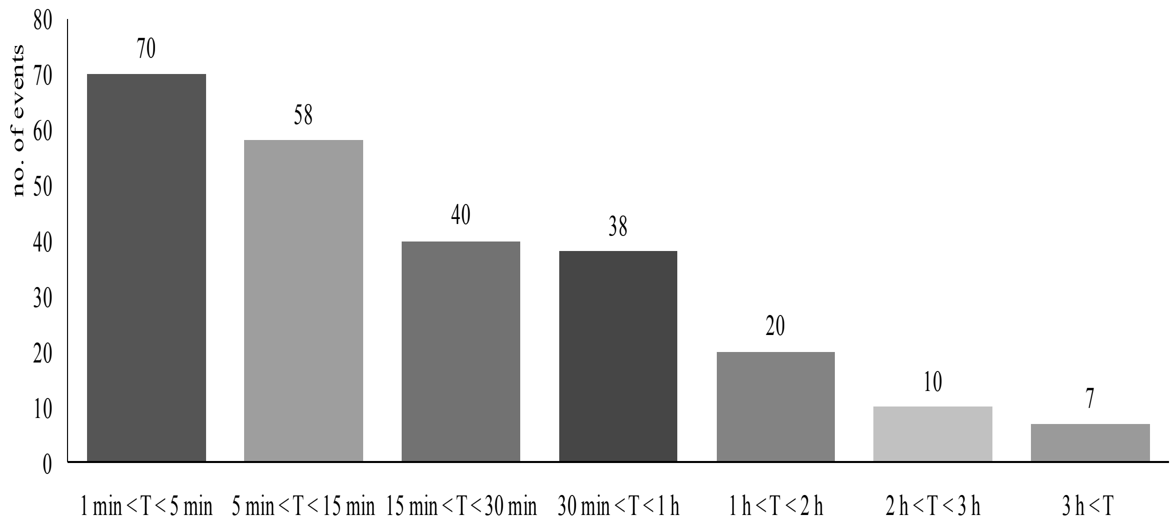


Figure 2: Time to fire suppression for all reported events

Figure 3 shows that a completely different distribution of suppression times is observed for the 11 events with known suppression times that led to severe structural impact as defined in this report ("Structural influence or collapse", "Adjacent rooms affected", "Total loss of one room", "More than one fire compartment affected"). For all events (see *Figure 2*) the suppression times decrease steadily from the peak at the lowest suppression time, but for events leading to severe structural impact the peak of suppression times is at the time interval of 30 min < T < 60 min, and the bulk of the distribution is at suppression times 30 min < T 45 % of the events leading to severe structural impact needed suppression times of more than one hour, in contrast to *Figure 2*, all events, where the contribution of this range of suppression time periods is only 11 %. This supports the forgone conclusion that fires leading to severe structural impact are more difficult to suppress. This is further corroborated by the observation that 40 % of the events leading to severe structural impact needed several attacks to be completely suppressed, whereas only 11 % of "all events" needed several attacks. For fires leading to severe structural impact a strong correlation between the need for several attacks and the time required to suppress the fire seems to exist.

There are five events leading to severe impact on safety trains as defined in this report (codings "All safety trains of one system affected", "More than 1 safety train (but not all) affected"). One of these events affected more than one fire compartment and is therefore included in *Figure3*. Its suppression time was in the 120 min < T < 180 min range. The distribution of suppression times (See *Figure 4*) is similar to that in *Figure 2*. Furthermore, none of the events required several attacks. Thus, regarding suppression times and number of attacks needed, there is nothing conspicuous about events affecting safety trains, unless they are accompanied by severe structural impact.

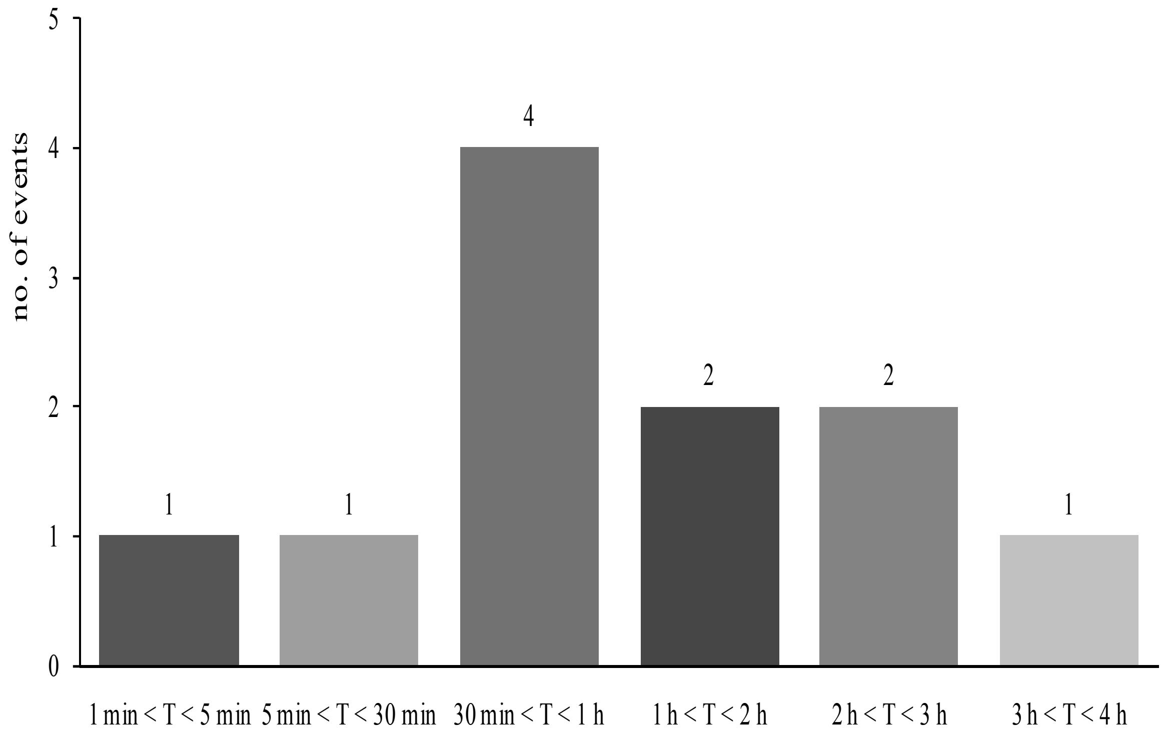


Figure 3: Time to suppression of fires with severe structural impact

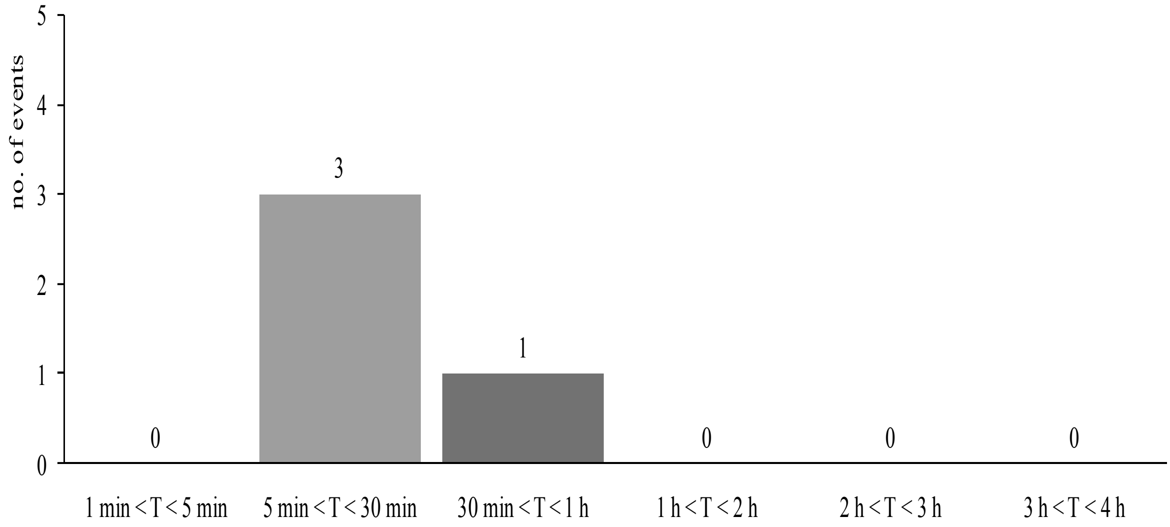


Figure 4: Time to suppression of fires with severe impact on safety trains

The contribution to fires from buildings is dominated by the turbine building (See *Figure 5*). For all events, this contribution is 27 %, for events with severe fire effects it is 40 %. Fires in the turbine building are more likely to lead to severe fire effects than those originating in other buildings.

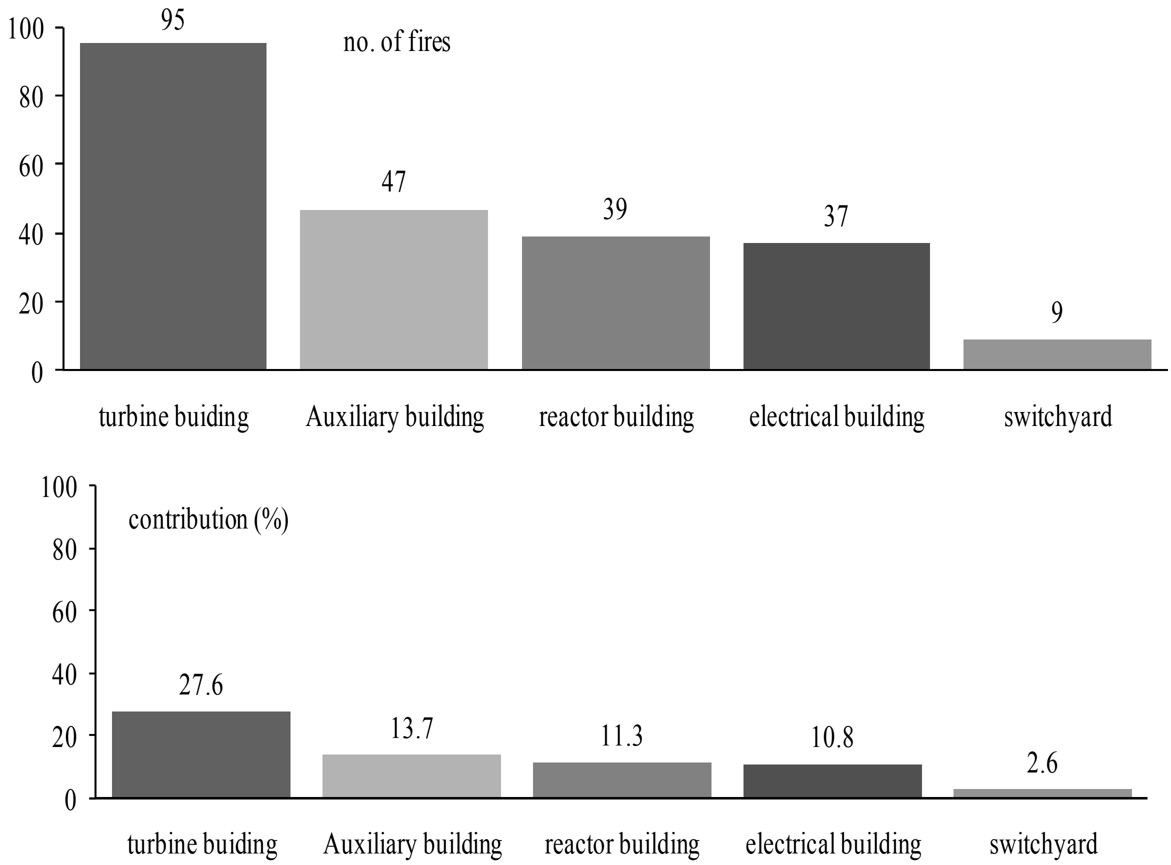


Figure 5: Contribution of buildings where fires mainly occurred

Regarding the types of rooms where fires have occurred, the highest contribution is found in process rooms (35 %, see *Figure 6*), approx. 60 % of these being located in the turbine building. For events with severe fire effects the contribution of fires in process rooms is 40 %. This indicates that fires in process rooms are more likely to result in severe effects than fires originating in other types of rooms.

The ignition mechanisms are dominated by “electrical” with approx. 47 % (see *Figure 7)*. However, the ignition sources “hot component” and “hot work” also represent significant contributors.

With regard to fire extinguishing, the dominant method for fighting fire is “manual fire fighting alone” with a contribution of nearly 50 % (see *Figure 10*) Fixed automatically actuated fire extinguishing systems were demanded in case of 8 % of the events, for 2 % of the events the fires were extinguished solely by automatically actuated systems. In the remaining cases combinations of several methods, which all included manual fire fighting, were applied. The category “self-extinguished, fire source isolation, controlled burn out” also contains manual actions. Thus, for most of the fire events collected in the Database the fire suppression involved manual actions.

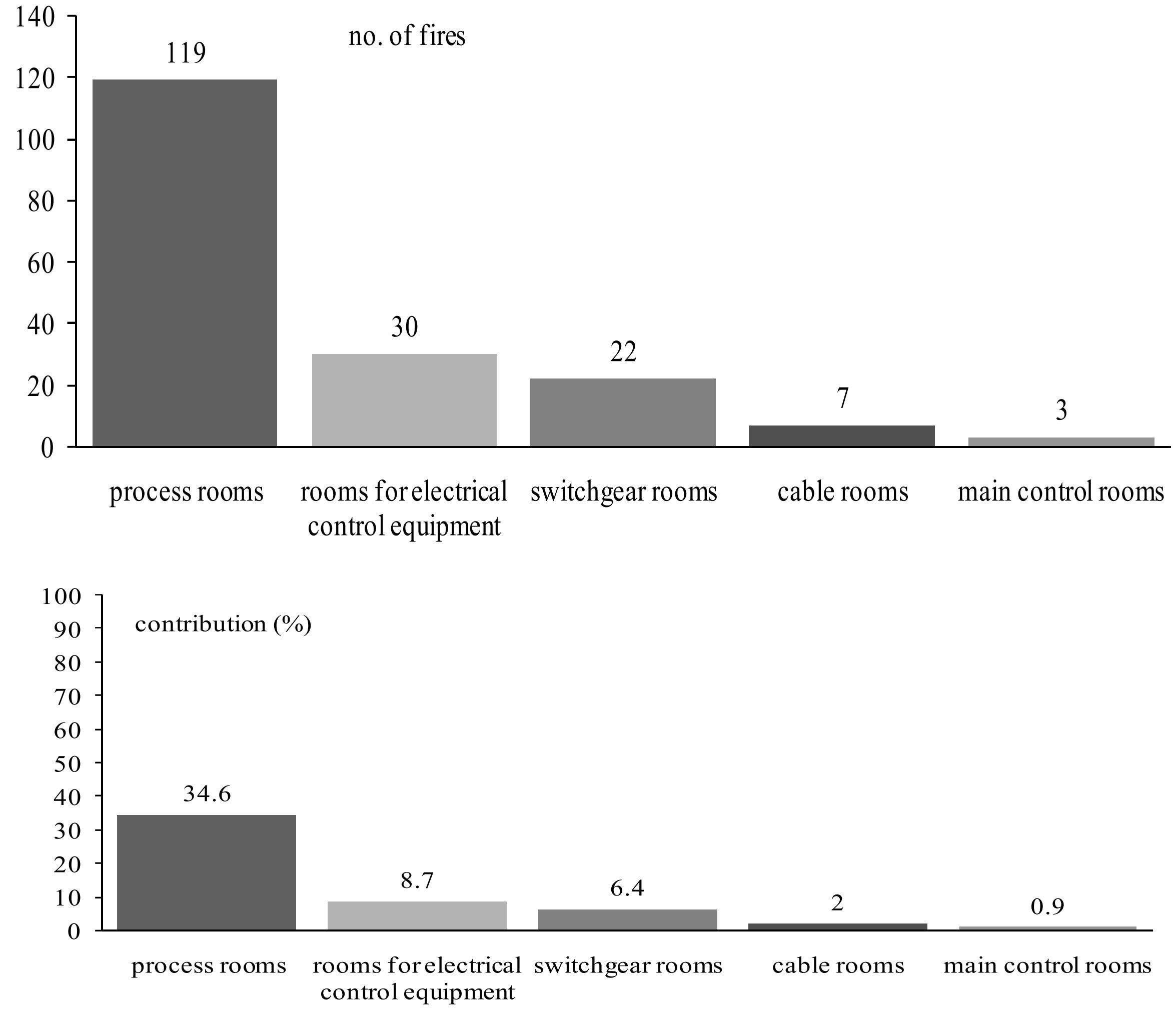


Figure 6: Contribution of room types where fires mainly occurred

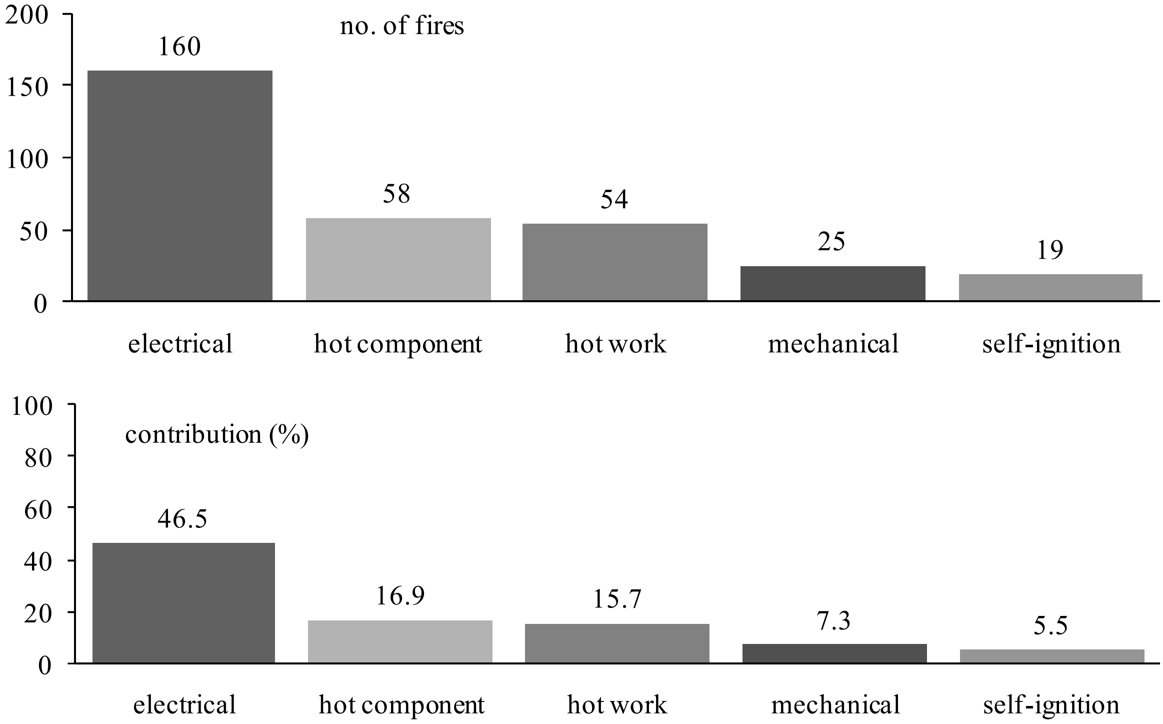


Figure 7: Contributions of the different ignition mechanisms

The ignition mechanisms are dominated by "electrical" with approx. 46% (see *Figure 7*). However the ignition sources "hot component" and "hot work" also represent significant contributors. For the consequence category "Two or more safety trains lost" the contributions from the ignition mechanisms are significantly different (See *Figure 8*).

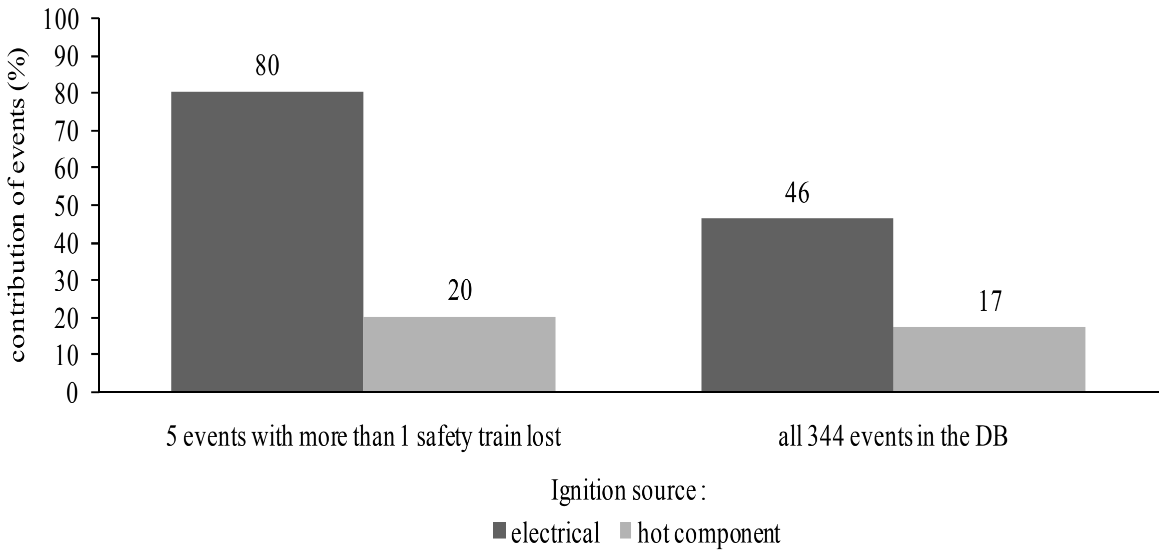


Figure 8: Comparison of percentage of significant contributions from ignition sources for events from consequence category "Two or more safety trains lost" and all events.

Similar differences are observed for the contributions from root causes (See *Figure 9*).

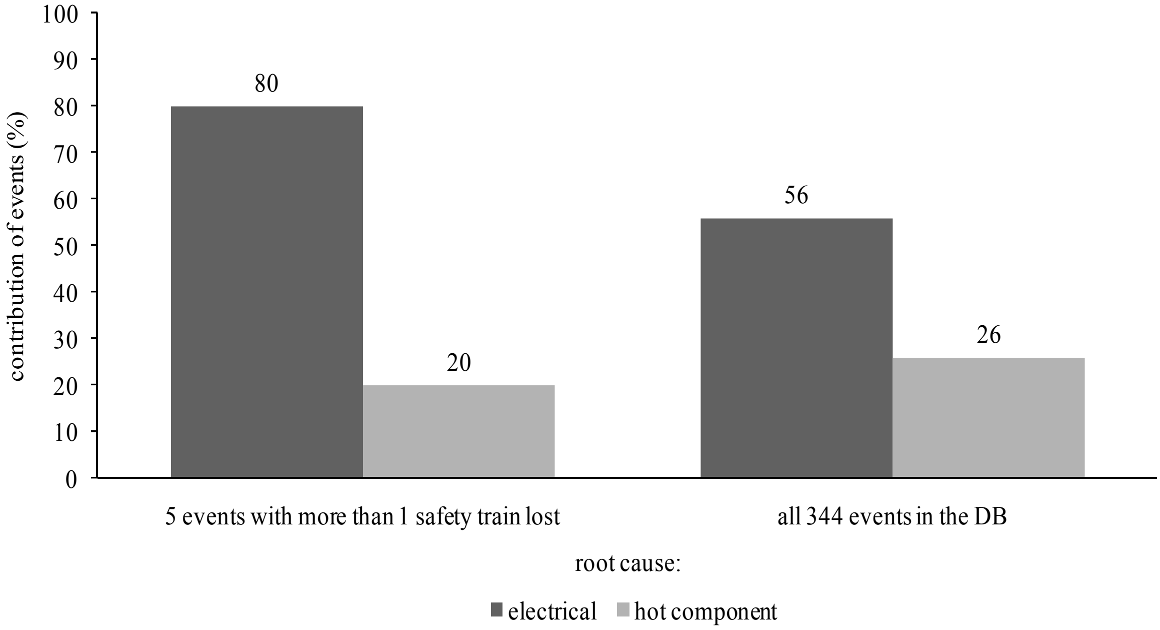
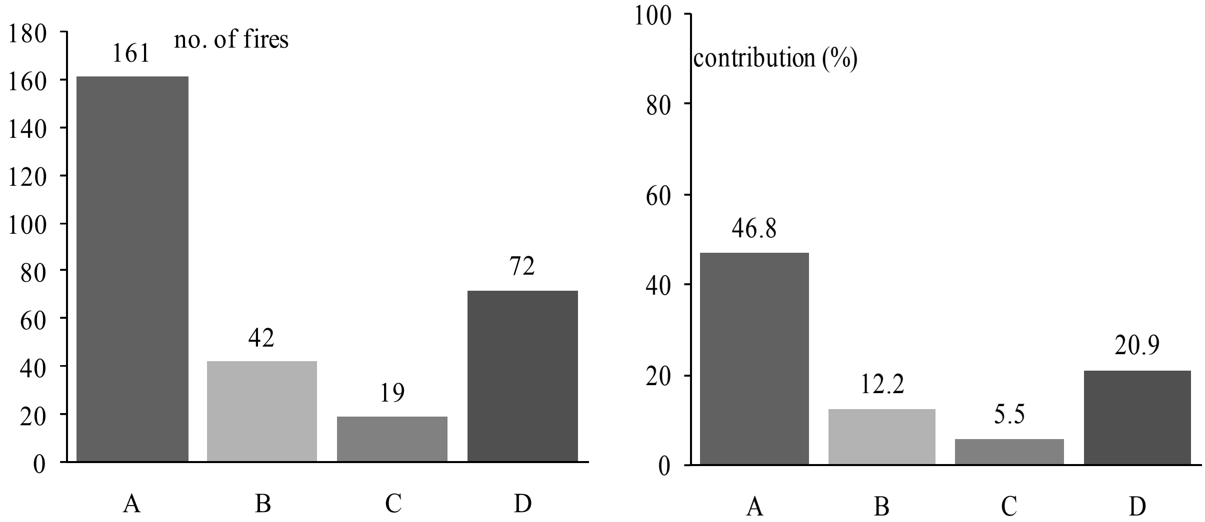


Figure 9: Percentage of important contributions from root causes for events from consequence category "Two or more safety trains lost" versus all events.

Comparison of the events from the consequence category “Two or more safety trains lost" to the complete OECD FIRE Database leads to the following findings:

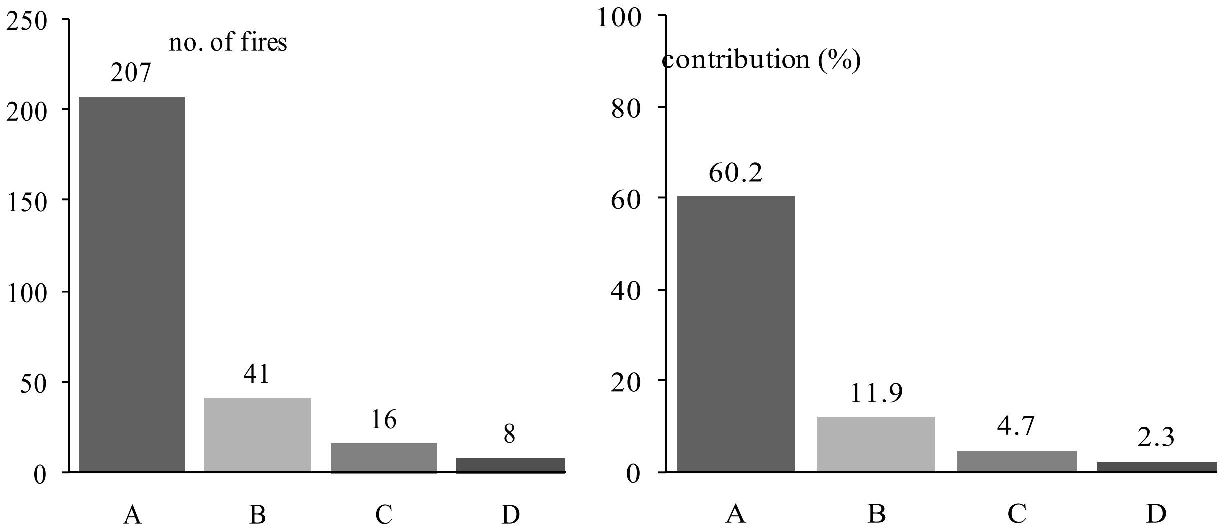
- *Ignition sources and root causes*
  For the consequence category “Two or more safety trains lost”, the contributions from the ignition source “electrical” and from the root cause “equipment” (approx. 80 %) by far exceed the average values (46 % and 56 %) for all events. In many cases where electrical devices are the source of ignition, these devices are no longer functionally available from the beginning of the fire event. Hereby at least one safety train may be lost. Additional trains may be lost due to fire spread, or due to inadequate response to the initial fire event.
- *Fire fighting performance*
  The fire fighting performance was coded “normal” in all cases. However, 40 % of the 14 events from the consequence categories “more than one fire compartment affected”, “adjacent rooms affected”,” total loss of one room”, or “structural impact or collapse” needed several attacks to finally extinguish the fire. For all events, only 11 % needed several attacks to extinguish the fire, see *Figure 12*. This comparison indicates that fires which are difficult to fight potentially lead to more severe effects as mentioned above. For the more severe events more detailed information on the fire fighting process is principally available.



Legend:
A: *manual fire fighting alone*
B: *fixed system manually actuated and manual fire fighting*
C: *fixed system automatically actuated, or manual fire fighting and fixed system automatically actuated*
D: *self-extinguished, or fire source isolation, or controlled burn out*

Figure 10: Types of fire extinguishing

The OECD FIRE Database demonstrates the importance of the on-site fire brigade and other plant personnel trained in fire fighting (See *Figure 11*). About two thirds of the fires were extinguished by plant personnel (including the on-site fire brigade) alone. In 12% of the cases plant personnel was assisted by an external fire brigade, only 2% of the fire events were extinguished by automatically actuated systems alone.



Legend:
A: *on-site plant fire brigade, shift personnel, people available in the fire area*
B: *on-site plant fire brigade or shift personnel with participation of an external fire brigade*
C: *fixed fire extinguishing system; on-site plant fire brigade*
D: *automatically actuated fixed extinguishing system alone*

Figure 11: Who extinguished the fire

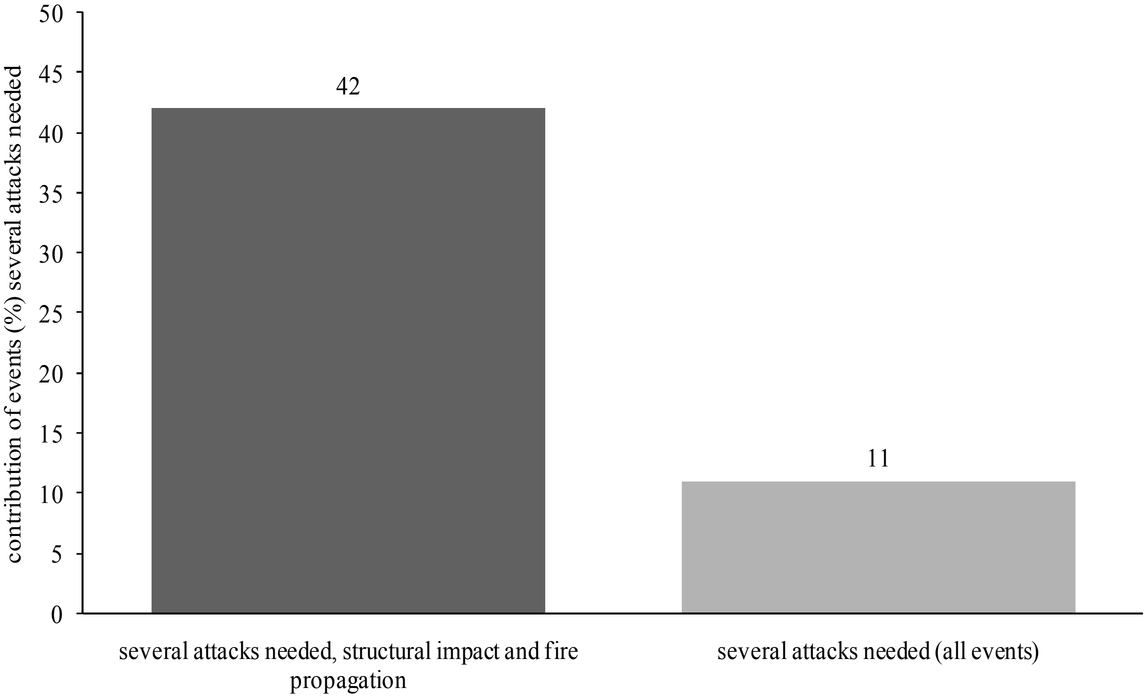


Figure 12: Percentage of several attacks needed for events from consequence categories" more than one fire compartment affected", "adjacent rooms affected", "total loss of one room", or "structural damage or collapse" versus all events.

4.3 Conclusions from the statistic analysis

The following conclusions can be drawn from the statistical evaluation of the information gathered to date in the actual version of the OECD FIRE Database with in total 344 events:

- *Confirmation of fires:*
  Approx. 70 % of the fires were confirmed within two minutes after the alarm, most of them within one minute. Only for 14 %, more than five minutes were needed for confirmation. On the plant wide basis, there is no statistically significant evidence that longer times to confirmation lead to more severe effects.
- *Times to suppression of fires:*
  There is a strong positive correlation between long suppression times and the severity of consequences of fire events, i.e. events associated with longer suppression times are more likely to result in severe effects than those with short suppression times. Furthermore, events with long suppression times are likely to require several fire fighting attacks, partly with different types/means of extinguishing.
- *Origin of fires:*
  Regarding the buildings of fire occurrence, fires are most likely to occur in the turbine building (approx. 30 %). With respect to the types of rooms of fire origin, process rooms (as defined in Appendix A), particularly in the turbine building, have the highest fire occurrence rate. Furthermore, fires in the turbine building and in process rooms are more likely to cause severe consequences (structural damage as well as significant impact on safety trains) than fires anywhere else.

  Note: Severe consequences on safety trains in turbine buildings can only occur in those plants where safety significant trains are located there.
- *Types of fire extinguishing:*
  The majority of events involved manual fire fighting actions. 11 % of the fires required several and partly different fire fighting attacks for successful suppression. Self-extinguished fires, fires terminated by isolation of the fire source or by controlled burn out also represent significant contributions. Fixed automatically actuated fire extinguishing systems were demanded in 8 % of the events, 2 % of the fire events were extinguished by automatically actuated extinguishing systems alone.
- *Who extinguished the fire:*
  About two thirds of the fires were extinguished by the on-site plant fire brigade, shift personnel, and other people available in the fire area, most of these by manual fire fighting alone, and fewer by a combination of manual fire fighting and fixed systems. Another 12 % of the fires were extinguished by the on-site plant fire brigade and shift personnel with participation of an external brigade. Only 2 % of the fires (mainly transformer fires) were suppressed solely by stationary fire extinguishing systems automatically actuated by the fire detection systems.
- *Fire fighting performance:*
  The fire fighting performance was "normal", meaning successful, in all cases. Only 11 % of all events in the Database needed several attacks for fire suppression, However, 40 % of the events in the consequence categories "more than one fire compartment affected", "adjacent rooms affected"," total loss of one room", or "structural damage or collapse" needed several attacks. This indicates that there is a correlation between the number of attacks and duration of suppression and the severity of the consequences.

5. NATIONAL APPLICATIONS OF THE DATABASE

Information from the OECD FIRE Database has been used by participating countries in the study of the following issues and more detailed descriptions are provided in Appendix C.

5.1 Fires and explosions (Germany)

A query in the OECD FIRE Database on the potential combinations of fire and explosion events has indicated a significant number of explosion induced fires. Most of such event combinations occurred at transformers on-site, but outside of the NPP buildings or in compartments with electrical equipment. Approximately 50 % of the fires were extinguished in the early fire phase before flashover. As a consequence of these indications, improvements concerning the fire protection of transformers are intended in Germany.

5.2 Filter fires (Germany)

Since reportable filter fire have occurred in German NPP, there is an interest of the regulators to find out more details on the potential ignition sources, fire duration and possibilities. The OECD FIRE Database surprisingly contains only a quite low number of filter fires. Most of these occurred in the auxiliary building. Unfortunately, only in few cases information on the type of the combustibles filter materials is available, indicating the necessity for improving the Database for statistical use.

5.3 Comparison of the OECD FIRE database with national databases (France, U.S.A.)

Section C-5 of Annex C provides the methodology implemented by IRSN for the estimation of the fire frequency using the French operating experience feedback, revealing a good consistency between the French and the OECD FIRE Databases. The same methodology has been applied using the OECD FIRE Database. This exercise has shown that the statistical use of the Database is easy and well adapted to define the reference numbers needed for the fire frequency estimation. Notably, the OECD FIRE Database is very useful for those countries whose operating experience feedback is insufficient for a statistical use of national fire events. In addition, even if the national operating experience is sufficient, for equipment for which no fire event occurred, the use of OECD FIRE data may be very helpful.

Currently, NRC is using two fire events databases based on U.S. NPP experience. The first database is essentially the EPRI fire events database [5] which has had a few additional features added due to the NUREG/CR-6850 project, and the second database containing LER and some smaller fire event data that is used in the OECD FIRE Project. In the near future, the NRC will be integrating the best features of each database. Upon completion of that work, the NRC plans to examine the international OECD FIRE Database for insights which will improve the overall NRC database. The NRC currently views the OECD FIRE Database program as a very effective program to better understand international NPP fire events.

5.4 Pre-incident planning (Sweden)

After a switchgear room fire in 2005 the need of making the existing pre-incident planning more effective became apparent. A support to plan the missions is the information on different types of fires. “Type fire” is a short description of how a certain type of fire may develop, what its risks possibly are, and what choices of extinguishing agents and methods have to be used for different fires and plant locations, how to do pre-planning, to update instructions for the fire brigades on how to extinguish a fire and to perform drills and exercises on those types of fire dominating the risk (see [6] and also the next application on “Type Fire”).

5.5 Use of "Type Fire” in pre-incident planning (Sweden)

The idea with respect to the emergency planning is to plan the efforts and working steps in order to give the operational and emergency staff good and up-to-date support to make decisions and to start the mission without delay (cf. [7]). The planning is to a large extent created on the basis of the identified and most common types of fires and their relevance checked against “real fire events” stored in the OECD FIRE Database.

5.6 Fire event tree (Sweden)

One idea of a recently ongoing activity [8] in Sweden is to develop fire event trees. By studying the OECD FIRE Database with all the events included fire event trees may be derived based on the documented fire types, causes, and consequences. One goal of this project is to possibly identify some common features for those fire scenarios that result in the most severe consequences in the event trees. The activity is explained in detail in Appendix C-3.

5.7 Ignition mechanism analysis (Japan):

Ignition mechanisms have been analysed (cf. [9]) in order to understand the ignition mechanism and to identify potential fire sources for Fire PSA. The OECD FIRE Database and the fire database [10] being developed in Japan have been analysed and the fire events have been categorised into seven classes with the result that the contribution of electric components from the perspective of ignition is significant. The activity is explained in detail in Appendix C-9.

6. FUTURE DATABASE APPLICATIONS (DETERMINISTIC AND PROBABILISTIC APPLICATIONS)

Currently, 344 fire event records from 12 countries are collected in the OECD FIRE Database. This constitutes a rich source of qualitative and quantitative information that can be used to support deterministic and probabilistic fire analyses. Below is a short description of fire analysis issues that can benefit from the data collected in the OECD FIRE Database. For some issues a more detailed explanation is provided in Appendix D.

6.1 Support to fire frequency estimation

Several different approaches are used to estimate fire frequencies in fire PSAs, such as room based frequency estimation, component based frequency estimation and frequency estimation by use of influence factors. The information collected in the OECD FIRE Database represents the reality of fire events observed. This provides the basis for estimating "real" initiator frequencies that can be used to corroborate or eventually update the frequencies currently used in Fire PSA (after member countries´ own quality assurance and verification process).

Appendix D-2 presents a detailed example of estimates of fire frequencies for process rooms, switchgear rooms and cable rooms/ducts, which typically are considered important in fire PSAs. The estimation performed shows an overall fire frequency of about 1.0 E-01/ry and, with the assumed number of rooms of a given type, fire initiator frequencies per room and reactor year in the range of E-04. (The numbers of rooms still have to be validated). This is significantly lower than the E-03 range used in some Fire PSAs as initiator frequencies for process rooms, switchgear rooms and cable rooms/ducts.

Fires in process rooms, switchgear rooms and cable rooms/ducts typically dominate the fire induced core damage contribution in most fire PSAs. As the calculated core damage frequencies are directly proportional to the fire initiator frequencies, the presented example suggests (with all mentioned reservations) that the results of some fire PSAs are too conservative. Differences between the member countries can be found in Appendix D with some detailed information provided in *Table 2* of this Appendix.

6.2 Support to fire scenario quantification

Fire event history contained in the OECD FIRE Database can be used to examine the completeness of Fire PSA event trees. It is also possible to generate statistical support to the quantification of branch point probabilities in fire event trees. Section D-3 in Appendix D presents an example of a fire event tree whose structure and branch point probabilities are based on information from the OECD FIRE Database. A comparison with the event trees used in the frame of Fire PSA studies, including the conclusions to be drawn, is still pending.

6.3 Fire suppression human performance analysis

Fast manual suppression is essential in many scenarios. To better understand human performance, influence factors should be identified and evaluated. Possible influence factors are the distance of the fire to fire fighting personnel, alarm routines, possibilities to reach the fire, etc.

6.4 Support to screening of fire scenarios

The OECD FIRE Database can be used to generate screening thresholds for support and facilitation of fire PSAs. An example for using the frequency estimates derived from the Database for screening purposes is provided in Section D-2 of Appendix D.

6.5 Information on causes of fires and related phenomena

The fire data experience stored in the Database can provide answers to several interesting questions and insights on phenomena, such as:

- *Examples of frequent fire initiators and their root causes:*
  One example of frequent initiators has been older electrical coils. Other types of frequent initiators can be identified by use of the Database.
- *Examples of electrical equipment failure modes:*
  In the fire analysis, modelling of “hot shorts” has been frequently discussed. Does the Database contain any example of “hot shorts”? Is it possible to use the Database to support the “hot short” discussion?
- *Examples of fire protection equipment malfunctions :*
  Fire events including some kind of failure in the extinguishing phase should be highlighted or when several attacks were needed.
- *Examples of fire barriers impaired:*
  Examples of impaired or destroyed fire barriers are rare, nevertheless it is important to study them. Fire barriers impaired can result in simultaneous failure of redundant equipment. These effects have up to now only been coarsely analysed.

6.6 Conspicuous data

The data in the OECD FIRE Database will be examined for conspicuous deviations from normal fluctuations. Results of such activities can potentially be used for feedback to the operating experience, and, in particular, for improvements of fire prevention, fire fighting and reporting. Furthermore, astonishing findings may lead to further improvements of the Coding Guidelines and the coding itself as well as to more careful event interpretation.

In the following, some conspicuous findings in the actual version of the Database are highlighted to give rough indications what should be done in the future in this context.

For example, the OECD FIRE Database shows that there are few events in the Database with in total 344 events that lead to more severe fire effects such as “Structural influence or collapse”, “Adjacent rooms affected”, “Total loss of one room”, or “More than one fire compartment affected”. Up to now, there are one event each from Canada and Czech Republic, two each from Finland, Germany and Spain, three events from France, and eight events from Sweden. Up to fate, there are no events with more severe fire effects in Japan, Korea, The Netherlands, Switzerland and the U.S.A.

There is no easy explanation why there are no such events reported from the U.S.A., which has a large number of reactors, while Sweden, which has a relatively small number of reactors, has reported a relatively high number of such events. Here, clarifications and/or explanations/interpretations are needed.

Another example for conspicuous data is a voltage transformer fire due to human error during maintenance outage reported from Finland (see also Appendix C-1). When performing statistical analysis of events with fires and explosions, this event came out with two codings for "Who extinguished the fire successfully?". The codings were "self-extinguished" and "on-site plant fire brigade", which could represent an inconsistency in the coding. The clarification is as follows:

"The event description is short and not very good to make others understand all details of the event, but saying "flames died out quickly" refers to a fire on the ground level which was self-extinguished (small amount of oil leaked down from the voltage transformer, which locates about 4 meters above the ground level). The description also says "The extinguished fire was located on one of the three protective casings containing the voltage transformers below the generator busbars, thus the fire occurred about 4 m above the ground level." Thus, the plant fire brigade extinguished a fire about 4 m above the ground and the burning oil on the ground level was self-extinguished - the voltage transformer failure caused spreading of fires: the fire inside the transformer casing and spreading to the ground level below the transformer casing due to oil leakage."

On the other hand, further fire and explosion events with the titles "An electric arc and fire in the 20 kV switchgear cabinet because of erroneous procedure" and "Fire at 6,6 kV switchgear" could not be found by the Database search on fires and explosions. For the latter, (which involved an electric arc, fire and severe damages the event description seems to lack the key words "electric arc" and "explosion", thus also the event description needs to be improved in the future.

The above mentioned examples of conspicuous data in the Database show that additional work has to be spent on this issue in the future.

6.7 Analysis of homogenous groups

In Sweden a project for the analysis of so-called homogenous groups of fire events (see below) is intended to be started. The purpose of this project is to gain knowledge on important factors that can affect small fires to become large fires. The project will be performed by the Department of Fire Safety Engineering and Systems Safety of Lund University, Sweden. The project will be financed by the Swedish Fire Research Board, BRANDFORSK, the joint agency of the Swedish government, local authorities, insurance companies and industry, and the national fire safety group, NBSG. NBSG represents research co-operation between the Swedish nuclear power plants and the nuclear authorities. The project will perform a number of case studies. The OECD FIRE Database will be used to support one of the case studies. The project will consist of the following three sub projects:

- In-depth study of a number of major fires of selected types (so-called homogenous groups), such as fires in department stores, in terrace houses, or at NPPs, etc., turbine halls fires;
- Identification if the fire scenarios being analysed differ from statistics collected from other types of fires;
- Verification if a scenario analysed can be identified in other major fires.

6.8 Support to analytical approaches from the database (fire development, HRR)

A number of events stored in the OECD FIRE Database contain information on the time-line of the event as well as a full text description of the fire loads involved and potential fire losses. Currently a master thesis is being performed under supervision of the GRS aiming to analyse the given data concerning the thermo-physical characteristics of the fire scenarios. The fire scenarios are evaluated in terms of:

- the fire stages;
- the fire growth coefficients;
- the maximum heat release rate;
- the total heat released, etc.

The description of the fire scenarios by a few common physical parameters will later on allow for a statistical evaluation. Finally, these parameters can be used for defining design fires with respect to a given occurrence probability.

The master thesis is written under the boundary conditions given by the OECD FIRE Project (confidentiality agreement, etc.). Results are expected in early summer 2009.

6.9 Application of the database for fire brigade response time estimation

Special training cases for the plant fire brigade are arranged at a NPP. During the training, timing of different steps of the fire brigade's operation during the attack is recorded to identify the time needed for the access to the fire compartment, starting from a fire alarm. Training is performed several times using different shifts of the fire brigade. An event tree is developed to describe the progress of the fire attack and identified dependencies. Later on, conditional probabilities are estimated for different actions included in the event tree.

Plant fire brigade attack route depends on the fire location. Training cases are performed to attack a fire in a cable tunnel. First, the time needed for the attack to the cable tunnel is compared to the sequences given in the fire database of the same NPP. Due to the low number of events in the national database, comparison will be performed with the sequences of foreign NPPs, especially considering Database events where fire occurred in a cable room or a cable tunnel. The sequences of foreign NPPs can be partially used for comparison purposes in a general level to understand possible differences in plant fire brigade operation and in communication between operators and fire brigade. Anyway, comparison is possible on a general level, e.g. to identify the time from departure from the fire station to the start of the fire fighting action.

The application does not include estimation of fire extinguishing, thus the aim is to define time to access the fire compartment. Extinguishing of fire depends strongly on the exact location of the fire compartment, local conditions inside the compartment and possible need to switch off high voltage of certain cables before the extinguishing can be started due to personnel safety. Real events in the OECD FIRE Database may point out different operation of fire brigades in different countries.

6.10 How do fires spread to other compartments

The aim of this application is to identify fire barriers (walls, fire doors, fire dampers, etc.), that were destroyed or at least impaired by fires (such that flames occurred on both sides of the fire barrier). Smoke spreading across fire barriers is not considered. Details are provided in Section 4 of Appendix D.

6.11 Analysis of high energy electric (arcing) faults (HEAF)

International operating experience of nuclear installations reveals a non-negligible number of reportable events with explosions and fast fires resulting from high energy electric faults e.g. induced by electric arcs in circuit breakers, switchgears, etc. leading to partly significant consequences. Investigations of these events have indicated failures of fire protection features due to pressure build-up in the electric cabinets and/or pressure waves. The OECD FIRE Database also reflects these observations.

This was the reasons that international experts started to work in common to perform in-depth investigations on events with HEAF including investigations on their causes and failure mechanisms. These investigations mainly aim on finding out if these events may represent significant contributors to impairing nuclear safety. At the actual stage of the investigations focusing on evaluating the operating experience from nuclear power plants first indications on the typical event sequences and their potential contribution to core damage have become available.

The OECD FIRE Database can be used to answer questions the experts want to be answered by the NPP licensees. As soon as the answers are available and have been statistically examined and interpreted, first coarse estimates on the contribution of HEAF events to the core damage frequency should be possible. Furthermore, the investigations may reveal additional findings on the event causes, possible measures either for event prevention or for limiting the consequences such that nuclear safety is not impaired.

The OECD FIRE members have meanwhile indicated the need for defining a common OECD task with the goal to develop deterministic correlations for predicting damage and establish a set of input data and boundary conditions for more detailed CFD modeling which can be agreed upon by the international community. The output of such an OECD project may directly support the development of improved treatment methods in fire Probabilistic Risk Assessment (PRA) for nuclear power plant applications.

This task is to start in 2009.

7. PERSPECTIVES

The OECD FIRE Database has become a quality assured tool for evaluating the operating experience from member countries with fire events in nuclear power plants during different plant operational states. It provides qualitative insights into the root causes of incipient as well as fully developed fires and the time dependent fire sequences and development.

Although the data are inhomogeneous due to the differing reporting thresholds and criteria in the Project member states, the existing data from the event sequences, particularly focusing on safety significant events, can be used e.g. as input information for fire modeling to support the model improvement. However, it may become necessary to extend the existing fire event trees to cover all the scenarios which can be derived from the Database.

It is well known by PSA experts that the quality of a Fire PSA strongly depends on the one hand on a careful modeling and, on the other hand, on reliable data; the latter one can be achieved in the future by further expanding the OECD FIRE Database supported by a continuous and consistent reporting of events by the Project members. Improvements in this direction are expected from the collection of more event data with additional information appropriate for the analysts.

First national applications of the Database have shown the high importance of a clear and meaningful fire event description which provides broader insights beyond the information in the coded fields when needed. Although first applications with respect to Fire PSA are possible on a more general level, it will be important to collect as many events as possible in the future to enlarge the data base and to encourage additional OECD Member States to support the OECD FIRE Database Project.

The positive and negative role of human factor in the fire ignition on the one hand, and in detecting and extinguishing on the other hand, has to be investigated in more detail to generate Fire PSA results with a higher confidence. Positive effects of human behavior for fire extinguishing can already be identified in the existing Database, however, with still low statistical significance. However, quantification with regard to PSA would be helpful in the future.

Improvements in the Database structure and a more consistent and exhaustive reporting to the Database will give the possibility to provide a high level of information. For meaningful analytical results it is essential that a quality assured international database will be available for use in the framework of Fire PSA as well as for application to deterministic fire hazard analyses.

One of the main questions which could be answered by the OECD FIRE Database is how fires can propagate from the initial fire compartment to other compartments even if there are protective means available for prevention of fire spreading. For generating meaningful event and fault trees for various safety significant fire scenarios a clear and as far as possible detailed (with respect to time dependencies and safety significance) description of the initial fire event sequence and its consequences are essential. The coding of events has to reflect as far as feasible the needs of the analysts. Therefore the Coding Guidelines are continuously being further improved and enhanced to meet these requirements.

8. CONCLUSIONS / RECOMMENDATIONS

8.1 Feedback to CSNI (WGRISK)

The recent activities with respect to fire risk analysis and, in particular, PSA performed in OECD member countries in the frame of safety reviews, have verified the non-negligible contribution of fires to the core damage frequencies as indicated in the WGRISK SOAR (state-of-the-art report) on "Fire Risk Analysis, Fire Simulation, Fire Spreading and Impact of Smoke and Heat on Instrumentation Electronics"[1]. To meet the expectations of the WGRISK, the OECD FIRE Database is intended to serve as a basic instrument for enhancing the existing Fire PSA results and for making them more robust.

In its succession plan WGRISK therefore requests as far as practicable meaningful output from the Database project to support risk analysis. Although the existing Database covers fire events from nuclear power plants in 12 member states generally within a period of 15 years, it is currently not exhaustive and not sufficiently consistent for statistical use. The main reason for this is the different accessibility of reportable and non-reportable (to authorities) fire events in the Project member states. In addition, another inconsistency in reporting events to the Database results from differences in the reporting criteria and thresholds between the member countries and their changes over time. Yet, a reliable and statistically meaningful database for PSA applications is expected in the future fulfilling the needs of analysts in OECD member states.

8.2 Feedback to CNRA (WGIP, WGOE)

One of the main conclusions from the OECD/NEA/CSNI/WGRISK 2005 workshop is that fire, depending on the design and operational characteristics can be a significant or even dominant risk contributor. In addition, the WGRISK SOAR on "Fire Risk Analysis, Fire Simulation, Fire Spreading and Impact of Smoke and Heat on Instrumentation Electronics" [1] noted the significance of fire. Moreover, some countries are in the process of introducing significant changes to the inspection process of fire protection programs specifically related to the use of risk informed inspections in order to assess the impact of fire on safety significant safety systems and components (SSC).

Based on these considerations and considering that fire operating experience feedback is very useful to identify potential weaknesses in the fire protection program and areas for improvements derived from actual fires, OECD/NEA/CNRA decided to create a specific Fire Working Group. The objective of this Working Group is to examine international and national databases with events observed from the NPP operating experience and determine, through analysis and trending, potential safety issues related to fires and to systems and facilities designed to cope with fires (e.g., prevention, mitigation, suppression, etc.). In addition, insights can be deduced from fire operating experience feedback to focus the inspection activities on those areas where the fire is considered to be safety significant.

In comparison to the IRS database that is not well adapted to the analysis of fire events (very low number of fire events and no specific coding for these), the contents of the OECD FIRE Database can provide more adequate information to the Fire Working Group.

8.3 Need for improving the database structure in the next term

Experience with the OECD FIRE Database in its current form suggests improvements that would enable more detailed analyses of fire events. This would entail revisions of the Coding Guidelines and corresponding changes of the Database coding and structure, as well as substantial re-coding work. Such improvements are envisaged to be implemented in the next phase of the Project.

Plans of revising the Coding Guidelines for the next phase following a logic of "if … then" have been discussed. This new logic would lead to an assessment of the effectiveness of systems, and identification of the reasons why a system was not effective. It was recommended to apply the logic to the entire set of codes, where appropriate.

8.4 Interest in extending the database to other OECD member countries for the next term

Although first applications with respect to Fire PSA are possible on a more general level, it will be important to collect as many events as possible in the future to enlarge the data base and to encourage additional participation of organisations from other OECD Member States to support the OECD FIRE Database Project.

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APPENDIX A - OECD FIRE CODING GUIDELINES

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OECD-FIRE CODING GUIDELINE (OECD-FIRE-CG-2008:2)

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OECD-FIRE Coding Guideline Revision Summary

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01	2002-07-08	Draft	A. Angner		
Version 1	8 Nov 2005	Approved	E. Mathet	2005:1 VERSION 1	
Version 2	28 Feb 2007	Approved	J. Gauvain	2007:1 VERSION 1	
Version 3	18 Dec 2007	Approved	M. Roewekamp	2008:1 VERSION 1	
Version 4	18 Jan 2008	Approved	M. Roewekamp	2008:1 VERSION 2	§ 3.3.1.b – 3.3.2.a
Version 5	24 Dec 2008	Approved	A Angner	2008:2 VERSION 1	§ 3.3.2a and § 3.4.5 Appendix A-2

CODING GUIDELINES TABLE OF CONTENTS

1. Introduction

Fire Hazard Analysis (FHA) and Probabilistic Fire Safety Analysis (PSA) have shown that fire may be an important risk contributor, especially for older nuclear power plants. Uncertainties in fire data have resulted in numerous research projects. However, the lack of reliable data, especially for larger fires, makes it difficult to realistically model fire scenarios.

CSNI/PWG5 established a Task Group to review the present status and maturity of methods used in fire PSA for operating nuclear power plants. The Task group issued a questionnaire in May 1997 to all nuclear power generating OECD countries. One of the concluding remarks presented in the summary report [NEA/CSNI/R (99)27] was as following:

"The shortage of fire analysis data is one of the major deficiencies in the present fire PSA. In order to facilitate the situation, it would be highly important to establish an international fire analysis data bank, similar to that set up by OECD for the CCF data collection and processing system (ICDE/CCF data base at OECD). Such a data base would provide fire event data on real fire cases, incipient fires (smoldering etc.) detected/extinguished before development, dangerous or threatening situations, reliability data on fire protection measures, and the unavailability's of fire fighting systems, for example, due to component failures or operational errors."

Based on the above concluding remarks several OECD member countries have agreed to establish the International Fire Data Exchange Project (OECD FIRE) to encourage multilateral co-operation in the collection and analysis of data relating to fire events in nuclear power plants. The objectives of the Project are to:

- record fire event attributes to facilitate quantification of fire frequencies and fire scenarios frequencies;
- collect and analyse fire events in the long term in order to better understand such events, their causes, and their prevention;
- generate qualitative insights into the causes of fire events, which can then be used to derive approaches or mechanisms for their prevention or for mitigating their consequences; and
- establish a mechanism for the efficient feedback of experience gained in connection with fires, including the development of defenses against their occurrence, such as indicators for risk-based inspections.

The guide provides instruction how to describe a fire event by use of a narrative description. The guide also defines codes to be used for classifying the event. The narratives and the coding are based on documented references.

The classifications of the fire event by use of codes provide the possibility to search for and identify specific fire events of interest in the OECD FIRE Database. The coding will also form a basis for statistical calculations.

2. Fire event analysis support data

The support data is supposed to be used in the fire data analysis phase. Support data is stored in two database support modules and one separate table "Plant data and table of correspondence". The support modules "Reporting thresholds" and "Fire brigade organisation" are accessible from the general data page in the OECD FIRE DB. The separate table includes following information:

- General data such as, plant code, operator, type of reactor, commercial operation start, etc. The general data is mainly based on the IRS Database.
- Dates for plant specific start of OECD FIRE data collection.
- A table of correspondence for the anonymous OECD Plant code ID

2.1 Reporting thresholds

The reporting threshold module defines reporting thresholds for reporting fire events from the utilities to authorities. The reporting threshold module is a part of the OECD FIRE DB.

The reporting thresholds for fire events vary amongst member countries. If collected fire data are to be used for statistical purposes it is essential to know the reporting routines applied in the various countries. There are two different reporting threshold levels:

- *LER level Fires* - If the reporting to OA only consists of Licensee event reports (LERs), LER definition history has to be known. The LER is normally defined in the technical specifications. Today there exist several different definitions depending on member country and date of the fire event. In some member countries a fire event will be reported as a LER if it had affected a safety component. Other LER definitions are based on the duration of the fire.
- *All Fires* - Some OECD FIRE member countries have access to all fire reports. This fact also has to be documented in the OECD FIRE database threshold history module.

To enter and edit reporting thresholds in the database you have to click the button "Reporting thresholds EDIT" under the "fire event general data" page. The criteria for reporting fires in OECD-FIRE participating countries are listed in Appendix A-1.

2.2 Fire brigade organisation

The fire brigade organisation module contains the general description of on-site and off-site fire brigade organisation. Distance in kilometers between plant and off-site fire brigade as well as off-site fire brigade response time are also given. Changes over time in the organisation can be addressed in the database.

3. Description of an OECD FIRE event

The scope for reporting fires to the OA is limited to nuclear power plants. Fires at research reactors, nuclear waste storage facilities, etc. are excluded. The reporting includes all plant internal fires on site (inside and outside buildings) as well as plant external fires if these have the potential to impact nuclear safety.

The reporting shall include fires in all operation modes. Also fires during construction and decommissioning shall be reported. The OECD FIRE PRG determines the observation period for which fires are to be reported.

A fire is defined as follows:

- A process of combustion characterised by the emission of heat accompanied by (open) flame or smoke or both;
- Rapid combustion spreading in an uncontrolled manner in time and space.

Note:

This includes incipient fires as well as fully developed fires. Fires shall be included in the database if they are relevant to safety and also if the same type of fire has the potential to be relevant/significant for safety under different boundary conditions (such as different ventilation conditions, other plant operating states (POS), same components affected in other locations, etc.). Explosions not resulting in an open flame shall be excluded.

The OECD FIRE event is described in documented references. The database into which it is included is divided into the following major parts:

- Fire event general data
- Description of the fire's initiating course of events
- Description of the fire's continuing course of events such as extinguishing measures etc.
- Description of the fire's consequences on the plant
- References
- Relevance index

Narrative event descriptions as well as coded fields are used for the description of the event. The narrative event description consists of:

1. *Event description:* it begins with a short description or title of the event, followed by a detailed factual description of the fire event, including all relevant circumstances.
2. *Sequence of events*: it is a structured record of the evolution of the event in form of a bullet list with time and description of the event. The reader should be able to understand how the event developed in time.
3. *Event interpretation*: it provides further explanations and interpretation, if required.
4. *Ignition phase comments*: may provide further details and comments on the fire ignition phase.
5. *Extinguishing phase comments*: may provide further details and comments on the fire extinguishing phase.
6. *Comments on consequences and corrective actions*

The entries of the coded fields are normally derived from the narrative event description. Coding can also be based on documented references. They are grouped into:

7. *Ignition phase: Describes (by use of codes) the initial course of the fire including items such as location of the fire, type of detection, fire loads, ignition mechanism and root cause.*
8. *Extinguishing phase: This section describes (by use of codes) the course of the event after the fire alarm trigged, type of extinguishing equipment used, who extinguished the fire.*

9. *Consequences: Heat and smoke influence on plant operation and systems are described (by use of codes). Secondary effects and corrective actions are included.*
10. *References: References used, and where to find more information on the specific fire event.*

The major part of the information asked for in the narratives and coded fields is compulsory information. However, there is information, such as amount of fire load that is time consuming to collect. This type of information is marked as “if available”. This information can be collected in a later stage, if necessary, for a limited number of events.

Terms used are listed in the glossary in Appendix A-2. They are consistent with terms used elsewhere in the literature. If any abbreviations will be used to describe the event, their contents or unabbreviated expressions should be described for avoiding misunderstandings.

3.1 General data

3.1.1 Event title

Text	The title should indicate the nuclear safety impact of the event (if any) as well as the apparent lack, failure or deficiency.

3.1.2 Plant

Code	The nuclear power plant where the fire event occurred. The table of correspondence is needed to identify the plant.

3.1.3 Registrar

Text	Name of the initial creator of the OECD FIRE event record. *Note:* This description field is to be found on page “References”.

3.1.4 Date and time of detection (YYYY-MM-DD HH:MM)

Alpha-numeric	Time of detection of the fire, manually, automatic, etc. Year/ month/ day/ hour/minute

3.1.5 Date of OECD FIRE event description (YYYY-MM-DD)

Alpha-numeric	Date when the OECD FIRE event record was first created. Year/month/day. *Note:* This description field is to be found on page “References”.

*3.1.6 Date of OECD FIRE event revision (YYYY-MM-DD***)**

Alpha-numeric/ Text	Date and cause (text) of OECD FIRE event revision. *Note:* This description field is to be found on page “References”.

3.1.7 OECD FIRE Event description

Text:

The text begins with a short description or title of the event, followed by a detailed factual description of the fire event, including relevant circumstances. As the factual event description forms the basis for the event interpretation and the coding it has to be as clear and complete as possible. Below are important items to be described:

- Operational mode (physical parameters; power level (% of full power) RCR coolant pressure and temperature prior to the fire
- Operation mode prior to the fire and after the fire
- Building and type of room where the fire started
- Type of component where the fire started and, if possible, age of component
- Ignition mechanism (Mechanical, electrical, etc.)
- Root cause (the most basic reason for the fire ignition)
- How was the fire detected? What type of detector?
- Fuel properties (quantities and materials)
- Permanently and temporarily available fire loads (information if available)
- Type of fire extinguishing
- Causes for fire protection equipment not activating/failing/not working as intended
- Multiple fires and dependencies
- If the fire spreads to adjacent rooms, specifying the pathway of hot gas propagation
- Influence (impact and/or functionality as well as damage) on equipment due to heat, hot gases and/or smoke; actuated safety functions and occurred radioactive releases; description of spurious actuation, control circuit response to cable damage from fire, instrumentation response and readout on the control panels. Influence on fire barriers (dampers, floor, ceiling, doors)
- Smoke influence on people's movement; smoke influence on main control room habitability
- At what elevation above the base of the fire was heat damage observed? At what radius around the centre-line of the fire was damage observed at the base? At what radius around the centre-line of the fire was damage observed at the ceiling (information if available)? Distance between fire source and damaged component (information if available)
- Damage due to secondary effects and cause of secondary effects
- Actions taken by the licensee to prevent the fire event from re-occurring

3.1.8 Sequence of events

Text

This narrative is a structured record of the event in form of a bullet list with time and description of the event. The reader should be able to understand how the event unfolded in time and logic. Short sentences or statements increase clarity. It should be easy to identify the individual occurrences. Below are examples of important occurrences:

- Time of the event
- Time of the alarm
- Time of the physical localisation of the fire
- Time when extinguishing started
- Time when fire was under control
- Time when fire was extinguished

3.1.9 Event interpretation

Text

Event interpretation or added text by the analyst(s) or (registrar) to clarify parts of the event which are neither clearly described elsewhere in the text fields nor in potentially available references. It is also possible to add reflections made such as:

- Applicability to other operational modes (information if available);
- Safety implications to other plants (information if available).

The interpretation of the event from the safety viewpoint should at least include information such as:

- Initiating event due to the fire events, e.g., SCRAM automatically, Manual Reactor Shutdown, or Transient Initiation etc.;
- Safety significant structures, systems and components (SSCs) affected by the fire event;
- Degradation of safety functions (e.g. degradation of (fire) resistance due to fire but safety function was not impaired. Such degradation can be identified by tests after the fire events.);
- SSCs utilised to bring the plant to a safe operational mode;
- Applicability to other operational modes, if available;
- Safety implication to other plants, if available.

3.1.10 Operation mode prior to the event

Code/Text	Plant operational mode prior to the fire.
Codes	*Definitions*
Construction phase	
Power operation	Power level > than 5 % of full power level
Hot stand by	Power level 0 (Residual heat system not connected)
Shutdown mode	The shutdown modes normally include several sub-modes such as hot shutdown (RHR connected), cold shutdown, refuelling shutdown and service/ maintenance shutdown (outage) (refuelling included), if possible add sub-mode in the narrative text field. The water level in the primary circuit is also important for events during shutdown operation of PWR (e.g. Mid-Loop Operation).
Start-up mode	
Decommissioning	
Unknown	

3.1.11 Confirmation time (HH:MM)

Alpha-numeric/ text	Confirmation time in hours and minutes; time interval between time of detection (field 3.1.4) and time of confirmation of the fire. The event specific definition of “Confirmation time” can be explained in the corresponding text field “Confirmation time clarification”.

3.1.12 Suppression time (HH:MM)

Alpha-numeric/ text	Suppression time in hours and minutes; time interval between time of detection (field 3.1.4) and time of suppression of the fire. The event specific definition of “Suppression time” can be explained in the corresponding text field “Suppression time clarification”.

3.2 Ignition phase

3.2.1 Building where the fire started

Code/Text	The exact location of the fire can be documented under item 3.2.2 and/or by use of 3.2.3. If a code is not available, select one of the following alternatives: • "Other building" and describe type of building by use of narratives • Unknown
Codes	*Definitions*
Reactor building	The fire has started inside the reactor building. The reactor building includes rooms inside the containment (including usually the reactor vessel, primary circuit and the areas of the primary circulation pumps), the space between containment and secondary containment and other rooms included in the reactor building according to the room coding.
Electrical building	The electrical building normally includes switchgear rooms, battery rooms, relay rooms and the unit control room.
Auxiliary building	The auxiliary building includes safety systems (pumps, valves, etc). The building may also include local switchgear rooms and the unit control room.
Turbine building	The turbine building includes turbines, feed water systems, condenser, etc.
Diesel generator building	Diesel generator building including rooms for diesel generator and diesel generator support systems
Intake building	Cooling water intake building including mechanical filters (sometimes also service water pumps)
Switchyard	Including external transformers such as start-up transformers (for the transformers which are really located at the switchyard), even if surrounded by protective walls. Compare to "Outside the plant"
Spent fuel building	Building where spent fuel and further nuclear waste is stored
Workshop (controlled area)	Plant area inside the controlled area of the NPP, where maintenance activities can be performed and materials/and equipment for these activities can be temporarily stored
Independent emergency building	Building including diverse auxiliary safety systems and normally also a back-up CR
Outside the plant (not switchyard)	Fire started on site area outside NPP buildings, e.g. main transformers and other outside areas. Fire in switchyard is specified by code Switchyard.
Other building	This code shall be used if the predefined codes are not applicable. The code shall be combined with a descriptive text that describes the type of building.
Unknown	There is no information on the type of building or area where the fire started.

3.2.2 Room/Plant area where the fire started

Numeric/ If available	Identify the room/plant area where the fire started. Use normal (local) plant coding system (room ID numbers). If the room code is known the following information can be obtained from general plant documentation (database or other types of register): • Fire loads and their distribution in the room (limited to a specific location, spread homogeneously over the room, distributed inhomogeneously over the room) • Room volumes (floor area, room height, if available) • Type of ventilation • Type, no. and location of fire detection equipment • Type, no. and location of fire extinguishing equipment This information is mainly intended for verification of the distribution factors. Distribution factors are used to generate room specific fire frequencies from the overall fire frequency of the building

3.2.3 Type of room where the fire started

Code/Text	If a code is not available, select one of the following alternatives: • "Other type of room" and describe type of room by use of narratives • Unknown
Codes	*Definitions*
Cable spreading room	Rooms typically including cables and electrical cabinets
Other cable room	Rooms including mainly cables, such as cable corridors, cable cellars, cable shafts, cable vaults
Room for electrical control equipment	Local electrical rooms in auxiliary buildings, relay room in electrical building, rooms for system control, etc.
Switchgear room	Room containing 6 kV buses, 6kV breaker, or power supply to valves and smaller pumps and fans (mainly 400 V and 220 V supplies etc). The type of breaker is described in the narrative description fields and by use of the field "component were the fire started".
Battery room	Rooms containing a large number of batteries
MCR	Main unit control room or reserve/emergency control room
Room for ventilation	Rooms containing fans and filters
Room for off-gas equipment	
Process room	Pumps, valves, mostly mechanical equipment; whether or not this equipment is part of a safety system does not affect the classification as "process room".

Staircase and/or corridors	
Office	
Workshop	Plant area where maintenance activities can be performed and materials/and equipment for these activities can be temporarily stored
Storage for nuclear waste	
Storage for other waste	
Storage for combustibles (liquids, gas, etc.)	
Elevator shaft	
Diesel generator room	
Transformer room/bunker	E.g. main transformers, auxiliary transformers, start-up transformers located at switchyard
Hydrogen cylinder bunker	E.g. containing process supply systems.
Switchyard	Switchyard includes outside area containing circuit breakers, disconnectors, measuring devices, busbars etc. Transformers located at the switchyard are coded with the type of room "Transformer room/bunker".
Other type of room	This code shall be used if the predefined codes are not applicable. The coding shall be complemented by a descriptive text that describes the type of room.
Unknown	There is no information on the type of room where the fire started.

3.2.4 Component where the fire started

The types of components listed below are representative of components used in risk analysis models. The components can be looked upon as "main components" or a "function". The number of types is therefore limited. Within the component boundaries several sub-components normally can be identified. The coding procedure should follow the examples given below:

1. A short circuit in a coil (relay or electronic circuits) inside an electrical cabinet has caused a fire; select code "electrical cabinet" and describe in the narrative description field all specific circumstances.
2. A lubrication oil pipe connected to the turbine generator broke and resulted in a turbine hall fire; Select code "turbine generator"

Code/Text	If a code is not available, select one of the following alternatives: 1. "Other component" and describe type of component by use of narratives 2. Unknown 3. Not applicable. No component can be linked to the fire (as cause of the fire, as fire load or damaged by the fire).
Codes	*Definitions*
High voltage breaker	Generator breakers 15-20 kV, Whether or not the breakers use oil should be described in the narrative description field.
High or medium voltage electrical cabinet	Electrical cabinets such as cabinets used for 6 kV breakers or 400 V motor breakers. Normally this type of cabinet is located in the switchgear room.
Low voltage electrical cabinet	Electrical cabinets such as cabinets used for instrumentation and control, logic build-up, regulation, etc. The type of cabinet can be described in narrative description fields. Normally this type of cabinet is located in relay rooms.
High voltage transformer	Start-up transformers etc.
Medium and low voltage transformer – oil filled	Cabinet external transformers using oils as coolant
Medium and low voltage transformer - dry	Cabinet external transformers, typically dry transformers with lower fire load
Rectifier or inverter	Including rotating and solid-state systems
Turbine generator	Including turbine and turbine generator
Diesel generator	Including diesel engine and generator
Electrically driven pump	Including motor, pump and support equipment for cooling, lubrication, etc.
Turbine driven pump	Turbine driven pump, such as auxiliary feed water pump (BWR, some PWR)
Motor operated valve	Including motor and valves
Pneumatic valve	Including solenoids and valve
Power Cable	6 kV, 500 V or 200 V power cable on a cable tray. Types of cables should be described in the narrative description field (IEEE/non qualified, fire retardant, fire retardant cable coating).
Control Cable	Instrumentation or control cable on a cable tray. Add current level (control cable) in milli Amps and voltage level in the narrative description field.
Heater	
Dryer	
Battery	
Battery charger	

Busbar	Busbar normally located in switchgear room. Level of voltage shall be specified in the narrative description field.
Mobile electric equipment	
Fan	
Compressor	
Separator	E.g. oil separator
Equipment for illumination	
Other component	This code shall be used if the predefined codes are not applicable. The coding shall be complemented by a descriptive text that describes the type of component.
Unknown	A component can be linked to the fire, but type is unknown.
Not applicable, no component involved	No permanently available component can be linked to the fire (cause to the fire, as fire load or damaged by the fire); e.g. fire due to hot work, human activity, ignition of transient fire loads.

3.2.5 Ignition mechanism

Code/Text	Use available codes to identify the ignition mechanism. Multiple alternatives can be selected. If a code is not available, select one of the following alternatives: • "Other " and describe type of ignition mechanism by use of narratives • Unknown. There is no information on ignition mechanism.
Codes	*Definitions*
Mechanical	Mechanical failure, machinery breakdown.
Electrical	Short circuit, short to ground, arcing, etc.
Self-ignition	E.g. oil in insulation (auto-oxidation), cable ignition
Hot component	Example: oil on hot pipes (no mechanical failure); "Hot component" can be a hot steam pipe or a hot component due to loss of cooling.
Hot work	Welding, cutting, etc.
Other	Other types of ignition mechanism such as lightning, explosions, external sources
Unknown	There is no information on the ignition mechanism.

3.2.6 Root Cause

Code	Use available codes to identify the root cause (the most basic reason for the fire ignition). Multiple alternatives can be selected. If a code is not available, select one of the following alternatives: • "Other" and describe type of root cause by use of narratives • Unknown. There is no information on root cause. Root cause codes (categories) are used in IAEA-TECDOC-1112 Root cause analysis for fire events at nuclear power plants.
Codes	*Definitions*
Equipment	Design, operational failure, maintenance
Human	Fire caused by non-observance of procedures, e.g. due to welding, cutting, not-appropriate treatment of flammable / combustible materials, etc.
Procedures	Fire caused by deficient procedures
Other	Other type of root cause than equipment, human error or procedures. This could also include external events, such as earthquake, high winds, vehicle collision, etc.
Unknown	There is no information on the root cause.

3.2.7 Type of fire detection

Code(s)	By which means was the fire detected? Use available codes and describe by use of the narrative description field. Multiple alternatives can be selected. Indicate only the detection means being involved.
Codes	*Definitions*
Fire alarm system	Automatic fire detection by fire alarm systems
Fire guard/watch	Manual fire detection
Plant walk down	Manual fire detection
Other personnel	Manual fire detection
Indirect signals	E.g. fire induced influence on process instrumentation
Signals from the fixed extinguishing systems	Signals from the fixed extinguishing systems
Undetected	An identified self-extinguished fire
Unknown	There is no information on fire detection.

3.2.8 Detector Type

Code(s)	If the fire alarm system was actuated, what type of detector indicated the fire? Multiple alternatives can be selected. Indicate only the actuated detector types.
Codes	*Definitions*

Optical detector	Optical including optical smoke detecting devices (ionisation detector coded separately below). A device that senses visible or invisible particles of combustion.
Heat detector	Temperature gradient, (fix temp.). A device that detects abnormally high temperature or rate-of-temperature rise.
Flame detector	A device that senses the presence of a flame
Ionisation detector	The principle of using a small amount of radioactive material to ionise the air between two different charged electrodes to sense the presence of smoke particles. Smoke particles entering the ionisation volume decrease the conductance of the air by reducing ion mobility. The reduced conductance signal is processed and used to convey an alarm condition when it meets preset criteria.
Infrared detector	
Other type of detector	
No detector actuation	The fire was detected by other means. Example, heat detectors did not alarm immediately, plant personnel detected the small fire.
Not applicable	Use this code for rooms where no detector exists.
Unknown	

3.2.9 Detection system performance

Code	Performance of detection systems
Codes	*Definitions*
Normal	Normal performance of the detection system
Fire detectors were not involved	Criteria for automatic actuation of fire detectors were not met. Detectors were not actuated (correct performance) but would have worked as intended (e.g. in case of low amount of smoke, low temperatures, etc.), fire was detected by other means (e.g. indirect signals, humans being present).
Malfunction	The detection system did not work as designed (complete failures or partial failures). Such as delayed automatic detection, unsuitably located detector, etc.
Not applicable	The fire was detected by other means (e.g. people available in the fire compartment), because detectors were not installed in the fire compartment.
Unknown	

3.2.10 Fuel/Combustibles/Fire loads

Code(s)	Identify the type of fuel(s) that was involved in the initial phase of the fire. Fuel properties (quantity and material) relevant to combustion in the narrative description field. Multiple alternatives can be selected.
Codes	*Definitions*
Permanent combustibles	The fuel is permanently available at the fire location. The coding shall be complemented by a descriptive text.
Gas	
Hydrogen	
Other gases	The coding shall be complemented by a descriptive text that describes the type of gas.
Liquid	
Flammable liquid	Liquid with low ignition temperature, e.g. gasoline or other mineral oils. If possible, add ignition temperature limits in narrative description field.
Hardly inflammable liquid	Fire retardant (hardly inflammable) liquid, normally with high ignition temperature, e.g. lubrication oil, grease, hydraulic fluid, fuel oil, etc. If possible, add ignition temperature limits in narrative description field.
Solid	
Cable insulation materials	
Wood	
Paper	
Trash/waste	
Plastics/Polymeric materials	
Other insulations	
Charcoal	
Other solid material	The coding shall be complemented by a descriptive text that describes the type of solid combustibles.
Transient combustibles	The fuel is only temporarily available at the fire location (transient fire loads). The coding shall be complemented by a descriptive text that describes the type(s) and configuration of the transient combustibles, such as scaffolding, staging area, etc.
Gas	
Liquid	
Solid	

3.2.11 Ignition phase comments

Text

In this text field specific comments concerning the ignition phase can be added such as:

- Reflections made;
- Clarification of coding.

3.3 Extinguishing phase

This section describes the course of the event after the fire alarm has been signaled. The section provides instructions how to describe OECD FIRE event scenarios. The fire's or the smoke's influence on the plant are described in section 3.4

3.3.1 Type of Extinguishing

Code(s)	Identify the equipment used for fire fighting. Multiple codes can be selected.
Codes	*Definitions*
3.3.1.a - Type of extinguishing	
Manual fire fighting	The fire was extinguished by use of e.g. portable fire fighting equipment or by use of water from fire hydrant and/or hose.
Fixed systems automatic actuation	The fixed extinguishing system was actuated automatically by the fire detection system.
Fixed systems manual actuation	The fixed extinguishing system was actuated manually.
Controlled burn out	An active decision has been made to not directly extinguish the fire.
Fire source isolation	If the fire source is an electrical arc, the fire (arc) can be extinguished by disconnection of electrical power source. Another example for the fire source isolation is the isolation of the oil or hydrogen source.
Self-extinguished	
Not applicable	
Other means	
Unknown	
3.3.1.b - Type of system/equipment used	
Fixed systems	
Wet pipe sprinkler	Wet pipe sprinklers are fixed systems consisting of a network of overhead pipes releasing water through nozzles onto the fire, when a predetermined temperature has been reached, The only operating components are the automatic sprinklers and (commonly, but not always) the automatic alarm check valve . An automatic water supply provides water under pressure to the system piping. All of the piping is filled with water. Until sufficient heat is applied, causing one or more sprinklers to fuse (open), the automatic sprinklers prevent the water from being discharged.

Dry pipe sprinkler	Dry pipe sprinklers are fixed fire extinguishing systems consisting of a network of overhead pipes releasing water through nozzles onto the fire. Water is not present in the piping until the system operates. The piping is pressurised with air, at a relatively low "maintenance" pressure compared with the water supply pressure. When one or more of the automatic sprinklers is exposed to sufficient heat, it operates, allowing the maintenance air to vent from that sprinkler. As the air pressure in the piping drops, the pressure differential across the dry pipe valve changes, allowing water to enter the piping system.
Pre-action sprinkler	Pre-action systems are hybrids of wet, dry, and deluge systems, depending on the exact system goal. There are two sub-types of pre-action systems: single interlock, and double interlock. The single interlock systems operation is similar to dry systems except that these systems require that a “preceding” and supervised event prior to the “action” of water introduction into the system’s piping due to opening of the pre-action valve. The operation of double interlock systems is similar to deluge systems except that automatic sprinklers are used. These systems require that both a “preceding” and supervised event and an automatic sprinkler actuaation take place prior to the “action” of water introduction into the system’s piping.
Spray water deluge	Deluge systems are fixed water based fire extinguishing systems that have open sprinklers, i.e. the heat sensing operating element is removed during installation, so that all sprinklers connected to the water piping system are open. Water is not present in the piping until the system operates. Because the sprinkler orifices are open, the piping is at ambient air pressure. To prevent the water supply pressure from forcing water into the piping, a deluge valve (mechanically latched) is used in the water supply connection. Water flows from all sprinklers simultaneously.
Water mist	Fixed water based systems using water sprays with very small droplet sise
Foam system	A foam fire extinguishing system is a fixed water based system, discharging a mixture of water and low expansion foam concentrate, resulting in a foam spray from the sprinkler.
Carbon dioxide	Fixed gas extinguishing systems using CO_2 as extinguishing agent
Halon	Fixed gas extinguishing systems using halon gas as extinguishing agent
Other inert gas	Fixed gas extinguishing systems using special inert gases, such as Inergen (a composition of N_2, Ar, and CO_2) as extinguishing agent
Other gases	Other type of fixed gas extinguishing systems. The coding shall be complemented by a text describing the type of the fixed gas system.
Water hose	Water from fire hydrant and/or hose with fixed water supply
Portable means	
Dry chemical	Portable fire fighting equipment, dry chemical (powder)
Gas	Portable fire fighting equipment, gas (e.g. carbon dioxide, etc.)

Foam (water based)	Portable fire fighting equipment:, foam (water based)
Other equipment	Other portable fire fighting equipment. This also includes water supply from fire trucks, etc. The coding shall be complemented by a text describing the type of equipment.
Not applicable	
Unknown	

3.3.2a Fixed fire extinguishing system performance

Code	Performances of fixed extinguishing systems. Manual fire fighting performance by use of e.g. portable fire fighting equipment or by use of water from fire hydrant and/or hose is coded under 3.3.4.
Codes	*Definitions*
Activation	The fixed extinguishing system was activated as per design requirements and was effective in suppressing the fire. This includes manual and automatically actuated systems, including automatic systems which are activated manually prior to automatic activation conditions being reached. For automatic systems activated manually because of failures in the automatic initiating system the code "malfunction" should be used.
Malfunction	The fixed extinguishing system did not work as designed. This includes situations involving malfunctions in: • system activation; • failure to discharge when activated manually, and; • general failure to perform or suppress the fire when operating.
Did not Activate	Criteria for automatic actuation of the fixed extinguishing systems were not met. The fixed extinguishing systems were not actuated manually. Details associated with the event should describe any information on why the automatic actuation criteria were not met and why manual activation was not initiated.
No system present	No fixed extinguishing systems were installed in the room where the fire occurred.
Unknown	

3.3.2b Portable fire fighting equipment performance

Code	Performances of portable fire fighting equipment and other equipment used by the fire brigade such as water hoses, etc.. Manual fire fighting performance is coded under item 3.3.4.
Codes	*Definitions*
Normal	The portable fire fighting equipment worked as designed.
Malfunction	The portable fire fighting equipment did not work as designed.
Not applicable	The of portable fire fighting equipment was not used because of other types of fire extinguishing (fire source isolation, fixed fire extinguishing systems performance successful, fire self-extinguished, controlled burn out, etc.).

No portable fire fighting equipment available	Portable fire fighting equipment was neither available in the room where the fire occurred nor in the vicinity of the fire compartment.
Unknown	

3.3.3 Who successfully extinguished the fire

Code	Identify who extinguished the fire. Multiple alternatives can be selected. Identify the number of fire brigade members or number of fire engines brought to fight the fire, give the number in narrative description field.
Codes	*Definitions*
Self-extinguished	
Fixed extinguishing system	Fire extinguished automatically by fixed (stationary) fire extinguishing system
Fire guard/watch	
People available in the fire area	
Shift personnel	
On-site plant fire brigade	
External (off-site) fire brigade participated	
External (off-site) fire brigade was notified for backup	
Unknown	

3.3.4 Manual fire fighting performance

Code	Manual fire fighting performance.
Codes	*Definitions*
Initial attack successful	
Several attacks needed	
Not applicable	No manual extinguishing actions were needed because the fire was extinguished by other means (fire source isolation, self-extinguished, controlled burn out, etc.).

3.3.5 Extinguishing phase comments

Text

In this text field specific comments concerning the extinguish phase can be added such as:

- Reflections made
- Clarification of coding

3.4 Functional consequence and corrective actions

3.4.1 Change in operational mode due to the fire

Code/Text	Plant operational mode just after the fire.
Codes	*Definitions*
No change in operational mode	The fire did not result in any influence on operation mode.
Change to hot stand by	Change to power level 0 (Residual heat system not connected)
Change to shutdown mode	The shutdown modes normally include several sub-modes such as hot shutdown (RHR connected), cold shutdown, refueling shutdown and service/ maintenance shutdown (outage) (refueling included), if possible add sub-mode in the narrative text field.
Unknown	

3.4.2 Heat or hot gases influence

Code	Identify the influence due to heat or hot gases on systems and components. Use specified codes. If feasible, identify the names of SSC s affected by the fire,
Codes	*Definitions*
None	No components took damage from the heat developed by the fire.
Limited to a single component	One component (main) has been damaged by the fire (a breaker, a pump).
Multiple component fire in one room	Part of a room is destroyed (e.g. a complete electrical cabinet) or several components in a room.
Total loss of one room	Significant damaged in a room up to total damage of one room
Adjacent rooms were affected	In addition, it may be also useful to include in the field the pathway of hot gas propagation. Components have been destroyed in two rooms due to the fire. The fire did not spread beyond the fire compartment.
More than one fire compartment affected.	The fire has spread between fire compartments. (Loss of a fire barrier or degradation of fire barriers, not only complete failures)
Structural influence or collapse	Structural influence or collapse of building structure

3.4.3 Smoke influence

Code	Identify the damage caused by the smoke spreading to the plant. Smoke on electrical cards, relays or breakers, shortcuts due to lack of insulation
Codes	*Definitions*
None	The smoke has not damaged components.
Smoke influence	Damage to components by smoke, or influence of smoke on plant personnel and actions of accident mitigating actions. Describe in the narrative description field smoke influence on people's movement, smoke influence on main control room habitability.

3.4.4 Secondary effects

Code	Identify the collateral secondary effects, e.g. from extinguishing. Use available codes
Codes	*Definitions*
None	No secondary effects
Flooding	Flooding from sprinklers etc.
Others	E.g. electric components failed due to extreme low temperature from fire extinguishing by carbon dioxide.
Unknown	

3.4.5 Impact to Safety Trains

Code	Identify the number of safety trains affected by the event including the information on the total number n of safety trains
Codes	*Definitions*
No safety trains lost	No loss of safety train functionality
One safety train lost	Functionality lost for one safety train. No impact to remaining trains. Text input should identify total number of trains and their function.
Loss of more than one train	More than one, but not all safety trains affected. Text input should identify total number of trains affected, function of trains, and total number of safety trains.
Loss of all safety trains.	Functionality of all safety trains lost. Text should identify total number of safety trains and their function.
Unknown	

3.4.6 Corrective actions

Code(s)	This field describes the actions taken by the licensee to prevent the fire event from re-occurring. Multiple alternatives can be selected. The following coding is used:
Code	Definition
No corrective actions	

Procedures modification	Modifications to general administrative /procedure controls. Modifications to specific maintenance /operation practices
Design modifications	Design modifications such as addition of diversity. This includes diversity in fire detection and fire fighting equipment, types of equipment, procedures, equipment functions, manufacturers, suppliers, personnel, etc. or modification of the equipment barrier (functional and/or physical interconnections). Physical restriction, barrier, or separation.

3.4.7 Comments on consequence and corrective actions

Text
In this text field specific comments concerning consequence and corrective actions as well as lessons learned can be added such as:

- Reflections made;
- Feedback for database coding.

3.5 References

Identify references, which have been used to describe the OECD FIRE event.

NOTE: References are documented in the "table of correspondence – references list" separately from the OECD FIRE DB.

3.5.1 References

Examples of relevant references	Describe reference ID and how to find the reports.
Local fire brigade report	
Operation log	
Fire root cause analysis	
Investigation report	
LER report	

3.5.2. Registrar

Text Name of the initial creator of the OECD FIRE event record

3.5.3 Date of OECD FIRE event description (YYYY-MM-DD)

Alpha-numeric Date when the OECD FIRE event record was first created. Year/month/day

3.5.4 Date of OECD FIRE event revision (YYYY-MM-DD)

Alpha-numeric/ Text Date and cause (text) of OECD FIRE event revision

3.6 Relevance index

The index is used to simplify the identification of reports especially suitable for different purposes (applications). Predefined search profiles can be used to perform the relevance search. Click the button “Search relevance index” on the main menu.

The relevance index is assigned by the OA. The definition of the relevance index is documented in Appendix A-3.

APPENDIX A-1: GLOSSARY OF TECHNICAL TERMS

Glossary

This report defines the terminology and abbreviations used in OECD FIRE Project documents. Codes used to classify OECD FIRE events should be defined in the OECD FIRE Coding Guidelines and are therefore omitted in this document. Reference to the source of the definition is given in many cases.

Abbreviations used

Below abbreviations used in OECD FIRE documents can be found. Codes for classifying the OECD FIRE events are defined in the OECD FIRE Coding guidelines.

OA: Operating Agent

NC: National Co-ordinator

CG: OECD FIRE Coding Guideline

PRG: OECD FIRE Project Review Group

LER: Licensee Event Report

Terminology and technical terms used for the project

Below the terminology specially used for the OECD FIRE Project is provided.

Other technical terms used in the OECD FIRE Project shall use and apply definitions according to NFPA Glossary of Terms (Fire term definitions) [1] and IAEA Safety glossary for terminology used in NPPs [2]. Both documents are available on OECD FIRE home page. Some terms from [1] and [2] often used in the OECD FIRE project are also listed below.

Classify: Assignment of key words to a fire event based on OECD narrative descriptions or related references

Codes: In order to make the data searchable and to make it easier to develop statistical conclusions, the data are classified with codes according to the OECD FIRE Coding Guidelines.

Coding Guidelines: The guide provides instruction how to describe a fire event by use of a narrative description. The guide also defines codes to be used for classifying the event.

Compulsory information: Most fields in the database are compulsory, which means that the information should be provided unless either it takes an unreasonable time to retrieve this information or it is unknown.

Description fields: Except for the narrative description fields the database contains a number of description fields, often with predefined codes. Examples of description fields are; “Title of event”, “Root cause” and “Detector type”

Detect: (1) Sensing the existence of a fire, especially by a detector from one or more products of the fire, such as smoke, heat, ionised particles, infrared radiation, and the like. (2) The act or process of discovering and locating a fire [1].

Explosion: The sudden conversion of potential chemical energy (l) into kinetic energy with the production and release of gases under pressure, or the release of gas under pressure. These high-pressure gases then do mechanical work such as moving, changing, or shattering nearby materials [1]

Fire alarm system: A system or portion of a combination system consisting of components and circuits arranged to monitor and indicate the status of fire alarm or supervisory signal initiating devices and to initiate appropriate response to these signals [1]

Fire compartment: A building or part of a building comprising one or more rooms or spaces, constructed to prevent the spreading of fire to or from the remainder of the building for a given period of time. A fire compartment is completely surrounded by a Fire Barrier [2].

Fire department: An organisation providing rescue, fire suppression, and related activities, including emergency medical operations; this includes any public, private, or military organisation engaging in this type of activity [1]

Fire extinguished: The point in time when there is no longer any abnormal heat or smoke being generated in material that was previously burning [1]

Fire Hazard Analysis (FHA): An analysis to evaluate potential fire hazards and appropriate fire protection systems and features to mitigate the effects of fire in any plant location

Fire load: The weight of combustibles in a fire area [ft^2] or [m^2] or on a floor in buildings and structures, including either contents or building parts, or both [1]

Fire load density: Fire load [MJ] per floor area [m^2] of the fire compartment

Fire frequencies: The number of occurrences per time unit, at which observed fire events occur

Fire scenarios: A description of a fire and any factors affecting or affected by it from ignition to extinguishment, including, as appropriate, ignition sources, nature and configuration of the fuel, ventilation characteristics and locations of occupants, condition of the supporting structure, and conditions and status of operating equipment [1]

Ignition: The initiation of combustion evidenced by glow, flame, detonation, or explosion, either sustained or transient. The moment when a fire first occurs [1]

Ignition source: Any item or substance capable of an energy release of type and magnitude sufficient to ignite any flammable mixture of gases or vapors that could occur at the site [1]

Incipient fire: Small or initial phase of fire, can evolve to a fire if nothing is done

Licensee Event Report: Report that the nuclear power plant has to send to the authority to report incidents

Member country: A country member of the OECD

Narrative description: A textual description of the fire event

National co-ordinator: Each Participant shall nominate one or more national coordinators who shall be responsible for the administration of the OECD-FIRE Project within his/her respective country

Observation period: The period of time for which fire events should be collected

OECD FIRE Database: MS ACCESS® database where all events downloaded from the web interface are stored. This database is distributed on a CD to project members

OECD fire event: Defined in the CG as:

- A process of combustion characterised by the emission of heat accompanied by (open) flame or smoke or both
- Rapid combustion spreading in an uncontrolled manner in time and space

Off-site fire department: A fire brigade located in a nearby city or village. The fire brigade organisation is independent from the NPP organisation.

On-site fire brigade: A fire brigade located at the NPP site or in the vicinity of the NPP. The fire brigade organisation is often subordinate to the NPP organisation.

Operating Agent: The Operating Agent operates the databank and verifies that the data from the National coordinators complies with the OECD FIRE Coding Guidelines.

Participant: An organisation that has signed and complies with OECD FIRE Project Terms and Conditions

Probabilistic Fire Safety Analysis: A comprehensive, structured approach to identifying failure scenarios, constituting a conceptual and mathematical tool for deriving numerical estimates of risk [2]

Project archive: All documents and databases generated within the project are stored in the Operating Agent server. All participants of the project can download the documents.

Project Review Group: All national coordinators together constitute the OECD FIRE Project Review Group.

Project Website: The OECD FIRE Project has a web site, where all referenced documents generated by the project are available for all participants. Access is restricted. The website is password protected. OECD-NEA provides participants with username and password.

Reporting routines: Reporting routines are either routines for reporting between a nuclear power plant and the authority or internal routines for describing and distributing the fire event at the nuclear power plant.

Reporting thresholds: This refers to the incident reporting level between utilities and authorities. What is to be reported is normally defined in the technical specifications (utilities document) as well as when or for which incidents information should be sent to the authorities.

Safety component: Component included in Final Safety Analysis Report (FSAR)

Safety system: A system important to safety, provided to ensure the safe shutdown of the reactor or the residual heat removal from the core, or to limit the consequences of anticipated operational occurrences and design basis accidents [2]

Self-extinguished fires: The fire extinguishes without fire extinguishing efforts.

Sequence of events: A narrative description in form of a bullet list sorted by the date and time of action

Significant damage: to be defined

Suppression - The sum of all the work done to extinguish a fire from the time of its discovery [1]

Technical specification: Rules that state how the nuclear power plant should be operated

Web interface: A web-based interface where data should be entered when submitting fire data to the project. Access is restricted. Username and password can be requested by sending an email to the NEA secretariat.

References

[1] Nuclear Fire Protection Association (NFPA)
NFPA 97 Standard Glossary of Terms Relating to Chimneys, Vents, and Heat-Producing Appliances, 2003 Edition (US$ 27.00)

[2] International Atomic Energy Agency (IAEA)
Safety glossary: Terminology used in nuclear, radiation, radioactive waste and transport safety, Version 1.2, September 2005

APPENDIX A-2: NATIONAL REPORTING LEVELS

Criteria for Reporting Fires in NPP in the OECD FIRE Member Countries

Country / Organisation	Source Document	Reportable Fire Event	Start Date	End Date
Canada / AECB	Draft Reg. Guide R-99 Reporting Requirements for Operating Nuclear Power Plants.	• Declaration of an alert or emergency, within the nuclear power plant, where personnel or resources are mobilized by the licensee in response to an unexpected occurrence of a radiological condition, chemical spill, **fire**, or **potentially explosive mixture of gases** that creates an actual hazard to the safe operation of the plant or the safety of persons. • The occurrence of any unusual external conditions at the site, including **fire**, flood, plane crash, **gas explosion**, **gas release**, high winds, missile or ice conditions, which results in operational transients.		2003
CNSC	Reg. Standard S-99 Reporting Requirements for Operating Nuclear Power Plants (March 2003)	• Quarterly Operation report (6.4.1): (t) a description of any **fires** that occurred at the nuclear power plant and an assessment of their safety significance Glossary: "**Fire**: any uncontrolled combustion, not restricted to open flame, that causes personal injury, death, property damage or results in the mobilization of the response emergency team." • Unscheduled reporting (6.3.1) External event (38): The occurrence of any unusual external conditions at the site, including **fire**, flood, plane crash, **gas explosion**, **gas release**, high winds, missile or ice conditions that resulted in or had significant potential to result in operational transients at the nuclear power plant	2003	
Czech Republic / REZ		Three levels of records about fire events exist: A) *Regulatory body for fire safety (DFRCCR)* Unique to the Czech Republic is that exists another regulatory body (fire regulatory body), the "Directorate of Fire Rescue Corps Czech Republic" (separate from SONS) reports to the "ministry of the interior" with primary responsibility for fire protection.		

Country / Organisation	Source Document	Reportable Fire Event	Start Date	End Date
Czech Republic (Cont'd)	Legislative act about fire protection No.133/1985, § 5 Fire definition according to § 51 Directive of Ministry of Interior CR No.21/1996.	Fire events are reported under the same system as other incidents and events. Specifically, fire reports are required to the regulator within 8 hours. Fire events are reported according to legislative rules. Reports include: 1. Place of the fire 2. Character of place 3. Year of putting in operation 4. Time of ignition fire 5. Fire loss 6. Number of intervening fire force 7.Cause of fire 8. Cause of propagation fire 9. Corrective actions and prevention Etc. B) *Regulatory body for nuclear safety energy (SONS):* SONS (State Office for Nuclear Safety) fire protection inspections are based on equipment performance data, and operational history. Fire is not explicitly mentioned but if a fire should affect a safety component or unit operations, the event should be reported. *C) OEF on NPP:* OEF (Operation Experience Feedback) system is based on IAEA and WANO guidelines. Reporting criteria are translated from IAEA NS-G-2.11. Basic reporting criteria include: Fires, failures and spurious initiations of fire protection and fire detection systems. Reporting duty due to every fire (report for *Regulatory body for fire safety).* Reporting duty due to fire which is I accord with fire definition (report for *Regulatory body for fire safety).*	1985 1996	

Country / Organisation	Source Document	Reportable Fire Event	Start Date	End Date
		A fire or an explosion has occurred at the plant site and at the same time satisfy following: *"The fire is each undesirable burning leading to the injury or kill of persons or animals. The fire is also each undesirable burning leading to the fire material damage."* According to methodical directive of the Head Fire Director of 1997 as fire are not considered: 1. Explosives explosions, if there it is not accompanied with fire of materials and constructions. 2. Burning of coils of electric rotating machines as a result of short circuit, if burning has not propagated outside coil volume. 3. Glowing of electric installation, if it has not propagated outside of installation. Ignitions, which occur during manufacturing, if the technological procedure could not exclude such cases and their liquidation is technically ensured, under assumption that burning will not spread outside the anticipated part of the technology, or the cases are not exclusively specified as operational accidents.		

Country / Organisation	Source Document	Reportable Fire Event	Start Date	End Date
Finland / STUK	Reg. Guide YVL 1.5 rev: 8 Sept; 2003	The regulatory guide 1.5, "Reporting nuclear facility operation to the Radiation and Nuclear Safety Authority" is published 8 September 2003. This Guide is in force as of 1 March 2004 until further notice. It replaces the earlier version of the Guide YVL 1.5, issued on 11 January 1995. (The formulation has been very similar also in all the older versions of reporting guide, thus similar criteria is assumed since the first NPP started its commercial operation in Finland, 9th May 1977. Anyway, the Finnish fire data is provided to this project by the utilities and they will submit “all fires” according to the criteria given in this guideline: Chapter 2.1 and the beginning of Chapter 3). Accordingly to chapter 3.2 (item q.) Special report is provided if “**A fire, an explosion or a chemical damage has occurred at the plant site**.” Nowadays STUK In Annual report covers Events with safety significance including also as summary of fire brigade alarms.	1977	

Country / Organisation	Source Document	Reportable Fire Event	Start Date	End Date
France / EDF		*Before 1994, fire events reported along NEA-IAEA/IRS Guidelines*	1978	1994
	EDF DI 060 (8 June 1994) The Autorité de sûreté nucléaire (ASN) and the Institut de radioprotection et de sûreté nucléaire (IRSN), its technical support organization, agree with these criteria.	Any fire event or situation caused by a fire event: • solicitation of external help (fire brigade call); • bodily injury; • material damage in excess of EUR 1500; • use of more than one hand-held fire extinguisher; • use of fire hose or mobile (non portable) fire extinguisher; • true actuation of fire suppression device; • fire event within the nuclear island or in an auxiliary building; • fire event affecting or potentially affecting a safety-relevant component; • fire event generating information of generic interest to safety. • It has to be underlined that one the criteria "solicitation of external help (fire brigade call)" that is a demanding criteria, has been specified later (beginning of years 2000). As all the fires events that can be provided to the data base occurred after 1994, it is not necessary to add older criteria.	1994	

Country / Organisation	Source Document	Reportable Fire Event	Start Date	End Date
Germany / BMU	AtSMV Anlage 1 Meldekriterien für meldepflichtige Ereignisse in Anlagen zur Spaltung von Kernbrennstoffen. (Reporting Criteria for Reportable Events in Installations for Fission of Nuclear Fuels)	In addition to the fire events reported to the authorities due to the following criteria, all fire events in German NPP GRS knows about will be reported (these events are incomplete up to now but might become complete in the future)		
		"**Any fire**." There are three classes of reportable events. They differ in their importance to safety and in the way they have to be reported. Fires belong to the class A events (immediately significant), but actually they were reported as class B (potentially significant) sometimes also as class C (other events).	1975	1985
		"**Any damage to systems and components** by plant internal fire, explosion or flood **that affects normal operation** (of the affected system or component)." There are three classes of events reflecting the significance in terms of safety. In contrast to the 1975 version most events show up in all three classes, depending on the systems affected and/or the severity of the event. The cited definition for fire events corresponds to the lowest level (N). A fire has to be reported as type E event, if systems or components important to safety are affected. There are no S class fires.	1985	1991
		"Internal fire, explosion or flood **causing the unavailability** of a **safety sub-system** or a redundancy of a **system or component important to safety**." The system is similar to the 1985 version using event classes S, E, and N. However, the new structure is such that the safety significance defines sub-classes of the event type. E.g., there is the event type 3.2 "fire, explosion, or flood" which is subdivided into the classes S, E, N.	1991	

Country / Organisation	Source Document	Reportable Fire Event	Start Date	End Date
Japan / JNES	Law for Regulations of Nuclear Source Material Nuclear Fuel Material and Reactors (LRNR) The Electric Utility Industry Law (EUIL)	*LRNR, Corresponding Ordinance: When there is a failure of equipment etc. important to safety by the fire. Excluding the concerned failure is due to the measure of fire extinguishing or prevention of the spread of fire;* *EUIL, Corresponding Ordinance: Electrical fire accidents.* *Both Laws have not changed but the Corresponding Ordinance article numbers were changed in 2003.* LRNR Article 62-3, Corresponding Ordinance Article 19-17, Item 4: When there is a failure of equipment etc. important to safety by the fire. Excluding the concerned failure is due to the measure of fire extinguishing or prevention of the spread of fire; EUIL Article 106, Corresponding Ordinance Article 3, Item 2: Electrical fire accidents.	1965 September 2003	September 2003
Korea **/KINS**	Reg. Guide 2008-29 Reporting criteria for event or failure within the nuclear facility	• The occurrence of any unusual external conditions at the site, including **fire**, leakage of the radioactive material, which results in operational transients. • The occurrence of **fire**, leakage, robbery, loss etc of the radioactive material while it is wrapped or transported.	2008	
Netherlands **/KFD**	NPPs technical specifications	Fire is not explicitly mentioned but if a fire should affect a safety component, the event should be reported as LER report to KFD (if the component function is degraded)		

Country / Organisation	Source Document	Reportable Fire Event	Start Date	End Date
Spain / CSN	Guia de Seguridad no. 1.6 - Sucesos notificables en Centrales Nucleares en explotación. (Safety Guide n. 1.6 Reporting events for operating NPPs).	• fire in the plant lasting more than 10 minutes from the time of detection [Section 3.1.5] • fire in the plant with the potential to impact plant safety or with the potential to impair the plant personnel's ability to safely operate the plant [Appendix: reporting form for abnormal events]	January 1990	November 2006
	Instrucción IS-10 Criterios de notificación de sucesos al Consejo por parte de las centrales nucleares. (Instruction IS-10 Reporting criteria of events to the CSN from NPPs).	• Fires that are confirmed with duration below 10 minutes and incipient fires that activate the corresponding detection systems, provided that they occur in cubicles, areas or fire zones in which structures, systems or safety-related components are located [Section 5.E.4]. • Uncontrolled fire situated to less than 5 Km away from plant's fence and it moves toward the plant [Section 5.H.1]. • A fire in the plant lasting more than 10 minutes activates the Internal Emergency Plan (PEI). Any activation of the PEI involves the report to the CSN.	November 2006	
Sweden	NPPs technical specification	Fire is not explicitly mentioned but if a fire should affect a safety component the event should be reported as a LER report to Swedish Radiation Safety Authority (SSM) (if the components function is degraded). In addition to these events all fire are reported which have activated the fire alarm. Swedish observation time starts in 1977.	August 1977.	

Country / Organisation	Source Document	Reportable Fire Event	Start Date	End Date
Switzerland / HSK		No formal reporting requirements	1969	1980
	Reg. Guide HSK-R-15 Berichterstattung über den Betrieb von Kernkraftwerken (1980, 1981)	Any fire or explosion if it either (1) causes a scram or (2) if it does not cause a scram but if there is an oil leakage with a risk of ignition or (3) if there is a major oil leakage	1981	1984
	Reg. Guide HSK-R-15 (1984, 1987)	Any fire or explosion in a building containing safety relevant (classified) equipment	1985	1994
	Reg. Guide HSK-R-15 (1994, 1999, 2004)	Any fire or explosion within the perimeter of the plant	1995	

Country / Organisation	Source Document	Reportable Fire Event	Start Date	End Date
USA NEIL	NEIL Loss Control Standards (Sept. 2002)	• Any fire involving activation or malfunction of a fixed fire extinguishing or detection system OR any physical damage loss in excess of $100,000.00 • Impairments to fire suppression systems, which exceed, or are expected to exceed 48 hours	2002	
USNRC	10 CFR 50.73 Licensee event report system.	• Any event that posed an actual threat to the safety of the nuclear power plant or significantly hampered site personnel in the performance of duties necessary for the safe operation of the nuclear power plant including fires, toxic gas releases, or radioactive releases.		
	10 CFR 72.75 Reporting requirements for specific events and conditions.	- Non-emergency notifications: Four-hour reports. Each licensee shall notify the NRC as soon as possible but not later than 4 hours after the discovery of any of the following events or conditions involving spent fuel, HLW, or reactor-related GTCC waste: • An event that prevents immediate actions necessary to avoid exposures to radiation or radioactive materials that could exceed regulatory limits, or releases of radioactive materials that could exceed regulatory limits (e.g., events such as fires, explosions, and toxic gas releases). • An unplanned fire or explosion damaging any spent fuel, HLW, and/or reactor-related GTCC waste, or any device, container, or equipment containing spent fuel, HLW, and/or reactor-related GTCC waste when the damage affects the integrity of the material or its container.		

APPENDIX A-3: RELEVANCE INDEX DEFINITION

Relevance Indices are implemented to characterise the quality of fire event reports collected in the OECD FIRE Project.

The rationale to introduce relevance indices is twofold:

- The Operating Agent wants to have a mechanism that allows filtering out issues in the reports for which more information must be sought.
- The user desires to have knowledge of the completeness of the information in the database and of the degree of confidence he can put in the information in the database if he wants to analyse data for various purposes.

The relevance indices essentially are "completeness indices", i.e. they measure how complete and detailed the reported information is and by what kind of references it is supported.

The relevance index grades are to be derived from information in the "event description" , "sequence of events", from the fire phase comment fields, and from the respective coded fields, if the latter contain information beyond that in "event description", "sequence of events" and fire phase comment fields. This qualification process requires to examine event descriptions and event sequence descriptions with respect to the six listed items and to assign the appropriate quality index to each of the listed items as part of the database.

The assignment of grades in the database will be made after quality control is completed.

Predefined relevance indices are assigned only to a limited number of important items, for example:

- Total
- Causes of fire (Concerned fields: 3.2.1, 3.2.4, 3.2.5, 3.2.6)
- Fire scenario (Concerned fields: 3.1.7, 3.1.8, 3.1.10, 3.2.7, 3.2.9, 3.2.10, 3.2.11, 3.3.2a, 3.3.2b, 3.3.4, 3.3.5)
- On-site fire brigade response (Concerned fields: 3.1.7, 3.1.8, 3.1.10, 3.1.11, 3.1.12, 3.3.1, 3.3.2b, 3.3.4, 3.3.5)
- Off-site fire brigade response (Concerned fields: 3.1.7, 3.1.8, 3.1.10, 3.1.11, 3.1.12, 3.3.1, 3.3.2b, 3.3.4, 3.3.5)
- Consequences of fire (Concerned fields: 3.1.10, 3.4.1, 3.4.2, 3.4.3, 3.4.4, 3.4.5, 3.4.7)
- Customise the grouping of fields: a software tool is implemented to groups any fields together.

<u>Assignment of grades:</u>
The calculation of the total index is based on the set of all narrative fields and most of the coded fields. The calculation of the indices 2. through 6. is based on subsets of the indices used for the calculation of 1.

Each index is calculated as the sum of the numerical attributes of its relevant indices.

Three different grades "H" (High), "M" (Medium) and "L"(Low) can be assigned to each narrative and coded field. The corresponding numerical attributes (values) differ for the various fields are defined below.
Note: The narrative fields 3.1.9, 3.2.11, 3.3.5, 3.4.7 have been added after the first events were inputted in the database. Previously only 3.1.7 was available for event description. This explains the different rating system in place. From now on, the system covers all narrative fields.

For events inputted before Sept 2004, the rating system is:

- Narrative field 3.1.7 : H~30, M~14, L~5
- Sequence of events field 3.1.8 H~10, M~5, L~0
- Coded fields: H~2, M~1. L~0

For events inputted after Sept 2004, the rating system is:

- Narrative field 3.1.7 : H~30, M~14, L~5
- Sequence of events field 3.1.8 H~10, M~5, L~0
- Narrative fields 3.1.9, 3.2.11, 3.3.5, 3.4.7: H~4, M~2. L~0
- Coded fields: H~2, M~1. L~0

"H" is assigned to 3.1.7, if this field contains a detailed and complete description that does not necessitate further explanations in other fields.

"M" is assigned to 3.1.7, if the description is complete and detailed, but is distributed over all five narrative fields. Thus, the maximum that can be attained by the narrative fields plus the sequence of events field is 40, regardless of how the information is spread out over the five narrative fields.

APPENDIX B - STRUCTURE OF THE NARRATIVE PART AND THE CODED FIELDS IN THE OECD FIRE DATABASE

Narrative part in the OECD FIRE Database

Event description: It begins with a short description or title of the event, followed by a detailed factual description of the fire event, including all relevant circumstances
Sequence of events: It is a structured record of the sequence of the event in form of a bullet list with time and description of the event. The reader should be able to understand how the event developed in time;
Event interpretation: It provides further explanations and interpretation, if required
Ignition phase comments: They may provide further details and comments on the fire ignition phase
Extinguishing phase comments: They may provide further details and comments on the fire extinguishing phase
Comments on consequences and corrective actions

Coded fields in the OECD FIRE Database

Ignition phase: This section describes (by use of codes) the initial course of the fire including items such as location of the fire, type of detection, fire loads, ignition mechanism and root cause
Extinguishing phase: This section describes (by use of codes) the course of the event after the fire alarm trigged (type of extinguishing equipment used, who extinguished the fire)
Consequences: Heat and smoke influence on plant operation and systems are described (by use of codes). Secondary effects and corrective actions are included
References: References used, and where to find more information on the specific fire event

The classification of the fire event through coded attributes provides the possibility to search for and identify specific fire events of interest and for specific features in the OECD FIRE Database for a wide range of applications.

APPENDIX C - NATIONAL APPLICATIONS OF THE DATABASE

C-1 FIRE AND EXPLOSION

One application of the OECD FIRE Database was a closer look at those events that were associated with explosions. As there is no specific field in the Coding Guideline to indicate explosions, the filter and the main source of information is by the event description field (Field 3.1.7).

The following filters were used for field 3.1.7:

- search for *explo* (explosion, exploded, etc.): 26 events
- search for *defla* (deflagration, deflagrated, etc.): no events
- search for *deto* (detonation, detonated, etc.): no events

Of these 26 hits, in three cases no explosion occurred according to the event description but the term “explo” was used in another meaning. In one event the explosive release of INERGEN gas out off a gas cylinder happened. Within the 344 events 22 reported explosions represent an amount of 6.4 %. Some interesting details of the explosions are listed in *Table 1*.

Concerning the process distinction should be made between an explosion as a process of rapid combustion (chemical explosion) and an explosion as a physical process that is resulting from a sudden air pressure rise by a high energy electric (arcing) fault (HEAF). A chemical explosion was clearly found in only three cases (solvent vapor, diesel fuel, hydrogen). In the other 18 cases, HEAF events obviously took place at the same time, which indicates a physical explosion. In some of these cases the electric fault might have caused a fuel pyrolysis/spread and acted as an ignition source for a chemical explosion, thus a HEAF event and a chemical explosion may have taken place simultaneously.

In one case, a fire led to the explosion of diesel fuel vapor (event no. 16 in *Table 1* of this Annex), while in another case a fire and an explosion occurred independently from each other in parallel (event no. 15 in *Table 1*). In all other cases explosions induced the fire.

The buildings/locations where the events took place are also listed in *Table 1*. Thirteen events took place outside buildings. Clearly, most (13 events, 59 %) components where the event started were transformers. The other nine events took place at electrical cabinets, other electrical equipment, or process equipment (each 3, 14 %).

External fire brigades were needed in 4 of 22 cases (18 %).

The 22 events were also evaluated concerning the fire duration:

- fire duration between 0 and less than 15 minutes: 11 events
- fire duration between 15 and less than 30 minutes: 3 events
- fire duration between 30 and 60 minutes: 3 events
- fire duration longer than 60 minutes: 3 events

For the remaining two events no information is provided on the fire duration.

Table 1: List of fires and explosions

No.	Event Title	Location	Component	Fuel	Process	Extinguished by	Duration [h:min]
1	Trip of main transformer, followed by fire in phase "S" due to manufacturing defect. Subsequently, turbine trip and, with permissive P-7, reactor trip (event #1)	outside the plant buildings (not switchyard)	high voltage transformer	hardly inflammable liquid	HEAF	fixed extinguishing system; on-site plant fire brigade; shift personnel	00:58
2	Trip of main transformer, followed by fire in phase "S" due to manufacturing defect. Subsequently, turbine trip and, with permissive P-7, reactor trip (event #2)	outside the plant buildings (not switchyard)	high voltage transformer	hardly inflammable liquid	HEAF	fixed extinguishing system; on-site plant fire brigade; shift personnel	00:15
3	When energising with sub-critical reactor, main transformer tripped, followed by fire in phase "R"	outside the plant buildings (not switchyard)	high voltage transformer	hardly inflammable liquid	HEAF	fixed extinguishing system; on-site plant fire brigade; shift personnel	00:08
4	Loss of a 6.6 kV emergency switchboard	electrical building, room for electrical control equipment	high or medium voltage electrical cabinet	cable insulation materials	HEAF	shift personnel	00:07
5	Fire of the station service load transformer caused by a defect on the power part of the branch lines switch followed by an explosion	switchyard	high voltage transformer	flammable liquid	HEAF	on-site plant fire brigade	00:16
6	Reactor trip due to a failure in a fast switch-over connection function. Failure in a commuter fuse in an electrical cabinet	electrical building, switchgear room	medium and low voltage transformer - dry	other solid material	HEAF	shift personnel	< 00:05
7	Unit Main Transformer fault and fire	transformer yard	high voltage transformer	flammable liquid	HEAF	on-site plant fire brigade	00:14

No.	Event Title	Location	Component	Fuel	Process	Extinguished by	Duration [h:min]
8	Incipient fire in a Site Communication System room	site communication system room	rectifier or inverter	plastics / polymeric materials	explosion of capacitor	shift personnel	00:15
9	Incipient fire on ultimate emergency diesel generator	diesel generator building, electrical/process room	high or medium voltage electrical cabinet	other insulations; plastics/polymeric materials	HEAF	self-extinguished	00:05
10	Loss of 400 kV power supply following a fire in the 6.6 kV AC Normal Distribution System cubicle	electrical building, switchgear room	high or medium voltage electrical cabinet	hardly inflammable liquid; plastics/polymeric materials	HEAF and vaporised oil explosion	shift personnel; external fire brigade participated	01:11
11	Switchyard fire in 34.5 kV circuit breaker	switchyard	high voltage breaker	flammable liquid	HEAF	on-site plant fire brigade	unknown
12	Failure of Startup Transformer ST-20	transformer yard	high voltage transformer	flammable liquid	HEAF	fixed extinguishing system	< 00:10
13	Explosion and injured persons following maintenance work	turbine building, process room	filter of the turbine control fluid system	vapors of a cleansing solvent	solvent vapor explosion	self-extinguished	00:01
14	Explosion of an oil-filled current transformer leading to a fire in the 400 kV platform	switchyard	high voltage transformer	hardly inflammable liquid	HEAF	shift personnel; external fire brigade participated	00:48
15	Unit 6 forced outage due to M. O. T. failure	switchyard, switchgear room	high voltage transformer	flammable liquid	HEAF	fixed extinguishing system	< 00:08
16	Liquid fuel discharge during a Diesel generator fire	auxiliary building, pumping station	diesel generator	flammable liquid	diesel fuel explosion	shift personnel; external fire brigade participated	02:35

No.	Event Title	Location	Component	Fuel	Process	Extinguished by	Duration [h:min]
17	Reactor trip due to Main Transformer Fault and Fire	outside the plant buildings (not switchyard), main transformer	high voltage transformer	flammable liquid	HEAF	fixed extinguishing system; on-site plant fire brigade	unknown
18	Voltage transformer fire due to human error during maintenance outage	outside the plant (not switch yard), voltage transformers near to the main transformer	medium and low voltage transformer - oil filled	hardly inflammable liquid; other insulations	HEAF	on-site plant fire brigade (one fire); self extinguished (another fire)	00:05
19	Fire (explosion like) in local transformer. The reactor tripped due to the fire.	outside the plant buildings (not switchyard), on-site electrical distribution system	high voltage transformer	cable insulation materials; flammable liquid; other solid material	HEAF	on-site plant fire brigade; external fire brigade participated	~ 01:40
20	Automatic Reactor Trip due to Circulating Water Pump Surge Capacitor Failure	intake building, process room	electrically driven pump	capacitor, insulation material	HEAF	self-extinguished	00:34
21	Hydrogen fire at high pressure hydrogen cylinders	hydrogen station, hydrogen cylinder bunker	pressure gauge at the hydrogen supply line	Hydrogen	hydrogen explosion	on-site plant fire brigade	00:13
22	Automatic Reactor Trip Due to a Turbine-Generator Trip Caused by a Fault on the 31 Main Transformer Phase B High Voltage Bushing	transformer yard	high voltage transformer	hardly inflammable liquid; transformer oil	HEAF	on-site plant fire brigade	00:12

C-2 FILTER FIRES

A further application of the database was a closer look at fires at filters used for cleaning of gaseous media. These filters are mainly used in HVAC systems or as local filter systems at welding/cutting workplaces. As there is no extra field in the CG to indicate filter fires, the interesting events were singled out by different description fields. Hints were the words:

- "filter" or "precipitator" in the description field (Field 3.1.7),
- "room for ventilation" as the type of room where the fires started (Field 3.2.3),
- "other component" in connection with "filter" or "heater" as the component where the fire started (Field 3.2.4) or
- "Charcoal" as fuel/combustibles/fire loads (Field 3.2.10).

By these criteria 35 events were found and had to be examined. From these 35 hits, in only nine events an air purification filter was actually involved in a fire. Within the 343 events, 9 filter fires represent 2.6%. Some interesting details of these events are listed in *Table 2*: Three fires (no. 2, no. 6, and no. 9 in *Table 2*:) occurred at filters which belonged to HVAC systems. The typical source of ignition is a heater which is not turned off after the fan of the system was turned off. Five events (no. 1, nos. 3-5, and no. 7 in *Table 2*:) occurred at local filter systems for purifying air from welding or cutting processes. These were ignited by hot work. One event (no. 8) occurred at a charcoal filter vessel of the radiolysis gas recombiner train, which was ignited either by self-ignition or an explosion. This case no. 8 is somewhat unique compared to the other cases. The time of 125 h until the temperatures were normal again is extremely long. Also it is the only event out of the 35 selected events where the plant operation mode changed to shutdown mode. All filter fires were fought by manual fire fighting. External fire brigades were not needed. The fire duration is also listed in *Table 2*:

Table 2: List of filter fires

No.	Event Title	Location	Component	Fuel	Process	Duration [h:min]
1	Welding Equipment Fire	unknown	welding smoke eater filter	other solid material	hot work	unknown
2	Fire in fan room in the waste disposal building. Fire has most probably started in the electrical equipment dedicated to an electrical heating battery.	waste disposal building, room for ventilations	HVAC / fan	cable insulation materials; other gases; other insulations; other solid material; plastics/polymeric materials	overheating of electrical equipment	01:33
3	Fire at welding smoke extractor - filter	auxiliary building	welding smoke extractor - filter	other solid material	hot work	unknown
4	Small Fire in Unit 4 - 254' elevation, RAB	auxiliary building	welding smoke extractor - filter	other solid material	hot work	unknown
5	Incipient fire on a cutting-off machine's filter in the mechanical workshop of an auxiliary building	auxiliary building, workshop	cutting-off machine's filter	other solid material; trash/waste	hot work, cutting	00:20
6	Incipient fire on a heater in the Spent Fuel Building	spent fuel building, Room for ventilations	HVAC / Heater	charcoal; plastics/polymeric materials	hot component	00:43
7	Smoldering Fire in Air Filtration Unit Attached to Welding and Cutting Table	controlled area, workshop	air filtration unit of welding and cutting table	other solid material	hot work: spark or a hot molten particle	00:19
8	Fire in a vessel of the delay line in one recombiner train	reactor building, process room	BWR, filter vessel with activated charcoal belonging to the radiolysis gas recombiner train	charcoal	self-ignition or resulting from an explosion	> 08:00
9	Smoldering fire in a preliminary air filter caused by an electric heater failed to switch off	reactor building, room for off-gas equipment	HVAC / bag filter and fine filter located close to the heater	filter material (organic bounding of glass fibre and polypropylene) and organic materials collected by the filter	electric heater	00:51

C-3 FIRE EVENT TREE

The Technical Research Institute of Sweden (SP) has, on behalf of Ringhals AB and NBSG (National fire safety group), studied the OECD FIRE Database in order to assess what further studies can be conducted in order to improve fire safety efforts in nuclear power plants and gain as much insight as possible from the Database (cf. [8]). One idea is to develop fire event trees. By studying the Database and the developed event trees it would be possible to identify some common denominators that exist for those fire scenarios that have the most severe consequences. One can divide this into two different studies, one where the denominators are identified based on how severe the fire is, i.e. how large, and one where the impact on the reactor safety is also included (this would then probably be based on whether the operational mode was changed). The denominators would be expressed e.g. as failure of the detection system due to:

- wrongly designed detection system,
- failure to interpret the alarm as an alarm,
- other reasons.

These sub-denominators could then also be grouped into other denominators, e.g. a failure to interpret the alarm as an alarm, identifies something lacking in the organisation and training.

A fire event tree takes a certain starting point, in this case it is that a fire has started and then there is a question in each node with an answer “yes” or “no” and a probabilistic value for yes and no respectively. At the far right hand side there is a consequence. From a fire safety engineering approach, SP suggests fire stop or mitigation mechanism nodes such as:

- Fire is self extinguished due to lack of fuel or oxygen;
- The fire is detected by an automatic or human system.
- The fire is extinguished by an automatic or manual system.
- The fire is limited to one room due to the construction.
- The fire is limited to one fire cell or fire compartment due to construction.

Similarly, development of the consequences could be conducted as:

- Fire and damage contained to starting object,
- Fire spread or damage to at least one more object in room,
- Loss of one room,
- Impact on adjacent rooms within one fire compartment,
- Impact on more than one fire compartment,
- Structural damage.

A generic event tree with these nodes and consequences will be rather large as the stop and mitigation mechanism can be active after each of the consequence steps, i.e. a fire can be extinguished either early on when only one component is damaged or later when several components have been damaged or even the entire room. It is possible to draw up a specific event tree for each event in the Database. This is probably of limited value for some of the events in the database as the information is very limited and some trees would be very similar. Setting up the event trees requires a thorough read through of the database and especially the event description. The event trees must take their starting points from the assumption that a fire has started since the information in the Database is too limited on how the fire started. A first estimate of probability values to be used at the different nodes in the generic fire event tree can be made from the event trees developed from the database. The uncertainty in the probability values needs to be estimated by statistics and the values can be refined as the database grows.

C-4 SWEDISH TEST APPLICATION FOR DETERMINISTIC DATABASE USE

ES Konsult AB has, on behalf of NBSG (National fire safety group), studied the OECD FIRE Database in order to get insights in fire scenarios [1]. The study was limited to 42 fires that occurred between 1990 and 2005 in Swedish NPP. The work was limited to qualitative insights, no statistical calculations were performed. A review group was made up by representatives from different categories of profession. The fire protection is built up by a defense in depth strategy including a number of barriers. The aim was to identify failure of barriers and their root causes. The review was based on the defense in depth strategy presented in INSAG-10 “Defence in Depth in Nuclear Safety” [11] and also in INSAG-12 “Basic Safety Principles for Nuclear Power Plants” [12]. The method is graphically presented in the **Figure 1** below.

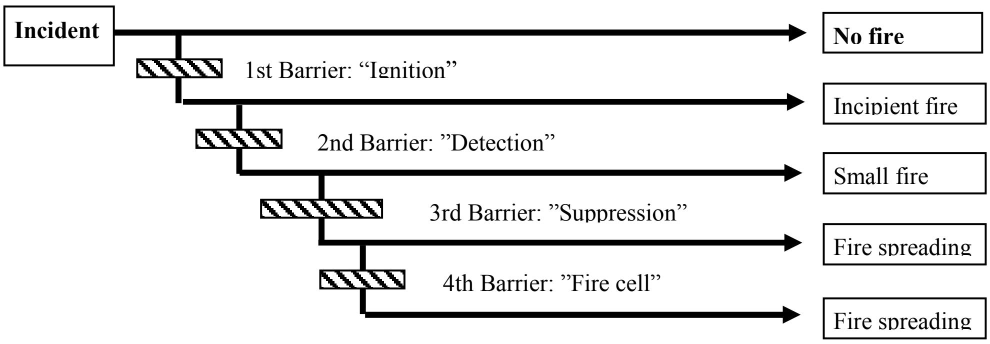

Figure 1: Fire defense in depth

The purpose of the analysis was to get answers on following questions:

- Are there any recurrent types of fires?
- Are there any problems with detecting fires?
- How did the extinguishing phase work?
- What are the safety consequences?

Results and observations of the study for Swedish NPPs:

- Due to the fire events occurred in Swedish NPPs, the first barrier has been affected. In two cases the initial fire extinguishing failed affecting the third barrier. Fire spreading affecting the fourth barrier has not occurred. However, smoke has spread between fire compartments due to design weakness of the ventilation systems. None of the fire events reported posed any risk of radioactive release to the public.
- Oil on hot pipes resulted in several fires and was the most frequent fire initiator. The phenomena are well known and material for insulation is changed to a less flammable material.
- Electrical failures were the most frequent fire causes. Fires in electrical cabinets are relatively frequent and often caused by overheated electrical coils.

- Fire detection by automatic means has been working as designed in almost all cases. Some smaller problems may be identified in fast detection in large rooms such as the turbine hall.
- No problems were identified in the fire extinguishing phase, except in two cases including electrical fires caused by arcing, where the first attempt of fire extinguishing failed. The selection of extinguishing equipment and the routines of how to deactivate electrical equipment such as bus bars have to be improved.
- Some cases of smoke spreading have been identified in the OECD Fire Database. In his respect, fires with the potential of propagation are of high interest. However, overall conclusions from these observations cannot be drawn, as fire effects on safety functions and possibilities for safe shutdown have not yet been analysed in detail.
- From the Swedish fire data it can be seen that the co-operation between shift personnel (control room staff) and the local fire department worked well, except for one case related to an electrical fire from arcing.
- However, fire does rarely affect reactor safety functions, and the safe shutdown function has not been jeopardised in any case, as documented in the Swedish fire data. Nevertheless, there is an example on long decision time before the shutdown order could be executed. As mentioned before, this study was performed only on Swedish data from the Database; therefore not all events have been analysed in this respect.

Experience feedback reporting has improved in Sweden, however well documented fire events are still rare. It was recommended that the OECD FIRE Coding Guidelines could be used as a tool to improve the event description and the experience feedback.

C-5 COMPARISON OF THE OECD FIRE DATABASE WITH NATIONAL DATABASES (VALIDITY CHECK)

C-5.1 France

This section provides the method implemented by IRSN for the evaluation of the fire frequency. The fires occurred in French NPP have been inventoried and analysed. This inventory has been used to define the reference numbers permitting to estimate the frequency of fires in a given area of a NPP.

The same methodology, as far as possible, has been applied to the OECD FIRE Database. Then a comparison of the results obtained using the French data and the OECD FIRE Database has been carried out.

C-5.1.1 Methodology implemented by IRSN for fire frequency estimation

C-5.1.1.1 Inventory of fires

The information collected to establish the Database on those fires which occurred in France in Pressurised Water Reactors (PWR) covers the period from April 21, 1975 to December 31, 2005. An analysis of the incidents caused by fires in the French NPP shows that in most cases it is possible to isolate the type of equipment or human intervention representing the origin of the fire. In order to facilitate the utilisation of operational experience as well as the approach which may be taken to evaluate the frequency of fires, it is better to group the materials of the same type into reference groups. This will make it possible to have, for each source of ignition, the broadest possible operational experience, while making the results more reliable. Fires reported in the French NPP operation were classified into groups. After analysing the operational experience and without entering into too many details, these groups were separated into sub-groups in order to better represent the risks of ignition. The equipment or interventions which were the cause of fires are indicated below for the French nuclear facilities.

Electrical equipment

Equipment for conversion of electrical energy:

- **E1: high tension equipment > 6.6 kV:** In this group are the fires which occurred on the equipment of high power electrical supply such as the Auxiliary Transformer, the Main Transformer, the Extraction Transformer.
- **E2: Turbo generator group:** All the fires which originate in the turbine generator or in a system whose operation depends on it are grouped together. This group also includes hydrogen fires associated with the cooling system of the generator.
- **E3: Diesel generator set**
- **E4: Batteries**
- **E5: Low and medium voltage equipment (lower or equal to 6.6 kV):** This group is made of fires which occurred on low and medium voltage equipment: inverters, rectifiers, transformers and electrical panels (30 V, 48 V, 125 V, 220 V, 230 V, 380 V and 6.6 kV).

  E5-1: Inverters

  E5-2: Rectifiers

  E5-3: Transformers

  E5-4: Electrical switchboards < 6.6 kV

  E5-5: 6.6 kV electrical switchboards: All the 6.6 kV electrical panels as well as their components (contactor, circuit breaker, disconnect switch, etc.) are part of this sub-group.

Control-command equipment:

- **E6: Decentralised control consoles and boxes:** In this group are the fires which occurred in the decentralised control stations in which the terminal block is the main cause of fire.
- **E7: Control cabinets (fire detection system cabinet, relaying circuitry cabinet, control cabinet (regulator):** The electrical switchboards are not to be considered as cabinets (see group E5). The cabinets classified in this group are the control, relaying and command cabinets which contain mostly electronic components.

Actuators:

- **E8: Motors (rotating machines other than motor driven pumps and fans) and motorised valves:** The initiating events in this group are broken down into the following sub-groups:

  E8-2: Compressors, refrigerating units, and motorised reducers

  E8-3: Overhead cranes, elevators and loading machinery

  E8-4: Motorised valves

  E8-5: Other motors: This sub-group includes all other motors (coils, electromagnets, etc.) not described above, electric valves, clusters control box, fire dampers, etc.

- **E9: Motorised pumps assemblies:** In this group are found all the fires which occurred in pumps powered by an electric motor, except for pumps integrated within refrigerating units, compressors, loading machinery, etc. Except for the specific case of ISBP and EAS (Low Head Safety Injection and Containment Spray System), motorised pumps whose motor is in a location different from the one of the pump, we shall consider both the pump and its motor as being the cause of the fire. The origin of the fires is linked to electrical short circuits, to oil leaks on heat insulators or to lack of lubrication.

E9-1: Primary motorised pumps

E9-2: Oil lubricated motorised pumps: From this sub-group the primary motorised pumps are excluded, because they are classified in the prior group. In this sub-group, we note that the majority of the fires are due to oil leaking on the hot pump.

E9-3: Motorised pumps not lubricated by oil: This sub-group includes all the pumps lubricated by grease as well as the non lubricated pumps.

Other cases

- **E11: Electric heaters, electric resistors:** This group includes all the fires which occurred at electric heaters and electric resistors. Many fires are caused by defective operation of electric resistors. If the electrical resistor is indeed the origin of the fire, it is still important to note that a malfunction of the control thermostat induced an overheating.

Hydrogen (H2 explosion in a tank, hydrogen leak following a valve repair)

- **H: Hydrogen** (outside of turbo generator group): This group includes the fires caused by a leak of hydrogen, not including the fires linked to the cooling system of the generator (see group E2). Hydrogen leaks have the distinction of catching fire spontaneously in air as soon as a sufficient concentration is reached within an area; this means that each leak is a potential source of fire.

Maintenance work (soldering, grinding, solvent catching fire during a cleaning process)

- **M: Maintenance:** This group includes all the fires which occurred during maintenance, under various states of unit operation. Note that the most frequent fires are those where cutting or soldering work was in progress, generating sparks which ignited flammable materials.

Turbine driven pump

- **TP: Turbine driven pump (pumps powered by steam turbines):** This group includes fires which occurred in turbine pump assemblies. The only turbine driven pumps installed in the units are the turbine pumps supplying steam generators: turbine driven feedwater pumps are turbine-driven auxiliary feedwater pumps.

Fans/blowers (motor or belt of the fan)

- **V: Fans** (electric motors included): In this group are listed the fires which occurred on air heaters and fans in ventilation systems. They are all caused by a motor-fan assembly. Very often the motor overheats and starts the fire.

Table 3 below sums up the constitution of the reference groups.

Table 3: Definition of reference groups

Reference Group	Origin of the Fire (equipment or human activity)
	1.Electrical equipment (E)
	1.1 Equipment for conversion of electrical energy
E1	High voltage equipment > 6.6 kV
E2	Turbo generator assembly
E3	Diesel generator set
E4	Batteries
E5	Medium and low voltage equipment lower or equal to 6.6 kV
E5-1	*Inverters*
E5-2	*Rectifiers*
E5-3	*Transformers*
E5-4	*electrical switchboard < 6.6 kV*
E5-5	*electrical switchboard 6.6 kV*
	1.2 Control-command equipment
E6	Cabinets and consoles for decentralised command
E7	Control-command, command-relay and regulation cabinets
	1.3 Operators
E8	Motors (rotating machines other than E9-V) and motorised valves
E8-2	*compressors, refrigeration units, RAM assemblies and motorised reducers*
E8-3	*overhead cranes, elevators and loading machinery*
E8-4	*motorised valves*
E8-5	*other motors*
	Motorised pumps assemblies
E9-2	*oil lubricated pumps*
E9-3	*pumps not oil lubricated*
E11	Electric heaters, electric resistors
H	**2. Hydrogen**
	3. Human activity
M	Maintenance work (soldering, cutting, ...)
TP	**4. Turbine driven pumps**
V	**5. Fans/Blowers (including electric motors)**

From the fire inventory, it is possible to associate with a reference group the number of fires whose origin is equipment in this group.

In addition, the T cumulative time of operation of French pressurised water reactors, from the start of commercial operation, can be estimated.

Knowing the number of fires associated with a reference group and the cumulative time defined earlier, we can estimate the FR_i frequency of fires associated with this reference group:

$$FR_i = number\ of\ fires / T$$

For equipment in the reference group for which the operational experience does not list any fires, the CHI Square law with a 50 % margin of error was used. This situation is encountered for equipment that is not at the origin of fire in the French NPP, but has experienced fire in foreign NPP. The frequency of the corresponding reference groups is considered and estimated using the relation below:

$$FR_i = 0.7 / T$$

The following *Table 4* shows the FR_i reference frequencies associated with each reference group.

Table 4: Frequency of reference groups (FR_i)

Reference Group	Frequency of Fires for Reference Groups [/ry]
E1: High voltage equipment	$1.8\ 10^{-2}$
E2: Turbo generator group (including H_2 leak)	$4.7\ 10^{-2}$
E3: Diesel generators	$1.2\ 10^{-2}$
E4: Batteries	$1.4\ 10^{-3}$
E5: Medium and low voltage equipment	
- E5-1: inverters	*7.9* 10^{-3}
E5-2: rectifiers	*.9* 10^{-3}
- E5-3: transformers	*5.9* 10^{-3}
- E5-4: low voltage electric switchboard (< 6.6 kV)	*1.6* 10^{-2}
- E5-5:medium voltage electric switchboard (6.6 kV)	$1.2\ 10^{-2}$
E6: Decentralised command consoles and cabinets	$5.9\ 10^{-3}$
E7: Control/command, relay and regulat. cabinets	$1.6\ 10^{-2}$
E8: Motors	
- E8-2: compressors, refrigeration units, ...	*5.9* 10^{-3}
- E8-3: overhead cranes, elevators, ...	• 10^{-3}
- E8-4: motorised valves	*.6* 10^{-3}
. E8-5: other motors	$1.4\ 10^{-3}$
E9: Motorised pumps groups	
- E9-1: primary motorised pumps	*.8* 10^{-3}
- E9-2: oil lubricated motor pumps	*.8* 10^{-3}
- E9-3: non oil lubricated motor pumps	*5.,9* 10^{-3}

E11: Electric heaters, electric resistors	2.6 10^{-2}
H: Hydrogen (not included in turbo generator group)	1.2 10^{-2}
M: Maintenance work	
- MP: under power	*2.6 10^{-2}*
- MA: shut down	*6.1 10^{-2}*
TP: Turbine driven pumps	9.8 10^{-3}
V: Fans/blowers (including electric motors)	3.3 10^{-2}

C-5.1.1.2 Evaluation of the fire frequency in a given room

a) Plant under power

i. Equipment: To estimate the frequency of fires at a given room we use the frequency of reference groups and the distribution of the equipment within the facility. We consider the frequency of fires to be proportional to the number of possible sources of ignition (equipment from the reference group).

Contribution of a reference group to the frequency of fires within a given room: Within a reference group i (i = E1, E2...), the reference frequency FR_i has been evaluated. If N_i is the number of pieces of equipment in a room and NT_i the number of pieces of equipment from the reference group i in the NPP, the contribution from this reference group to the fire frequency in a room is:

$$Fi = FRi\ x\ \frac{Ni}{NTi}$$

Frequency of fire at a given room: Knowing the contribution from each i reference group, the F_1 frequency of fire at a room, due to the equipment, is obtained by adding the contributions of F_i frequencies from the various groups:

$$F1 = \Sigma Fi$$

ii. Human interventions: The number of human interventions in a room being unknown, we have to consider that their contribution is uniform over the entire NPP. If MP is the reference frequency for a plant under power associated with the human interventions, their contribution to the frequency of fire on a given room is:

$$\frac{MP}{NL}$$

where NL is the total number of rooms in the plant where the human activities are taking place.

Frequency of fire when unit is under power: When the reactor is under power, the frequency of fire at a given room is:

$$FP = F_1 + \frac{MP}{NL}$$

b) Shutdown state

For shutdown states of the reactor, the frequency of fires due to equipment in a given room will be considered as proportional to the duration of the considered shutdown. The contribution from the identifiable equipment is thus:

In this formula, D is the duration of the shutdown state. For estimation of the fire frequency in a room, the following table can be used.

Table 5: Frequency of fires per reactor year

Plant Under Power in The Given Location: (X)					
Reference Group	Frequency of Reference FR_i	Number of Sources of Ignition in the Room (N_i)	Number of Ignition Sources in a 900 MW_e Plant (NT_i)	Proportion Factor $P_i = N_i/NT_i$	Frequency of Fire $F_i = FR_i*P_i$
Contribution Due To Identifiable Equipment					
E1	1.8 10^{-2}		8		
E2	4.7 10^{-2}		1		
E3	1.2 10^{-2}		3		
E4	1.4 10^{-3}		30		
E5-1	*7.9* 10^{-3}		*9*		
E5-2	*3.9* 10^{-3}		*40*		
E5-3	*5.9* 10^{-3}		*43*		
E5-4	*2.6* 10^{-2}		*84*		
E5-5	*1.2* 10^{-2}		*7*		
E6	5.9 10^{-3}		1475		
E7	1.6 10^{-2}		1706		
E8-4	*1.4* 10^{-3}		*130*		
E8-5	*1.4* 10^{-3}		*587*		
E9-1	*9.8* 10^{-3}		*3*		
E9-2	*9.8* 10^{-3}		*41*		
E9-3	*5.9* 10^{-3}		*153*		
E11	2.6 10^{-2}		473		
H	1.2 10^{-2}		210		
TP	9.8 10^{-3}		1		
V	3.3 10^{-2}		208		
				TOTAL ($F_1=\Sigma F_i$)	

Contribution Due To Maintenance Work, Plant under Power					
MP: Maintenance under power	2.6 10^{-2}	NL: Number of locations where human interventions	664	Contribution due to maintenance under power = MP/NL	3.92 10^{-5}
Frequency of fire in the given room				**TOTAL FP = F1+ MP/NL**	

C-5.1.2 Information deduced from the OECD FIRE Database

For each fire event of the OECD-FIRE Database, the equipment that is at the origin of the fire has been identified. Then the events compiled in this Database have been distributed on the reference groups defined in the IRSN fire frequency methodology. This application has been performed for the fire data delivered to the OECD FIRE Project for the observation period from January 1, 2001 to December 31, 2004. The data of the OECD FIRE Database is sufficient to carry out this application. Moreover, no additional reference group has been revealed by the data collection of OECD FIRE Project.

The operation time of the reactors corresponding to this period is actually not provided by the Project, so it is not possible to estimate the fire frequency of the reference groups. For this reason, only the rate of fire events contained by each referenced group has been estimated. The table below provides the results obtained.

Table 6 : Fire frequencies of reference groups

Reference Group	Fire Event Rate [%]
E1: High voltage equipment	11
E2: Turbo generator group (including H_2 leak)	9.6
E3: Diesel generators	2.9
E4: Batteries	0.7
E5: Medium and low voltage equipment	
- E5-2: rectifiers	*1.5*
- E5-3: transformers	*3.7*
- E5-4: low voltage electric switchboard (< 6.6 kV)	*14*
- E5-5: medium voltage electric switchboard (= 6.6 kV)	*10.3*
E7: Control/command, relay and regulat. cabinets	
E8: Motors	
- E8-2: compressors, refrigeration units, ...	*0.7*
- E8-4: motorised valves	*2.2*
- E8-5: other motors	2.9
E11: Electric heaters, electric resistors	8.1
H: Hydrogen (not included in turbo generator group)	*4.4*

M: Maintenance work	
- MP: under power	*8.8*
- MA: shut down	*8.1*
TP: Turbine driven pumps	
V: Fans/blowers (including electric motors)	*2.2*

This *Table 6* shows that the reference groups that have the most important contribution to the fire frequency are, by decreasing importance:

- Low voltage electrical switchboards,
- High voltage equipment,
- Electrical switchboard of medium voltage (approx. 6.6 kV),
- Turbo-alternator assembly,
- Maintenance works during power operation,
- Maintenance works during shutdown state,
- Electric heaters and the electric resistors.

C-5.1.3 Comparison of the results obtained from the OECD FIRE Database and from the French operating experience

In order to compare the results based on the French operating experience and the results deduced from OECD FIRE, the French fire event rate of each reference groups has been estimated. The table below presents the results obtained.

Table 7: French fire event rate of reference groups

Reference Group	OECD FIRE Fire Event Rate	French Fire Event Rate
E1: High voltage equipment	11	4.4
E2: Turbo generator group (including H_2 leak)	9.6	11.4
E3: Diesel generators	2.9	3
E4: Batteries	0.7	0
E5: Medium and low voltage equipment		
- E5-2: rectifiers	*1.5*	*1*
.....- E5-3: transformers	*3.7*	*1.5*
.....- E5-4: electric switchboard < 6.6 kV	*14*	*6.4*
- E5-5: electric switchboard of medium voltage	*10.3*	*3*
E8: Motors		
- E8-2: compressors, refrigeration units, etc.	*0.7*	*1.5*
- E8-4: motorised valves	*2.2*	*0*
- E8-5: other motors	2.9	0
E11: Electric heaters, electric resistors	8.1	6.4
H: Hydrogen (not included in turbo generator group)	*4.4*	*3*
M: Maintenance work		
- MP: under power	*8.8*	*6.4*
- MA: shutdown	*8.1*	*15.3*
V: Fans/blowers (including electric motors)	*2.2*	*8.4*

The table above shows that the list of reference groups having the most significant contribution to the fire frequency are almost the same in the 2 databases but with a different ranking and some differences in the level of the event rate. Generally speaking, the fire event rate of the OECD FIRE Database is higher for the switchboards and transformers. The most important differences are for the high voltage equipment (11% for OECD FIRE and only 4.4% for French operating experience), for the medium voltage electric switchboard (10.3% for OECD FIRE and 3% for French data). The contribution of fans is higher in the French operating experience (rate of 8.4 instead of 2.2).

Concerning the motorised valves and the other electric motors, the OECD FIRE Project shows that an electric motor can be at the origin of a fire. Even if this kind of fire did not occur in a French NPPs, this initiator cannot be excluded from the Fire PSA. This example shows that, when at national level there is no operating experience, the international data could be used for the estimation of fire frequency of the corresponding reference group instead of the CHI square law.

C-5.1.4 Conclusions

This application shows that the statistical use of the OECD FIRE Database is easy and well adapted for defining the reference numbers needed for the fire frequency estimation. This data base permits to know the kind of equipment that can be at the origin of a fire. Each kind of equipment according to their general design can be put together in families called reference groups. For each reference group from the Database it is possible to deduce the number of fire events occurred at the NPP. Knowing the plant operational time of the NPP corresponding to the observation period, the fire frequency of a reference group can be estimated.

At the time being, this operational time is under estimation by the Project. So, in the future, the estimation of the reference group fire frequencies will be possible. These frequencies, combined with the data of a NPP (more particularly the number of each piece of equipment), will permit to estimate the fire frequency in each room of the NPP. The fire frequencies of reference groups will be very useful for countries whose operating experience feedback is insufficient for a statistical use of fire events. Even if this operating experience is sufficient, for equipment for which no fire event occurred, the fire frequency of the corresponding reference group can be very helpful.

C-5.2 USA

This section provides details on the methods used by the United States Nuclear Regulatory Commission (NRC) in the development and evaluation of fire frequency data. Currently, the NRC is using two fire events databases supported by U.S. nuclear power plant (NPP) experience. The first database is essentially the EPRI fire events database, which has had a few additional features added due to the NUREG/CR-6850[1] [5] project, and the second is a separate NRC database containing LER and some smaller fire event data. In the near future, the NRC will be integrating the best features of each database to develop a single NRC fire events database. Once NRC has established the new database, it will compare those frequencies with the OECD FIRE Database frequencies, to the extent the frequency bins are comparable.

The database used for NUREG/CR-6850 [5] contains data from 1968 to 2000, and that data was analysed to determine the fire ignition frequencies. Data was from power operations, and low power, as long as the lower power operating mode did not affect the likelihood of ignition of a particular component. U.S. data between the years 2000 and 2008 will be collected and analysed. The NRC also plans to examine the international OECD FIRE Database for insights which will improve the overall NRC database. The NRC currently views the OECD FIRE Database program as a very effective program to better understand international NPP fire events. NUREG/CR-6850 [5] contains the data used by the NRC and the methods used to collect and analyse this data. This is the primary source of information and should be referenced for a more detailed understanding of the process developed and implemented by the U.S. NRC.

With respect to the database, NUREG/CR-6850 [5] developed a classification on which to retain data for its frequency calculation. Fires which were classified as potentially challenging or undetermined were retained and counted as one full event and one-half of an event, respectively. Potentially challenging fires were those which have the potential to become self-sustaining fires that challenge plant safety. Practically, these fires had the potential to produce damage beyond the initiating source, and include fires where personnel intervened to prevent such a consequence from occurring. For example, fires which required multiple extinguishers to extinguish the fire were retained for frequency; fires which were judged severe by heavy smoke were also retained. Of course, fires which actuated automatic suppression systems or had hose streams applied were kept as well. In

[1] EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities, Vols. 1 and 2, Electric Power Research Institute (EPRI), Palo Alto, CA, and U.S. Nuclear Regulatory Commission Office of Nuclear Regulatory Research (RES), Rockville, MD. September 2005. (Found at the following web address: www.nrc.gov/reading-rm/doc-collections/nuregs/contract)

some cases, judgment of the event is needed to establish if a fire is potentially challenging, a necessary limitation due to lack of information for certain events in the database. In cases where a fire may have the potential to be challenging, but it is difficult to ascertain, a weighting of ½ is given to the fire event. The full set of criteria for retaining an event for a frequency determination is documented in NUREG/CR-6850 [5].

Since fire PRAs typically develop fire scenarios from either an ignition source or a set of sources, the NRC predominantly uses component-based fire ignition frequencies developed in NUREG/CR-6850[5]. In this document, a generic set of fire ignition frequencies in units of per reactor year were developed for specific components. A two-stage Bayesian approach has been applied to develop these fire frequencies to account for plant to plant variability. Such variability occurs from differences in record keeping and reporting which affect the content and completeness of reporting. Prior distributions for this two-stage Bayesian approach were developed by a panel of experts and assumed a lognormal distribution. The smallest fires possible were assumed to be the lowest distribution's 5th percentile; the largest fire frequencies were assigned the 95th percentile; and an error factor of 10 was assigned. Uncertainty distributions are determined using the R-DAT program, a computer-based Bayesian reliability, data collection and analysis tool. This prior distribution was updated by the 1968-2000 data available to produce a posterior distribution. The full characterisation of component frequency is available in NUREG/CR-6850 [5] and can readily be integrated into an uncertainty analysis.

Fire frequency for a component is generally assumed the same on a reactor basis. Furthermore, different types of fires can be assumed for certain ignition sources. For example, both electrical and oil fires can arise from emergency diesel generators and pumps. Formulae for weighting factors have been developed to account for the distribution of frequency within a plant to account for differences in configuration. For example, factors for maintenance, occupancy, and storage have been developed in NUREG/CR-6850 [5] to distribute transient fire frequency across the plant.

The approach to counting plant components is also a key factor in distributing the frequency within the plant. Refinements in applying NUREG/CR-6850 [5] in the counting method have been developed and documented as a part of the U.S. NRC NFPA 805 Frequently-Asked-Questions program. Although NUREG/CR-6850 [5] provided counting guidance for plant electrical cabinets, clarifications were needed to ensure that the community as a whole consistently identifies a single electrical cabinet, and guidance was provided on the means to count outlier configurations as well. Counting guidance also extends to plant components beyond cabinets, such as transformers and pumps. Finally, a refinement in high energy arcing fault fire frequency has also been documented in this program, to apportion the majority of fires to medium voltage cabinets to be more consistent with the damage model for such fires.

NUREG/CR-6850 [5] has identified 37 different classifications of components, or bins. Each bin has an associated fire frequency. Such a classification is developed to enable the user to distinguish the fire scenario based on the type of fire expected to arise from such a component. For this analysis, the bins used in NUREG/CR-6850 [5] are compared to those used by OECD. Differences in the organisation and structure of each group's bins exist. For example, the OECD database has separate bins for High/Medium Voltage Electrical Cabinet and Low Voltage, whereas the NUREG/CR-6850 [5] has one general bin, plus a separate bin for high energy arcing fault events. (Note that the U.S. NRC NFPA 805 FAQ process has established two separate bins for high energy arcing faults fire frequency in order to align the majority of fires with medium voltage cabinets, consistent with the damage model in NUREG/CR-6850 [5]) With respect to fires due to transients, or fires from cutting and welding, NUREG/CR-6850 [5] breaks down these fires into fires from the turbine building and fires from other locations in the plant. Such a distinction is made due to the more numerous activities related to those sources in the turbine building. The OECD FIRE Database would allow such discrimination, but this distinction has not been drawn in the OECD frequency bins[2]. Main feedwater pumps are also called out separately in the NUREG/CR-6850 database due to the presence of significant amounts of oil and the potential damage of the fire, whereas the OECD database doesn't make such a distinction. Some other bins are similar between the OECD and NUREG/CR-6850 fire events databases.

Estimates of the fire frequency per year for those events in the OECD FIRE Database is on the order of 0.1.[2] Although higher, the same overall order of magnitude holds for the frequency of potentially challenging fires from the NUREG/CR-6850 database. The fire frequency per reactor year for a BWR or PWR is approximately 0.25 and 0.28, respectively. A comparison of frequencies at a greater resolution is difficult as the frequencies from the NUREG/CR-6850 database are on a component level, as opposed to the OECD FIRE Database frequency calculations for a room level.

Extracted tables of fire ignition frequency from NUREG/CR-6850 [5] follow:

[2] "Proposals for the Future Use of the OECD Fire Database," Wolfgang Werner (SAC) and Anders Anger (ESKonsult), Presented at the 11th OECD FIRE Meeting, October 2008.

Table 8: Fire Frequency Bins and Generic Frequencies

ID	Location	Ignition Source (Equipment Type)	Mode	Generic Freq (per rx yr)	Split Fractions for Fire Type					
					Electrical	Oil	Transient	Hotwork	Hydrogen	HEAF[1]
1	Battery Room	Batteries	All	7.5E-04	1.0	0	0	0	0	0
2	Containment (PWR)	Reactor Coolant Pump	Power	6.1E-03	0.14	0.86	0	0	0	0
3	Containment (PWR)	Transients and Hotwork	Power	2.0E-03	0	0	0.44	0.56	0	0
4	Control Room	Main Control Board	All	2.5E-03	1.0	0	0	0	0	0
5	Control/Aux/Reactor Building	Cable fires caused by welding and cutting	Power	1.6E-03	0	0	0	1.0	0	0
6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Power	9.7E-03	0	0	0	1.0	0	0
7	Control/Aux/Reactor Building	Transients	Power	3.9E-03	0	0	1.0	0	0	0
8	Diesel Generator Room	Diesel Generators	All	2.1E-02	0.16	0.84	0	0	0	0
9	Plant-Wide Components	Air Compressors	All	2.4E-03	0.83	0.17	0	0	0	0
10	Plant-Wide Components	Battery Chargers	All	1.8E-03	1.0	0	0	0	0	0
11	Plant-Wide Components	Cable fires caused by welding and cutting	Power	2.0E-03	0	0	0	1.0	0	0
12	Plant-Wide Components	Cable Run (Self-ignited cable fires)	All	4.4E-03	1.0	0	0	0	0	0
13	Plant-Wide Components	Dryers	All	2.6E-03	0	0	1.0	0	0	0
14	Plant-Wide Components	Electric Motors	All	4.6E-03	1.0	0	0	0	0	0
15	Plant-Wide Components	Electrical Cabinets	All	4.5E-02	1.0	0	0	0	0	0
16	Plant-Wide Components	High Energy Arcing Faults[1]	All	1.5E-03	0	0	0	0	0	1.0
17	Plant-Wide Components	Hydrogen Tanks	All	1.7E-03	0	0	0	0	1.0	0
18	Plant-Wide Components	Junction Boxes	All	1.9E-03	1.0	0	0	0	0	0
19	Plant-Wide Components	Misc. Hydrogen Fires	All	2.5E-03	0	0	0	0	1.0	0
20	Plant-Wide Components	Off-gas/H2 Recombiner (BWR)	Power	4.4E-02	0	0	0	0	1.0	0
21	Plant-Wide Components	Pumps	All	2.1E-02	0.54	0.46	0	0	0	0
22	Plant-Wide Components	RPS MG Sets	Power	1.6E-03	1.0	0	0	0	0	0
23a	Plant-Wide Components	Transformers (Oil filled)	All	9.9E-03	0	1.0	0	0	0	0
23b	Plant-Wide Components	Transformers (Dry)			1.0	0	0	0	0	0
24	Plant-Wide Components	Transient fires caused by welding and cutting	Power	4.9E-03	0	0	0	1.0	0	0

ID	Location	Ignition Source (Equipment Type)	Mode	Generic Freq (per rx yr)	Split Fractions for Fire Type					
					Electrical	Oil	Transient	Hotwork	Hydrogen	HEAF[1]
25	Plant-Wide Components	Transients	Power	9.9E-03	0	0	1.0	0	0	0
26	Plant-Wide Components	Ventilation Subsystems	All	7.4E-03	0.95	0.05	0	0	0	0
27	Transformer Yard	Transformer – Catastrophic[2]	Power	6.0E-03	1.0[3]		0	0	0	0
28	Transformer Yard	Transformer - Non Catastrophic[2]	Power	1.2E-02	1.0[3]		0	0	0	0
29	Transformer Yard	Yard transformers (Others)	Power	2.2E-03	1.0	0	0	0	0	0
30	Turbine Building	Boiler	All	1.1E-03	0	1.0	0	0	0	0
31	Turbine Building	Cable fires caused by welding and cutting	Power	1.6E-03	0	0	0	1.0	0	0
32	Turbine Building	Main Feedwater Pumps	Power	1.3E-02	0.11	0.89	0	0	0	0
33	Turbine Building	Turbine Generator Excitor	Power	3.9E-03	1.0	0	0	0	0	0
34	Turbine Building	Turbine Generator Hydrogen	Power	6.5E-03	0	0	0	0	1.0	0
35	Turbine Building	Turbine Generator Oil	Power	9.5E-03	0	1.0	0	0	0	0
36	Turbine Building	Transient fires caused by welding and cutting	Power	8.2E-03	0	0	0	1.0	0	0
37	Turbine Building	Transients	Power	8.5E-03	0	0	1.0	0	0	0

1. See Appendix M for a description of high-energy arcing fault (HEAF) fires.

2. See Section 6.5.6 below for a definition.

3. The event should be considered either as an electrical or oil fire, whichever yields the worst consequences.

C-6 SWEDISH USE OF "TYPE FIRE"

In Sweden a study *"Guidance for pre-incident planning in NPP facilities"* [2] has been performed. Ringhals AB has been a model for this study, but the purpose has been to make the report applicable for all NPP in Sweden. The work has been performed in close co-operation with the Swedish NPP and Rescue Services in the nuclear power municipalities Östhammar, Oskarshamn, and Varberg. The plant internal fire brigades at the nuclear power plants have also been involved.

The idea with the emergency planning is to plan the efforts and working steps in order to give the operational and emergency staff effective support for making decisions and for starting the mission without delay.

The guidance expressed in the SKI Report 2008:54 [2] gives the readers suggestions on how to create a modern pre-incident planning documentation with instructions on how buildings, building areas, corridors, rooms, equipment can be reached in case of a fire extinguishing situation. It also includes guidance on what kind of fire extinguishing equipment is recommended to be used in different locations and rooms affected in a fire situation.

The pre-incident planning documentation for a NPP is to a large extent created on basis of the identified and most common type fires and relevancy checked against the information stored in the OECD FIRE Database.

A Report "P*re-incident planning*" has been prepared by the Department of Fire Safety Engineering and Systems Safety of Lund University in Sweden [3]. The aim of this report is to illustrate that a well done pre-planning effectively helps fire fighting in nuclear power plants. Experiences from this study of fire in nuclear power plants can be used in forthcoming pre-planning. In a nuclear power plant there are several hazards, which can contribute to complex fire scenarios and difficult rescue actions for the fire fighters. To cope with these rescue actions, good pre-planning is needed. Such pre-planning is also demanded by Swedish law.

Experiences from this study of fires in nuclear power plants can be used in forthcoming pre-planning. The background material for this study was the international OECD FIRE Database. The following issues of the study are:

- What is pre-planning?
- Which parts is included in the pre-planning?
- How do you pre-plan in a nuclear power plant?
- Is the OECD FIRE Database a good reference for use in pre-incident planning for NPPs?

A method was created to study the database and the result is presented in diagrams. During the study of the database, the content, the functionality and the fields of application were analysed. Simultaneously with the database study, a literature study of extinguishing equipment was performed. This study is a theoretical study of extinguishing equipment and it is a complement to use in the pre-planning of fires. The result of the study shows that a fire in electrical components is the most frequent type of fire incident in a nuclear power plant. The study also illustrates that all type of extinguishing equipment in needed depending on what type of fire is to be extinguished. The choice of extinguishing equipment depends on the type of fire, availability and personnel safety. The analysis of the Database can also be used to examine the training of the personnel involved.

C-7 EXAMPLES OF IMPORTANT FIRES AND THEIR CONSEQUENCES INCLUDING EVENTS WITH POTENTIALLY SEVERE CONSEQUENCES

C-7.1 Swedish Examples

In the following, a short summary of a report by SKI (reference [6 9 of the main CSNI report) on a safety significant fire event in a Swedish NPP is given. On July 1, 2005 a fire occurred in an electrical switchgear room at Forsmark NPP. The cause of the fire is yet to be determined; however the starting point of the fire was an arc, due to failure in a rectifier inside an electrical cabinet. By the evaluation of the incident it was identified that the pre-fire plans did not provide sufficient information for making the appropriate decisions. Lessons learned from the fire at Forsmark were that pre-incident planning was at hand but the information was not sufficient to make the correct initial decisions that might be critical for life and property.

The overall aim of the project has been to give general pre-incident planning recommendations with respect to electrical switchgear room fires, to determine and establish an appropriate delegation order and clarify the overall responsibility of the fire fighting operation as well as the operation of the plant before, during and after an incident. The project has been funded by NBSG (National fire safety group). The report is presented as an SKI Rapport due to the interesting topic and that it is important to spread the information and lessons learnt to a larger public.

The aim of the SKI report is as follows:

- to clarify the appropriate fire fighting tactics
- and to give recommendations on the type of extinguishing media to be used, based on the risk and consequence of a fire with respect to smoke, radiation, chlorides etc. resulting from the extinguishing media.

C-7.2 Czech Examples

First Event "Fire of the station service load transformer …"

The service load transformer 3BT02 exploded, while the unit was operating in mode 1 at 100 % power. The defect occurred due to the failure of the power part of the left branch lines switch. As a result, in a very short time a large volume of gases was generated which caused the explosion of the switch power part and subsequent rupture of the transformer vessel, ejection of oil in the adjacent area, and oil fire. The accident led to the discharge of approximately 32 t of oil from the collecting tank underneath the transformer, and subsequently into the aeration channel and to cable ducts. The event led to the loss of 400 kV with the subsequent unit transient. This was the most serious event in the history of that Czech NPP.

The fire did not spread to the turbine building, because the fire was extinguished on-site by the plant fire brigade. As a result of transformer oil leak and foam fire extinguishing a part of the waste water purification system was lost and subsequently oil products escaped into the environment (the root cause was in unsuitable design). The transformer damaged by the explosion was replaced with a new one.

Event "Self-ignition of hydrogen in a battery car …"

The plant fire brigade received a report about a fire at the outside hydrogen storage Fire was reported by the shift engineer of the secondary circuit, who heard an emergency call of the worker who performed manipulations for operational hydrogen make-up in the distribution lines to unit generators. The fire occurred on the reduction valves box by self-ignition. Pressure bottles were cooled and the flame was extinguished by water.

Analysis of the event has shown that the fire was caused by incautious manipulation by the worker. Opening o fan incorrect valve led to the burst of a dust blind and subsequently to uncontrolled hydrogen leakage. It was confirmed that if the rate of hydrogen escape is higher than 4 m/s, it self-ignites. The hydrogen system is housed in the self-contained, well vented building, sufficiently distant from the reactor units. For the reasons mentioned before hydrogen could eventually have exploded. Safety significance is "Unknown", because of difficult judgment of extent and consequences in the event of explosion hydrogen.

C-7.3 Spanish Examples

Event "Fire in the Main Turbine Generator Group N.2"

In October 1989, a fire occurred when the NPP was at power operation. The fire affected the main turbine generator group no. 2, due to a failure in the corresponding turbine.

The facts of the fire were that pipes of the turbine lubrication oil system were broken and cooling hydrogen for the alternator was released. The ignition mechanism was, consequently, a hydrogen deflagration. The root cause was a mechanical failure in the rotor of the high pressure turbine-

As a consequence of the fire, several components were damaged (burned and marred):

1. Some electric power cables of main auxiliary equipments, necessary for the operation of turbine driven fans no. 3 and 4;
2. Some electric power cables of the pumps related with RAiE function;
3. Pump motors related with EDOR function;
4. Part of the control and regulation circuits (48 V);
5. Several auxiliary components of the main turbine generator groups no. 1 and 2.

Water and foam were used massively in the fire extinguishing by the fire fighters (both on-site and external brigades). The elevation "3.5 meters" was flooded by the fire fighting action. Additionally, demineralised water from EDOR tanks and sea water, due to loss of isolation in the external cooling circuit of the condenser, contributed to the flood. Estimated volume of water ranged from 4,000 to 5,000 cubic meters.

After the event, several investigations were carried out and subsequent actions took place, though, in the end, the NPP was shutdown.

Event "Fire in the Alternator Area (Turbine Building), due to the Actuation of a Differential Protection in the Main Transformer"

In August 2008, a 3-loop Westinghouse PWR plant was operating at 100 % power operation (1055 MW_e) when an unplanned reactor shutdown occurred due to a turbine trip.

This turbine trip happened because of the actuation of the differential protection in the main transformer. The direct cause was an electrical fault (short circuit) in the 21 kV phase "S" of the main circuit breaker (from the main generator towards the main transformer).

Detection of the fire in the alternator area occurred 8 seconds after the reactor scram, as the detection alarms from the fire detectors triggered in the area close tohe main generator. The corresponding fire pump started immediately.

The fire is likely to have started inside the box of bushes of the neutral from the main alternator. When the differential protection of the main transformer triggered, the phases "R" and "T" cut the short circuit current but the over-current kept on running through the phase "S".

The actuation of the on-site fire brigade occurred 2 minutes after the shutdown, by means of the public address system. The fire extinguishing tasks started 5 minutes later. First, the fire brigade was sent to the transformer area, because it was assumed that the fire was in this area. However, it was verified that there was no fire in that area, but smoke was coming out from the Turbine Building. Inside that building, smoke was discovered in the 2 bearings of the alternator, and the extinguishing was started using all the carbon dioxide extinguishers available in the area and the smoke stopped coming out. Later, smoke started coming out again from the bearings area of the alternator. It was necessary to use water and foam. Then, fire was found in the bushing box of the neutral of the main generator. After checking that there was no voltage, the fire brigade used water hoses and the fire was extinguished. In total, 16 people took part in the fire extinguishing (all of them from the plant), and 10 of them were professional fire fighters.

The pre-alert emergency was declared at the plant due to the fact that the fire lasted more than 10 minutes, without having affected any safety systems.

The fire was completely extinguished after one hour and a quarter of extinguishing tasks, though the emergency was maintained. The total duration of the emergency was 1h. 25'.

The fire supposedly damaged the seals of the bush box and, subsequently, caused a hydrogen leakage in the alternator that could be the direct source of the fire.

C-8 JNES APPLICATION TO IGNITION MECHANISM ANALYSIS

JNES has developed the internal fire PSA methodology and is developing the seismic-induced fire PSA methodology. Preliminary results from internal fire PSA revealed that the total core damage frequency of internal fire events might be larger than that of internal events. Then JNES would intend to enhance the internal fire PSA methodology, in order to evaluate the precise fire risk, to identify vulnerabilities of structures, systems and components, and to assess the validity of fire prevention and mitigation measures quantitatively.

JNES began to analyse the ignition mechanism of internal fire events that were registered in the domestic NUCIA Database and in the OECD FIRE Database as a part of methodology enhancement. The NUCIA Database that is disclosed on the website has been voluntarily developed by the Japan

Nuclear Technology Institute (JANTI) in co-operation with the Electric Power Companies, and includes the information of any accidents and incidents with plant data.

Fire events where a component itself was ignited or a component affected by the fire lost its function were analysed. Fire events due to human error during test and maintenance and events for which the ignited component or the fire cause could not be identified were screened out.

The number of fire events analysed was 11 events in NUCIA Database and 41 events in the OECD FIRE Database, where FIRE data was applied if event was overlapped in both Databases. The analysed events were categorised into seven classes of fire causes in the following *Table 9*. Thirty-one events out of 52 (62 %) were related to electric components. Devices that were responsible for fire were identified in *Table 10* and the key fire ignition mechanisms were are explained in *Figure 2* through *Figure 6*.

JNES had analysed the selected fire events for the study of fire initiation mechanism as a first step of a qualitative analysis on the OECD FIRE Database. Preliminary results were as follows;

- Due to the failure of the device, or to ignition of leaking gas (such as hydrogen) or volatile gas, the fire occurred directly. So, for such kind of fire event, its frequency itself might be considered to be a fire frequency.
- A fire caused by a lubricant required leakage, contact, and heat up as ignition mechanism.
- All the phenomena analysed here are related to a defective insulation or a poor contact of the connecting section of the electric device or wiring such as power cable or panel.

Analysis results will be applied to the deterministic fire development analysis, Fire PSA and so on, in phased approach. Collection and analysis of fire events will be performed subsequently to evaluate fire frequencies in the future. For discussing fire severity and fire scenario, a fire intensity distribution will be assigned to each fire ignition source.

Table 9: Fire Event Classification by Fire Causes

Class	Fire Cause	Number of Events
A-1	Leakage of current (ground fault) caused by defective insulation or others of the electric device or wiring	6
A-2	Short circuit caused by defective insulation or others of the electric device or wiring	16
A-3	Intrusion or adhesion of foreign materials such as dust particles or water droplets to the connection section of the electric device or wiring	5
A-4	Poor contact of the connection section of the electric device or wiring	4
B	Problem of the device	4
C	High-temperature section’s contact with oil such as a lubricant or adhesion of such an oil to that section	12
D	Ignition of a leaked gas (such as hydrogen) or volatile gas	5

Table 10: Device Contribution to Fire Occurrence

Device responsible for fire	Fire Event Classification						
	A-1	A-2	A-3	A-4	B	C	D
Inverter		X					
Gas Circulator (Filter)						X	
Air Pre-heater					X		
Pump						X	
Circuit Breaker				X			
Charger		X					
Control Valve						X	
Rectifier, Storage Battery		X					
Power-Transmission Line	X						
Turbine Generator						X	X
Diesel Generator						X	
Electric Board		X		X			
Power Cable	X	X	X				
Motor-Driven Pump						X	
Piping							X
Bus Duct			X				
Heater					X		
Fan						X	
Valve						X	
Transformer	X	X	X	X	X		
Motor Control Center			X				

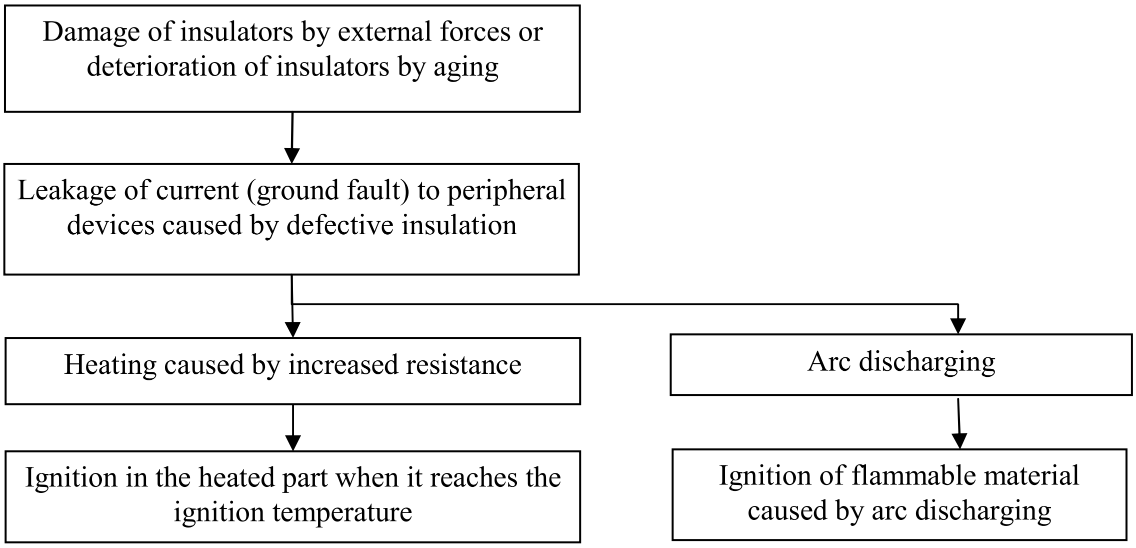

Figure 2: Ignition Mechanism of Class A-1

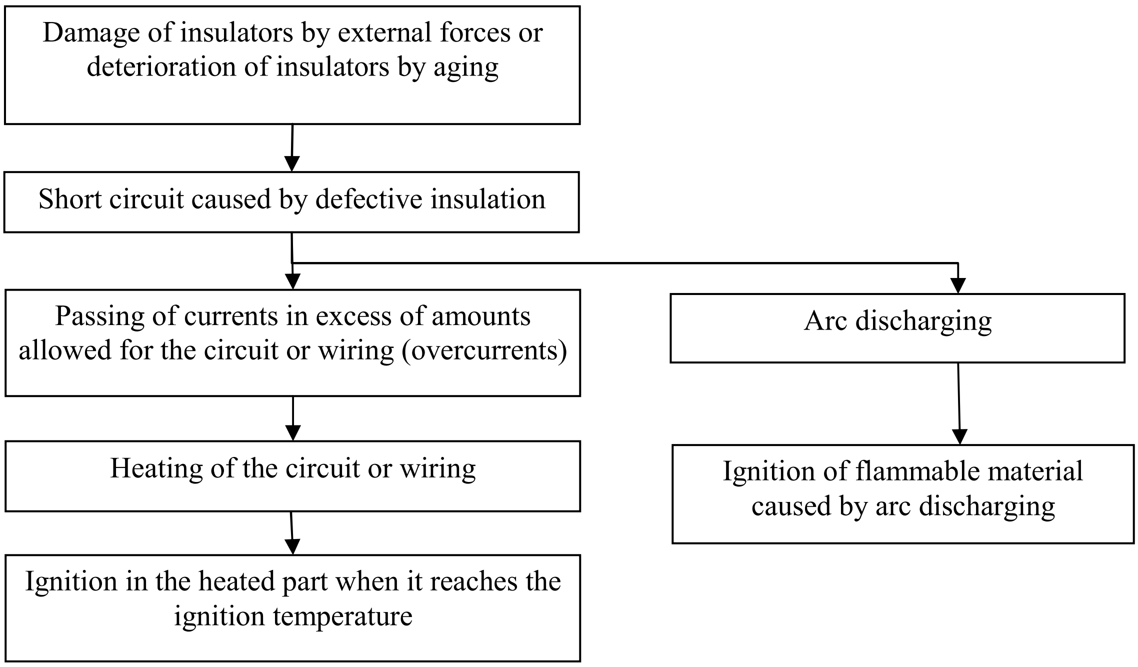

Figure 3: Ignition Mechanism of Class A-2

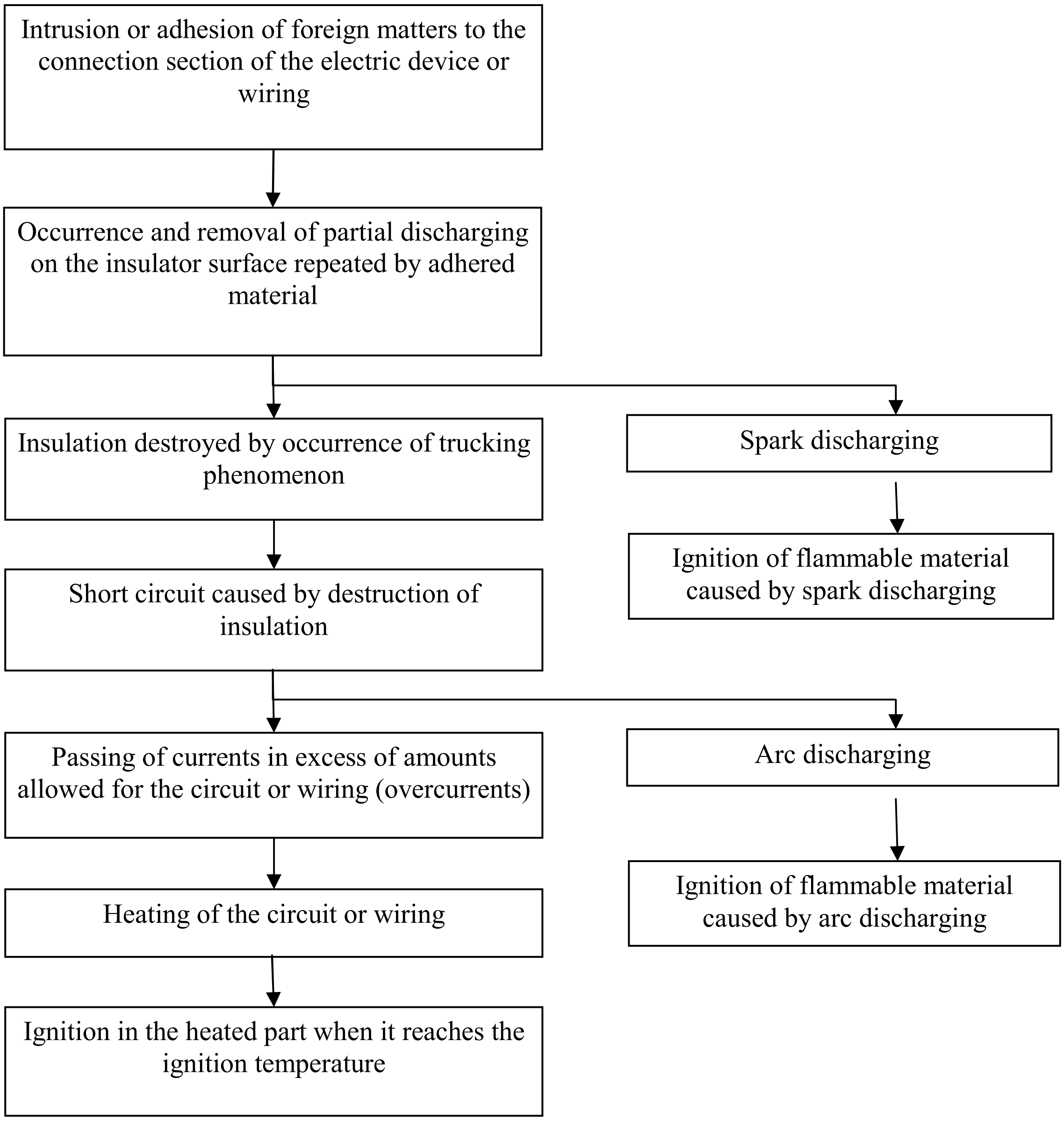

Figure 4: Ignition Mechanism of Class A-3

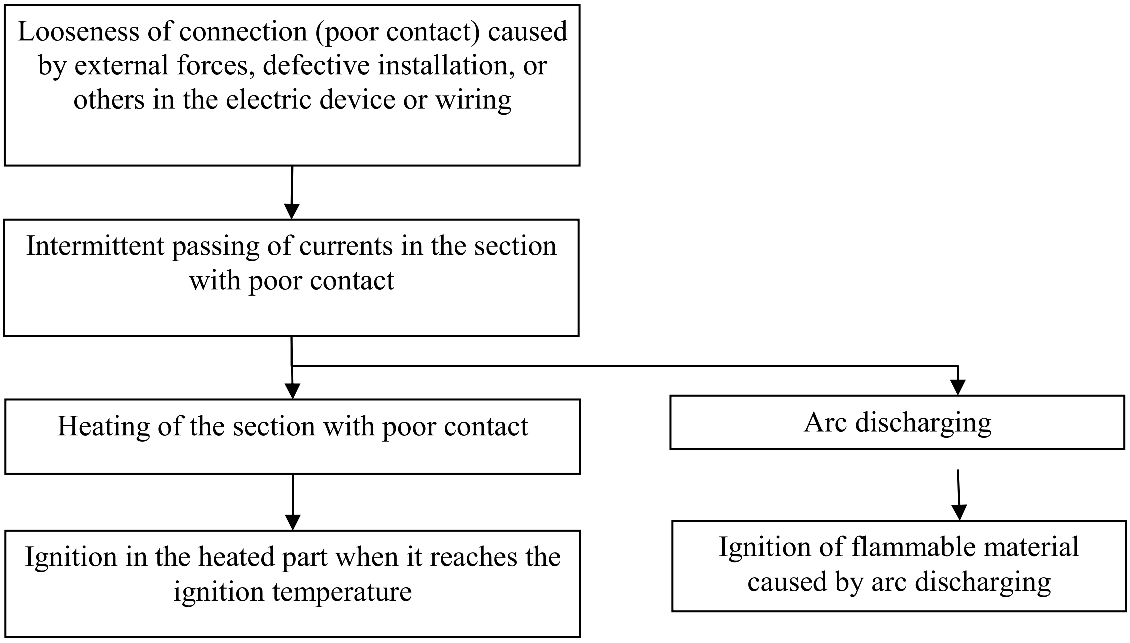

Figure 5: Ignition Mechanism of Class A-4

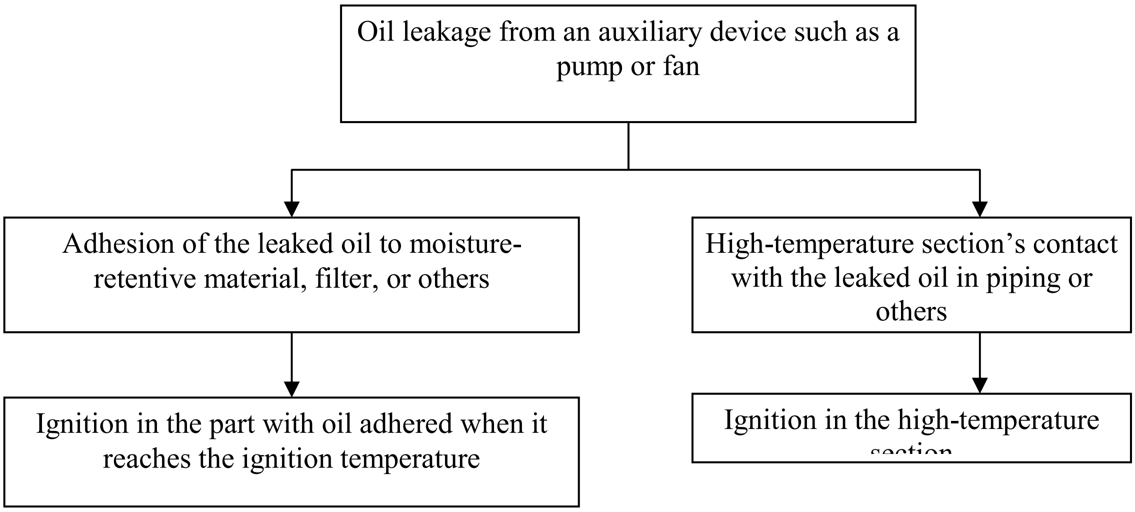

Figure 6: Ignition Mechanism of Class C

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[1]ES Rapport 2002042:001 "*NBSG 09#05 Qualitative analysis of fires in Swedish NPPs"* Year of publication 2006

[2]Swedish Nuclear Lnspectoarate (SKI):
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"P*re-incident planning*" Report 5272008, Lund, 2008

APPENDIX D - DETAILS OF FUTURE APPLICATIONS OF THE OECD FIRE DATABASE

This Appendix contains detailed explanations of some of the issues listed in the report.

D-1 INITIATOR FREQUENCIES

Initiator frequencies are an important input to Fire PSA. Currently they are frequently obtained by analytical estimates that are rather poorly supported by statistical data, or they are directly obtained from national databases. Initiator frequencies are either assigned to individual rooms of a certain type, or to certain components. If these initiator frequencies were to be obtained from national databases the small amount of observations and the limited observation periods would lead to very large uncertainties. In practice a screening process is applied to the rooms (or components), at the end of which only rooms or components are retained which are considered significant for PSA purposes. Initiator frequencies are an important element in this screening process.

The information collected in the OECD FIRE Database represents the reality of fire events observed in a large international population. This provides the basis for estimating "real" initiator frequencies that can be used to corroborate or eventually update the frequencies currently used in Fire PSAs.

The OECD FIRE Database provides generic counts of fire occurrences for buildings and various types of rooms, for example, process rooms or cable rooms/tunnels, and also for components. If the total operating years of the included plants and the average number of rooms of a given type is known generic "real" fire initiator frequencies for individual rooms of the specific type can be estimated and used in the PSA analyses.

The "real" frequencies also provide a basis for putting the screening process on a more realistic basis and simplifying it. In this context it is important to be aware of the existence of different reporting levels in the countries contributing to the OECD FIRE Database. Coarsely speaking, there is a dichotomy into countries reporting all or almost all events, and others that report only events above a certain severity level, for example, only LER events, which means that they report only events with "severe consequences", for details see *Figure 1*

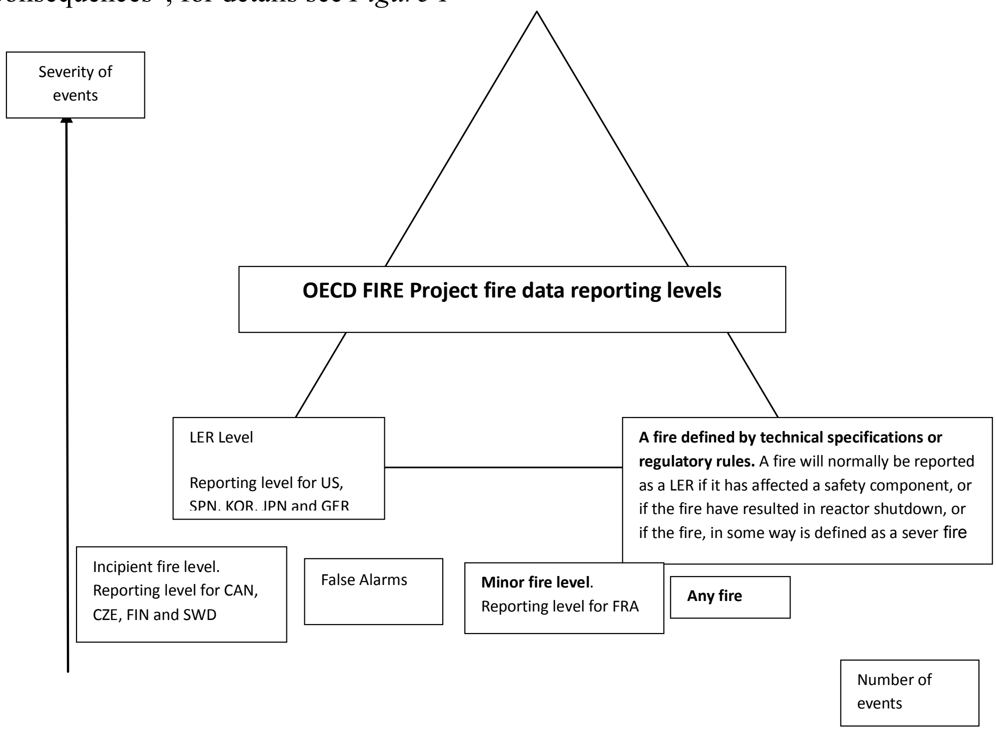

Figure 1: Overview of reporting levels in OECD FIRE member countries

Table 1*Table 1* shows the number of events collected in the participating countries for the various reporting levels.

Table 1: Overview of the statistics of events collected in the OECD FIRE Database

Country	No of reported events	Observation period	Estimated reactor years [ry]	Reporting level
Canada	64	2000-2008	132	all events
Czech Republic	12	1991-2008	46	all events
Finland	19	1991-2007	68	all events
France	53	1999-2008	548	all events
Sweden	102	1981-2007	292	all events
Germany	26	1987-2008	449	LER
Japan	10	1976-2008	1293	LER
Korea	2	2003-2008	120	LER
The Netherlands	1	2006-2008	3	LER
Switzerland	7	1984-2008	125	LER
Spain	24	1987-2008	190	all events, but incomplete
USA	24	1997-2008	1249	LER
Grand Total	344		4515	
Total, all events reported	248		1086	
Total, only LER events reported	96		3429	

Propagation and consequences of fire
The OECD FIRE Database also contains information on the propagation of fires after initiation and on the consequences of fires, including the associated conditional probabilities. These conditional probabilities obtained from the OECD FIRE Database can be used for comparison with the corresponding conditional probabilities generated by the computational models in fire PSAs, as manifested by the fire event trees, thus providing the possibility to check the models' validity.

Definition of "severe consequences"
In the discussion in this proposal of using information from the database for screening purposes reference is made to the notion "severe consequences". This is defined as follows:
The plant state is changed from "power operation" to "shutdown" and one or more of the following options apply:

- Structural influence or collapse,
- More than one fire compartment affected,
- Total loss of one or more rooms,
- Two or more trains of one or more safety systems affected,
- All trains of a safety system affected.

D-2 Example for initiator frequencies, based on data in the OECD FIRE Database and on preliminary assumptions

The potential results of the proposed activity can be depicted by an example, which is based on the fire event data currently collected in the OECD FIRE Database for power operation states and on the available information on the assumed average operation time factor of 0.85 of the plants included in the data collection. The activity to collect numbers of individual rooms of certain types is still ongoing. Therefore, estimates of average numbers based on the currently available information are used in the example. These assumed numbers are shown in the bottom rows of *Table 2* and *Table 3* (in parentheses).

The conclusions presented in the example heavily depend on the estimated numbers of individual rooms used for calculating fire initiator frequencies for rooms. A final decision on the numbers to be adopted has to be made by the OECD FIRE national co-coordinators, once information from all countries is available. Currently, information on the room numbers is available from Czech Republic, Finland, and Sweden, shown in the Tables in Appendix D. As can be seen, the numbers differ widely, making it difficult to define “averages”.

Table 2 is based on information from countries that report all or almost all events, *Table 3* on information from all countries, because it can be assumed with high confidence that all countries with an elevated reporting level have reported the events with severe consequences.

Table 2 shows an overall fire frequency of approx. 1.0 E-01/ry, and, with the assumed number of rooms, fire initiator frequencies per room and reactor year in the E-04 range. (The numbers of rooms still have to be estimated and agreed upon) This is significantly lower than the E-03 range used in some Fire PSA as initiator frequencies for process rooms, switchgear rooms and cable rooms/ducts.

Fires in process rooms, switchgear rooms and cable rooms/ducts typically dominate the fire induced core damage contribution in Fire PSA. As the calculated core damage frequencies are directly proportional to the fire initiator frequencies the presented example suggests (with all mentioned reservations) that the results of some Fire PSA are too conservative.

The comparison of the frequencies per room and reactor year in *Table 2* and *Table 3* permits to estimate the conditional probability that a fire occurring in a room of a certain type leads to severe consequences of that fire. These probabilities are, for example:

- Process rooms: 0.02
- Switchgear rooms: 0.07
- Rooms for electrical control equipment: 0.025
- Cable rooms: 0.11

These numbers suggest that fires originating in cable rooms/ducts and switchgear rooms are significantly more likely to lead to severe consequences than fires originating in other rooms.

Since the populations supporting *Table 2* and *Table 3* respectively, are relatively small and differ significantly; the “conclusion” is still not well founded.

In all fire PSAs screening processes are used to eliminate probabilistically insignificant event sequences, often on basis of cut-off criteria based on fire frequencies for individual rooms and associated average unavailability’s of safety functions. Other issues like availability of fire detection and suppression means and fire loads are also considered. Such screening processes are used to avoid the costly analysis of areas (or components) that are insignificant contributors to core damage.

The numbers of rooms of certain types are currently collected. The result of this activity will be estimates of the average number of rooms. This will enable estimates of generic average fire frequencies for the individual rooms of the types listed in *Table 2* and *Table 3*.

The use of these average frequencies can be two-fold:

- Guidance for screening processes to eliminate insignificant event sequences,
- Guidance and support to production and review of Fire PSA.

Example of the kind of results that could eventually be obtained:

Based on the provisionally assumed numbers of rooms (shown in parentheses in the bottom rows of *Table 2* and *Table 3*), the two tables together suggest that process rooms, switchgear rooms and cable rooms/ducts, perhaps with the exception of such rooms in the containment and intake building, should always be included in a fire PSA, eventually also rooms for electrical control equipment, but rooms in workshops and offices, battery rooms, storage rooms and rooms for ventilation are candidates for getting screened out on basis of fire initiator frequencies and the associated average unavailability of safety functions. In an existing fire PSA the average unavailability of safety functions is ~ 6.5 E-05. Assuming 40 rooms each for workshops, offices, battery rooms, storage rooms (empty columns in *Table 2*) the initiator frequency per room and year is < 2.5 E-05. With the average unavailability 6.5 E-05, the core damage contribution from each room is 1.6 E-09.

If fire frequencies for components are the starting point of a fire PSA, analogous methods can be used to corroborate or improve initiator frequencies for components.

Table 2: Reported occurrences of fire events in the OECD FIRE Database. Only events from countries reporting all events (no restriction on reporting level) during power operation until 2007

Room Type / Building Type	Process rooms	Switchgear rooms	Rooms for electrical control equipment	Workshop	Office	Battery rooms	Cable rooms, cable ducts	Storage rooms	Rooms for ventilation	Other types of rooms	Total Events Frequency per ry
Turbine building	22		1			1				5	29
Diesel generator building	0		1							2	3
Auxiliary building	7	1	2	1				1	2	4	18
Reactor building	3		1				1				5
Containment	1										1
Electrical building	1	4	8				1			1	15
Intake building	2										2
Switchyard	1	2								3	6
Independent emergency building	1	1									2
Others	1						1		3	4	9
Total	39	8	13	1		1	3	1	5	19	90
Total frequency/ry **(989 x 0.85 ry)**	4.4 E-02	8.8 E-03	1.05 E-02	1.0 E-03		1.0 E-03	3.5E-03	1.0E-03	6E-03	2.3E-02	1.0E-01
Frequency/(room x ry) (number of rooms assumed)	2.3 E-04 (186)	1.3 E-04 (63)	1.9 E-04 (54)	2.5 E-05 (40)		2.5 E-05 (40)	3.0 E-05 (116)	2.5 E-05 (40)	6.0 E-05 (~ 100)	< 7.0 E-05 (> 300)	

Table 3: Reported occurrences of fires with severe consequences in the OECD FIRE Database until end of 2007. Severe consequences: (Plant state changes from power operation to shutdown) and (structural influence or collapse, more than one fire compartment affected, total loss of one or more rooms, two or more trains of one safety system affected, all trains of a safety system affected)

Room Type / Building Type	Process rooms	Switchgear rooms	Rooms for electrical control	Workshop	Office	Battery rooms	Cable rooms, cable ducts	Storage rooms	Rooms for ventilation	Other types of rooms	Total
Turbine building	3	1					**1**				5
Diesel generator buiklding											
Auxiliary building											
Reactor building											
Containment											
Electrical building		**1**	1								2
Intake building											
Switchyard										**1**	1
Independent emergency building											
Others										1	1
Total	3	2	1				1			2	9
Total frequency/ry **(3891 x 0.85 ry)**	9 E-04	6.2 E-04	2.6 E-04	2 E-04 chi sq.50%	2 E-04 chi sq.50%	2 E-04 chi sq.50%	3.2 E-04	2 E-04 chi sq.50%	2 E-04 chi sq.50%	6.0 E-04	2.6 E-03
Frequency/(# of rooms x ry) (number of rooms assumed)	4.8 E-06 (186)	1 E-05 (63)	4.8 E-06 (54)				2.7 E-06 (116)		2 E-06 (~100)	<2 E-06 (>300)	

D-3 BRANCH POINT PROBABILITIES FOR FIRE EVENT TREES

A frequently used tool in fire PSAs is the fire event tree. It permits to conveniently track and describe the sequences resulting from fires. To be successful, corroborated branch point probabilities are needed at the branch points of the tree. In most existing PSAs the branch point probabilities are only poorly supported by statistical evidence For the purpose of the proposed activity it is attempted to design a generic fire event tree and to derive the branch point probabilities from the statistical evidence in the OECD FIRE Database. Important fire propagation issues for which such probabilities have to be estimated are listed below.

Branch points:

- The fire is detected by an automatic system;
- The fire is detected by plant personnel;
- Fire is self extinguished due to lack of fuel or oxygen;
- The fire is extinguished by an automatic system;
- The fire is extinguished by a manual system.

End states of event trees

The ensuing consequences of fires have to be characterised by end states of the event tree (consequence categories), for example:

0. No heat or smoke influence (denoted as “none” in the following)
1. Fire and damage contained to fire initiating object
2. Fire spread or damage to at least one more object in room
3. Loss of one room
4. Impact on adjacent rooms within one fire compartment
5. Impact on more than one fire compartment
6. Structural damage
7. Impact limited to one safety train
8. Safety significant impact on safety trains

The various end states of the event tree result from different combinations of successes/failures of fire detection/fighting activities. Note that the consequence categories are not mutually exclusive, for example, categories 7 or 8 can occur concurrently with one of the categories 3 to 6).

The estimates of the branch point probabilities (including uncertainties) for the different nodes in the generic fire event tree are derived from the Database. The database is now large enough to give reasonable assurance of the credibility of the derived figures. The values can be refined as the Database grows. In this way the results of fire PSAs can be corroborated or improved.

The structure of the generic event tree derived from the data collected in the OECD FIRE Project and the estimated branch point probabilities are shown in *Figure 2* and *Figure 3*. The tree structure is a simplified example, as it does not yet account for fire fighting details like fire source isolation and controlled burn-out, and others. *Table 4* through *Table 7* show the numbers of occurrences of the various consequence categories and their conditional probabilities of occurrence, given a fire event for power generation states and non-power generation states, respectively.

Note:
Table 4 and *Table 5* cannot be compared with *Table 3*, because in the latter, the additional assumption is made that the plant went from power generation to shutdown.

As the current update of the Database is not yet complete, these numbers are preliminary. Nevertheless, they show that the conditional probabilities of fires leading to severe consequences are very low.

The next step will be the comparison of the OECD FIRE generic event tree and fire event trees used in existing PSAs.

Figure 2: Illustration of potential applications of branch point probabilities for power generation states only
Conditional probability of minor effects (categories 0, 1, 2, 7 in *Table 4*):0.932
Conditional probability of severe effects (categories 3 - 6, 8 in *Table 5*): 0.068

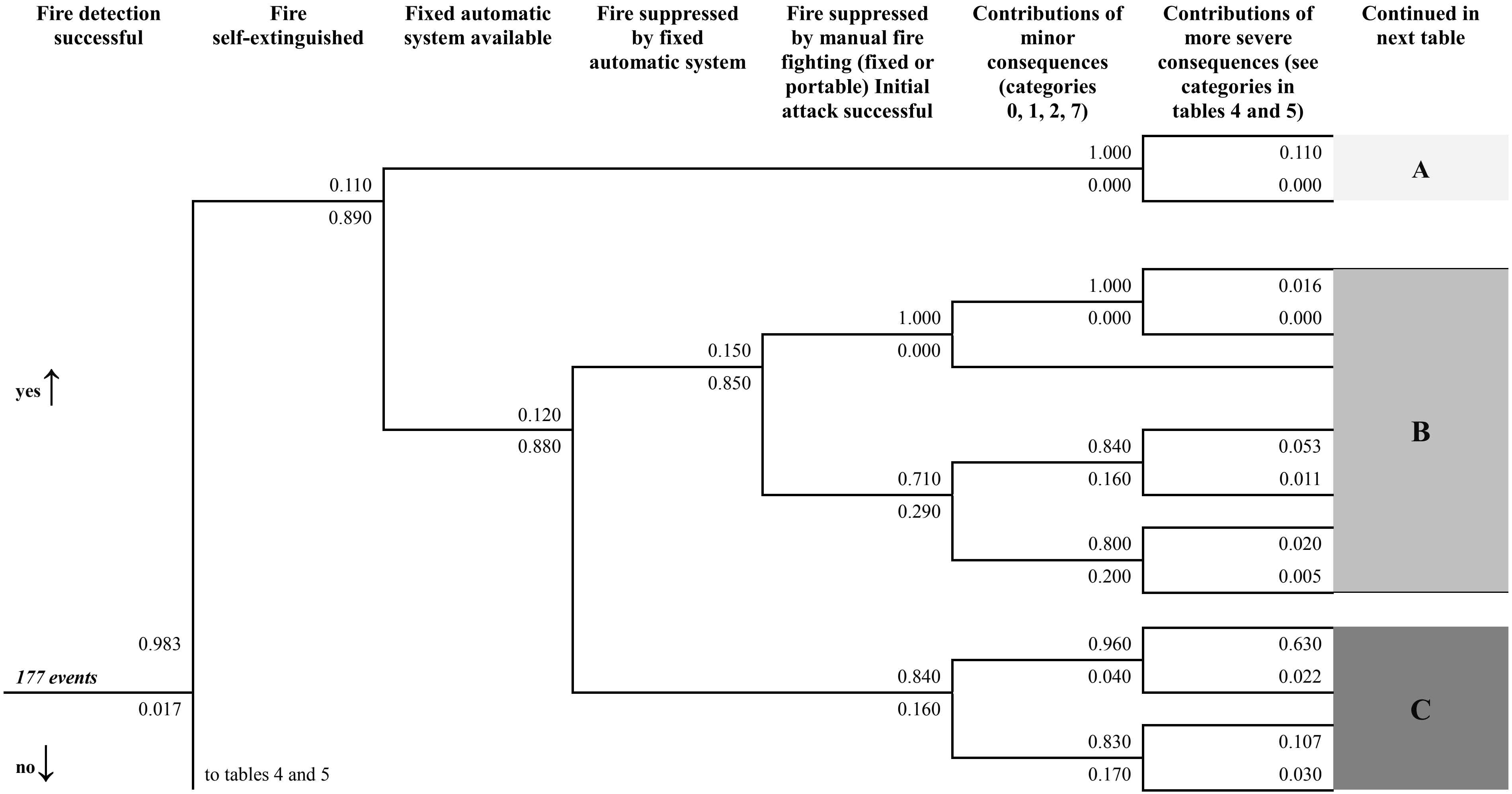

Figure 3: Illustration of potential applications of branch point probabilities for non-power generation states
Conditional probability of minor effects (categories 0, 1, 2, 7 in *Table 6*): 0.959
Conditional probability of severe effects (categories 3 - 6, 8 in *Table 7*): 0.041

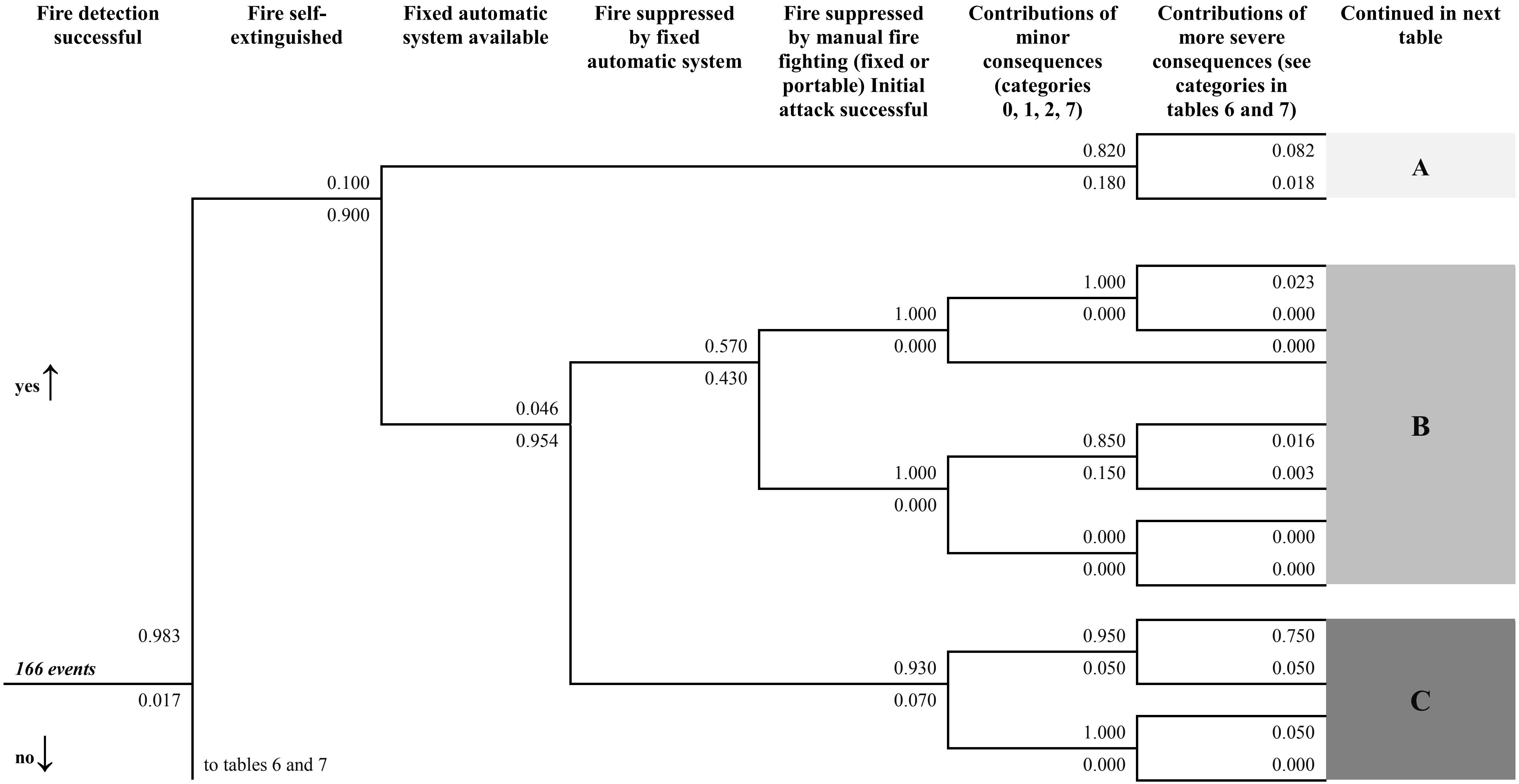

Table 4: Numbers of occurrences of fire events in specific consequence categories for power generation only

Consequences	A	B	C	D	Sum (contains double counts)
0 None	9	7	29	1	46
1 Fire and damage contained to fire initiating object	11	10	73	2	96
2 Fire spread to at least one more object in room		1	20		21
3 Loss of one room			1		1
4 Impact on adjacent rooms in one fire compartment		1	2		3
5 Impact on more than one fire compartment			3		3
6 Structural damage		1	2		3
7 Impact is limited to only one safety train (partly double count, coincidence with 0, 1, 2)	6	3	26	1	36
8 Safety significant impact on safety trains (partly double count, coincidence with 3, 4, 5 or 6)		1	2		3
Total (contains double counts)	26	24	158	4	212

Table 5: Conditional probabilities of occurrences of specific consequence categories, given a fire event for power generation only
Note: events are not mutually exclusive

Consequence	A	B	C	D	Sum
0 None	**0.05**	**0.039**	**0.164**	**0.005**	**0.226**
1 Fire and damage contained to fire initiating object	**0.06**	**0.056**	**0.412**	**0.011**	**0.54**
2 Fire spread to at least one more object in room		**0.005**	**0.11**		**0.118**
3 Loss of one room			**0.005**		**0.005**
4 Impact on adjacent rooms in one fire compartment		**0.005**	**0.011**		**0.016**
5 Impact on more than one fire compartment			**0.015**		**0.016**
6 Structural damage		**0.005**	**0.011**		**0.015**
7 Impact is limited to only one safety train (partly double count, coincidence with 0,1,2)	**0.033**	**0.017**	**0.147**	**0.005**	**0.20**
8 Safety significant impact on safety trains (partly double count, coincidence with 3, 4, 5 or 6)		**0.005**	**0.011**		**0.016**

Table 6: Numbers of occurrences of fire events in specific consequence categories for non-power generation

Consequences	A	B	C	D	Sum (contains double counts)
0 None	**11**	**1**	**56**		**68**
1 Fire and damage contained to fire initiating object	**5**	**5**	**71**	**2**	**83**
2 Fire spread to at least one more object in room	**2**		**9**		**11**
3 Loss of one room		**1**			**1**
4 Impact on adjacent rooms in one fire compartment			**2**		**2**
5 Impact on more than one fire compartment	**1**				**1**
6 Structural damage			**1**		**1**
7 Impact is limited to only one safety train (partly double count, coincidence with 0,1,2)	**1**	**1**	**5**		**7**
8 Safety significant impact on safety trains (partly double count, coincidence with 3, 4, 5 or 6)			**2**		**2**
Total (contains double counts)	**20**	**8**	**146**	**2**	**176**

Table 7: Conditional probabilities of occurrences of specific consequence categories, given a fire event for non-power generation

Consequences	A	B	C	D	Sum
0 None	**0.065**	**0.03**			**0.406**
1 Fire and damage contained to fire initiating object	**0.03**	**0.012**		**0.012**	**0.497**
2 Fire spread to at least one more object in room	**0.012**		**0.054**		**0.066**
3 Loss of one room		**0.006**			**0.006**
4 Impact on adjacent rooms in one fire compartment			**0.012**		**0.012**
5 Impact on more than one fire compartment	**0.006**				**0.006**
6 Structural damage			**0.006**		**0.006**
7 Impact is limited to only one safety train (partly double count, coincidence with 0,1,2)	**0.006**	**0.006**			**0.042**
8 Safety significant impact on safety trains (partly double count, coincidence with 3, 4, 5 or 6)					**0.012**

D-4 IDENTIFICATION OF SCENARIOS TYPICAL OF FIRES LEADING TO SEVERE CONSEQUENCES

By studying the OECD FIRE Database and the developed event trees, commonalties potentially existing for the fire scenarios with the most severe consequences can be examined. The commonalties could consist of failures of detection systems due to:

- wrongly designed detection system,
- failure to interpret the alarm as an alarm,
- other reasons;

or deficiencies of fire fighting activities due to:

- equipment failures,
- misinterpretation of the situation,
- faulty fire fighting strategy,
- inadequate training of the fire fighting crew.

D-5 HOW DO FIRE EFFECTS SPREAD TO OTHER COMPARTMENTS

The aim of this application is to identify fire barrier elements (walls, fire doors, fire dampers, etc.) whose integrity was degraded by fires (such that flames occurred on both sides of the fire barrier). Smoke spreading across fire barriers is not considered. If a failure of a fire barrier is identified it should be examined what kind of barrier did fail and how this happened (e.g. by a door left open, or by a cable penetration seal not being functional after installation works).

According to the Coding Guideline, the events of interest for the analysts can be filtered by field 3.4.2 (Heat or hot gas influence), where the field must be coded “More than one fire compartment affected” or “Structural influence or collapse” (see the Coding Guidelines as provided in Appendix A).

Table 8: Coding of fire spreading

Code	Identify the influence due to heat or hot gases on systems and components. Use specified codes. If feasible, identify the names of SSC s affected by the fire,
Codes	**Definitions**
None	No components took damage from the heat developed by the fire.
Limited to a single component	One component (main) has been damaged by the fire (a breaker, a pump).
Multiple component fire in one room	Part of a room is destroyed (e.g. a complete electrical cabinet) or several components in a room.
Total loss of one room	Significant damaged in a room up to total damage of one room
Adjacent rooms were affected	In addition, it may be also useful to include in the field the pathway of hot gas propagation. Components have been destroyed in two rooms due to the fire. The fire did not spread beyond the fire compartment.
More than one fire compartment affected.	The fire has spread between fire compartments. (Loss of a fire barrier or degradation of fire barriers, not only complete failures)
Structural influence or collapse	Structural influence or collapse of building structure

The field must be coded with "More than one fire compartment affected" or possibly "Structural influence or collapse". From the 315 events of the 2008 version of the Database CD there are four events for each of the two codes mentioned above.

Results for coding "More than one fire compartment affected":

"Maintenance oversight in transformer 6.9/0.4 kV T5AB3 (star point in low voltage side was left disconnected) that caused damage to some components"
No loss of a fire barrier or degradation of fire barriers. Instead the fire was ignited at three different locations by an electrical failure.

"A and B protection on 230 kV ring breaker damaged from fire"
The fire occurred in the station A switchyard relay building cable trench. Any fire spread in other compartments or degradation of fire barriers is not recorded in the event description.

"Safety relevant cable fire"
This event occurred in the Greifswald NPP in 1975, being located in the former German Democratic Republic. The fire was ignited by a short circuit on a 6 kV cable that lasted for about 7.5 minutes and overheated the cable over a distance of about 120 m. After ignition of the power cable the fire spread over the whole cable tray also destroying other power and control cables.
The 6 kV cable was located in an intermediate building which was situated between the reactor building and the turbine building. The fire occurred in the intermediate building, the turbine building and the outside the turbine building at the offsite transformer RT1. It is mentioned that fire barriers in the turbine building were degraded during the event – the fire-rating of them is not reported. It is not recorded whether the fire spread through barriers or did ignite separately at different locations due the powerful long lasting ignition source.

"Fire in an electrical cabinet …"
The event description shows that the fire did not degrade any fire barriers. Instead components of redundant trains in the same room have been affected by smoke and chloride. The coding should be checked. and might be improved to "Multiple component fire in one room".

Results for coding "Structural influence or collapse":

"Fire (explosion like) in local transformer …"
The fire ignited at a local transformer and spread by leaking oil via the sand bed to the cabinet of the main transformer. Both transformers were located outside the plant in the same concrete structure which has no roof and which has a concrete separation between both transformers. Damage of concrete structures is not reported. The local transformer was completely destroyed by an explosion at the beginning of the event. The explosion is assumed to have also destroyed a cable penetration to the turbine building. The fire rating of the cable penetration is not reported. Smoke leaked into the turbine building via the cable penetration.

"Structural influence or collapse" is not reported in the event description. The Coding Guideline might be extended to distinguish between "Structural damage" and "Damage of fire barriers".

"Fire in main turbine-generator group no. 2 and flooding of the cellar"
Turbine lubrication oil and cooling hydrogen were released and first ignited and then ignited or destroyed electrical cables and other components. "Structural influence or collapse or building structure" is not reported in the event description. The coding might be a lapse or might refer to a reported "loss of insulation in the external cooling circuit of the condenser" which resulted into water leaking out of some tanks causing a flood.

"Fire in turbine hall, room D1.80. Lubrication oil for turbine bearings caught fire. There were some indications of turbine bearing damage"
Lubrication oil for turbine bearings was released through a 12 mm oil pipe which was broken. The oil caught fire. In the event description it is reported that "there were some indications of turbine bearing damage", however it is not reported whether this was confirmed and whether the assumed damage came from the fire or from missing lubrication due to the broken pipe. A "Structural influence or collapse of building structure" is not reported in the event description.

"Isolation material in roof caught fire"
The event occurred 1977 during the construction phase of the NPP. The roof of the diesel generator building was set on fire by the diesel generator exhaust piping. After structural modifications have been undertaken this type of events can be ruled out.

D-6 OUTLOOK ON FURTHER STATISTICAL AND OPERATION EXPERIENCE USE

The OECD FIRE Database can be used statistically not only for assessing fire detection and suppression means. It also should be able to provide more information on incipient /pilot) fires, their causes, effects and frequency.

One further goal of the Database is to gain more and more reliable insights in the fire propagation pathways, the propagation of flames, heat, smoke and soot inside the fire compartment as well as to other compartments and/or fire cells including their corresponding probabilities.

In the future, it should be possible to estimate how small fires grow to large ones. From viewpoint of the nuclear safety it will be essential to find out from the Database the contributions of changes in the plant operational mode, of reactor trips due to fire and all the further impact on the plant safety.

Further deterministic as well as probabilistic applications of the OECD FIRE Database may become obvious with the continuously increasing amount of events in the Database.

APPENDIX E – OECD FIRE DATABASE MEMBERS

Member Country	Institution	National Co-coordinator
		Name
Canada	CNSC	Grant Czerkas
Czech Republic	NRI Rez	Ladislav Kolar & Milan Patrick
Finland	STUK	Jouko Marttila & Matti Lehto
France	IRSN	Remy Bertrand & Karine Delalande-Pelissier
Germany	GRS	Marina Roewekamp
Japan	JNES	Yusuke Kasagawa & Katsunori Ogura
Korea	KINS	Jong Seuk Park
The Netherlands	MVROM	Arend Rooseboom
Spain	CSN	Francisco Olivar
Sweden	SSM	Ralph Nyman
Switzerland	ENSI	Annette Ramezanian
United States	NRC	J.S. Hyslop
	Operating Agent	
	Institution	Name
	ESKonsult AB	Anders Angner
	SAC	Wolfgang Werner
	OECD/NEA Secretary	
	Institution	Name
	NEA / NSD	Jean Gauvain