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# SUMMARY REPORT ON EVENTS RELATED TO THE SUPPLY OF NUCLEAR POWER PLANTS COMPONENTS

Stanislovas Ziedelis

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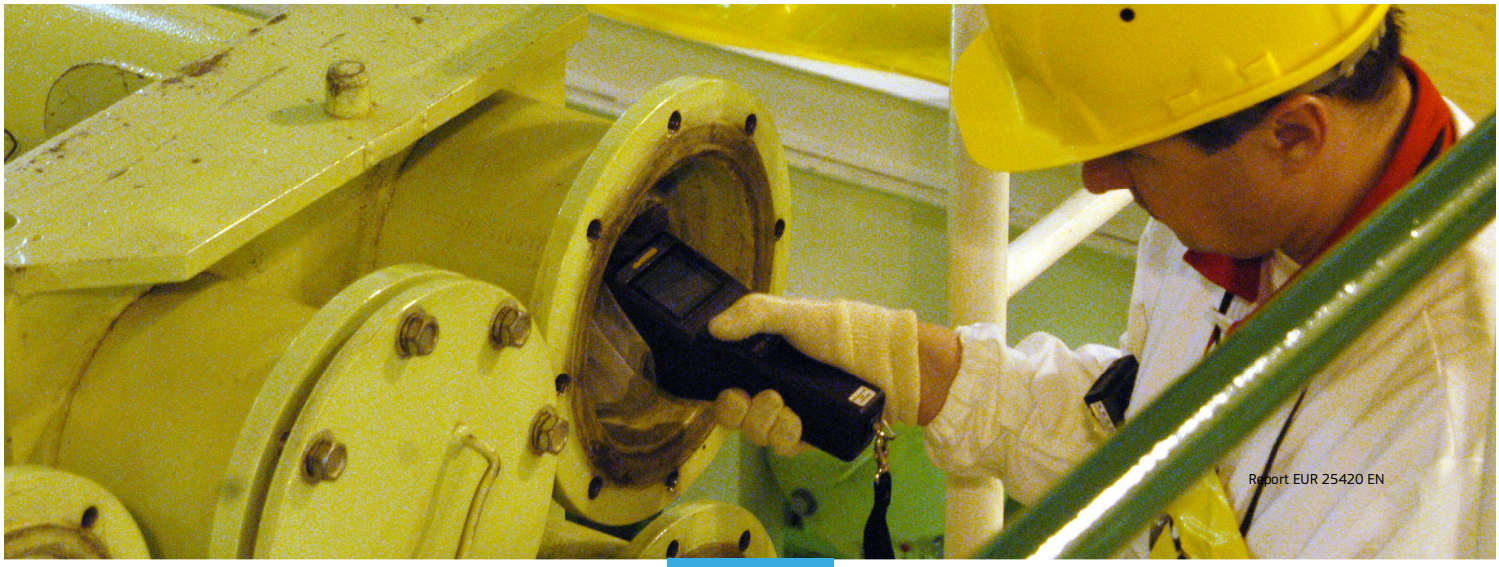

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## TABLE OF CONTENT

# 1. INTRODUCTION

Supply of products and components starts early before the construction and commissioning of a Nuclear Power Plant (NPP) and subsequently continues during plant operation and outages until decommissioning. Effectively functioning and properly managed nuclear supply chain can in a large extent guarantee adequate quality of supplied products, contributing to safe and reliable operation of nuclear installations. However, safety related incidents and events due to substandard components continue to occur; number of such reported incidents is not decreasing, and there are some potential for its growth. Consequently, lessons learned from the large operational experience as well as from current trends in the global nuclear supply chain are very important for utilities and regulators.

During the last decades the nuclear supply chain experienced a number of serious changes. New specific features recently became usual such as shortage of skilled design, deficit of manufacturing and engineering capacity in the market, alterations in the manufacturing environment, including the rising costs of manufacturing, the shrinking resources of manufacturing bases, shortened product life cycles, emerging new materials, technological processes and standards, and the globalization of market economies. State-of-the-art nuclear supply chain is an integrated process wherein a number of various business entities (i.e., suppliers, designers, manufacturers, distributors, and retailers) work together with the end users - NPPs. Analysis of this complicated system as a whole and highlighting of its deficiencies could help to reduce the frequency of occurrences when substandard components are delivered to NPPs and causing safety related incidents.

Attempts aiming to use operational experience in the area related with supply of components have already been made in the past. However, majority of these works are covering only some particular issues related with supply of components and not covering the entire nuclear supply chain as a whole. In order to identify the main recurring causes, contributing factors and lessons learned, and to disseminate and promote recommendations to reduce the recurrence of similar events in the future it was decided to conduct an up-to-date analysis of events related to supply of components to NPPs.

This summary report represents results of study [1] performed by the centralized office of the European Clearinghouse on Operating Experience Feedback (OEF). It covers events at NPPs caused directly or partially by inadequate spare parts, products or components supplied by suppliers/vendors during the operation of NPPs. The general purpose of this work is the further improvement of safety provisions by means of identifying and eliminating circumstances, precursors and causes of said events, as well as highlighting the most important lessons learned and developing recommendations.

# 2. METHODOLOGY

This study has been performed by means of extracting, systematising and analysing adequate operational experience-related information from event reports stored in the IRS (OECD NEA/IAEA), NRC (US), IRSN (France) and GRS (Germany) databases during period 1980-2010.

The process of identification, retrieving and screening of relevant events consists of several steps (see Figure 1). Aiming to limit the number of potentially relevant event reports and to avoid overlapping with analogous studies already performed, only events at NPPs which were directly or partially caused by inadequate spare parts, products or components supplied by suppliers/vendors during the period of operation were selected. Events during construction and

commissioning of initial set of equipment before start of operation of NPP (analyzed in [2]) or caused by deficiencies in maintenance, modifications or services on site provided by subcontractors were considered as not relevant for this study, if they are not directly related to the supply of components. The final list of events used for analysis contained 222 IRS incident reports, 709 reports from the US NRC data base (section corresponding to 10CFR part 21), 197 IRSN reports and 93 GRS reports.

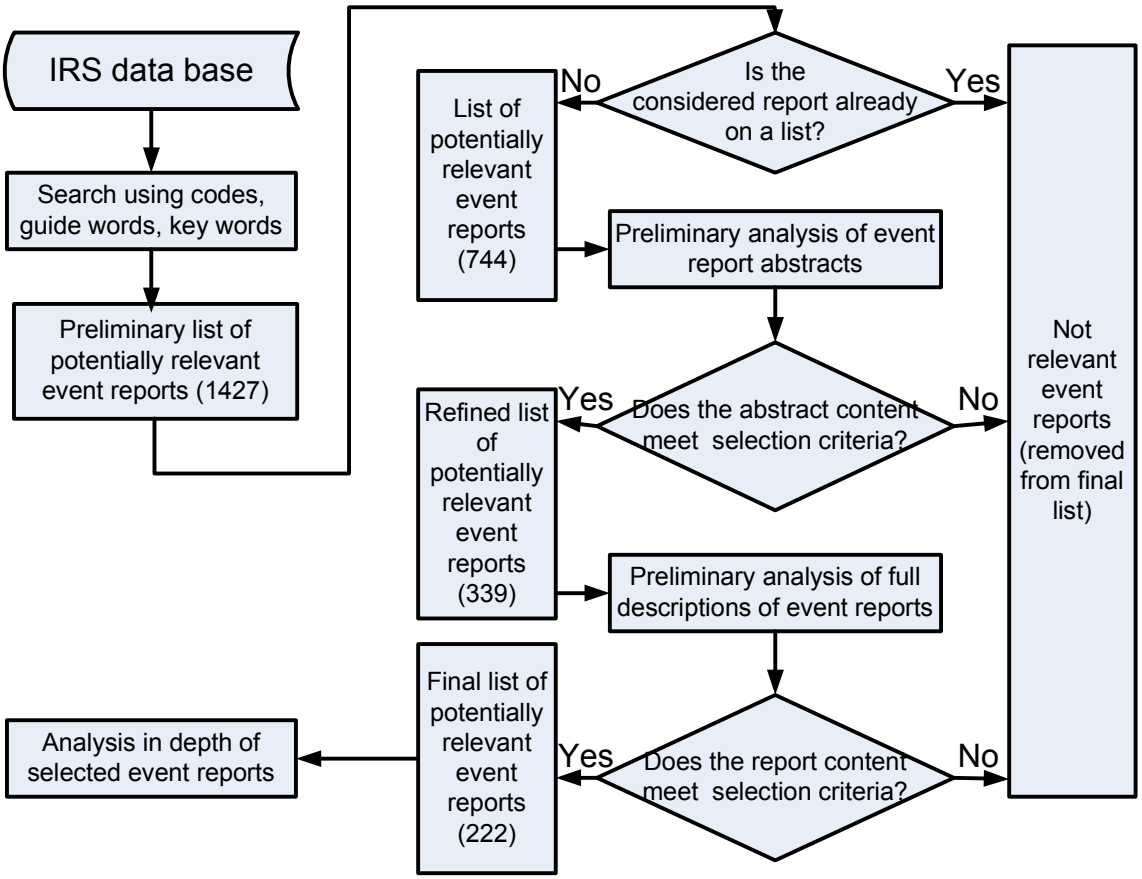


Figure 1. Algorithm of screening and retrieving of IRS event reports

In a second stage, the selected events reports were classified into the selected families, subfamilies, groups and subgroups and analyzed in depth striving to examine the direct causes, contributing causes and root causes, safety significance of the events, main significant corrective actions and lessons learned. In order to understand better the mechanisms for how and why substandard components originate and how they become installed into the structures and systems of NPPs, causing undesirable incidents or events, two different classification systems were used during the analysis. The first classification system consisted of seven event subfamilies corresponding to all separate stages of the supply chain (including design, manufacture, transportation, storage and distribution) and the licensee's main lines of defence designed to prevent the installation of substandard components. The second classification system was established following the goal to determine the types of most frequently failing components and was based on the four main groups with relatively different physical working principles: mechanical (including hydraulic/pneumatic), electrical, instrumentation/control and fuel.

# 3. MAIN FINDINGS

The most contributing processes of the nuclear supply chain to the supply of inappropriate components are (see Figure 2): component design (42%), manufacturing (32%), and inadequate technical documentation provided by supplier (9.4%).

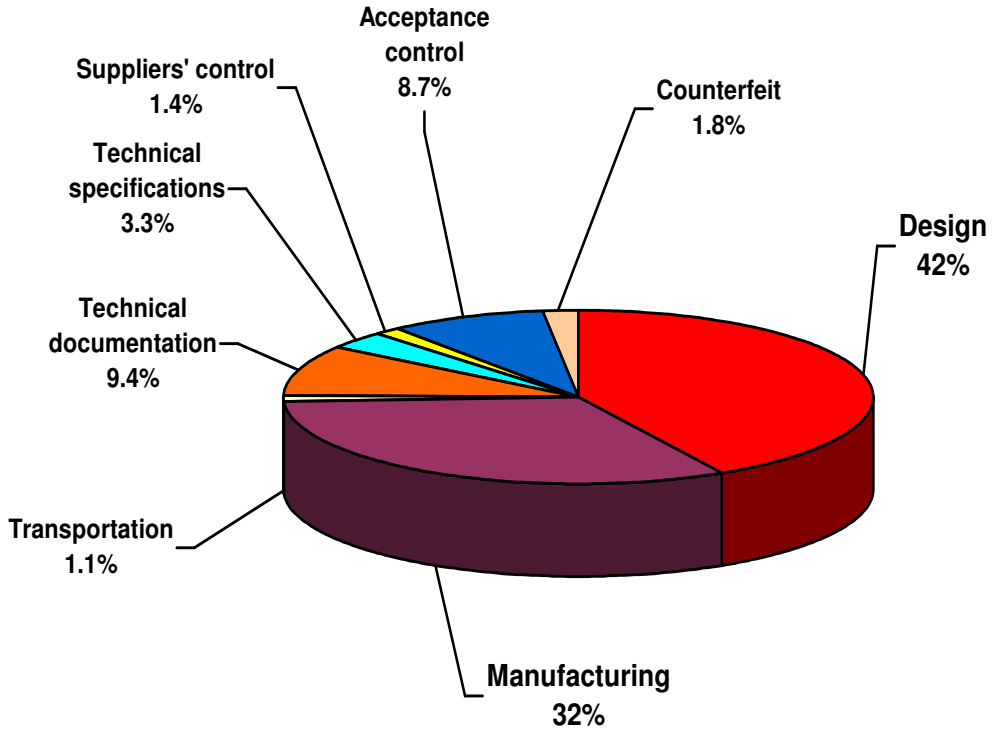


Figure 2. Distribution of events from the IRS data base related to the supply of components in regard to the different stages of production and supply chain

Comparing rate of failures of components with relatively different physical working principles, the groups of mechanical (including hydraulic/pneumatic) and electrical components are obviously the most prevalent (see Fig. 3 to 5). Among mechanical components, valves (including safety/relief/check/solenoid valves, pressure switches, valve operators, controllers, dampers and fire breakers, seals and packing) are quite clearly the most frequently failing – they are causing up to 64% reported events. Among electrical elements, three subgroups can be distinguished by the frequency of faults: a) circuit breakers, power breakers, fuses; b) relays, connectors, hand switches, push buttons, contacts; c) wiring (including logic circuitry, controllers, starters, electrical cables, printed boards/cards, governors).

The identified causes in the most populated subfamily of events related to design are mainly of technical nature. The design errors most frequently referred to in the event reports of this subfamily are: inadequate selection of material and/or heat treatment, inappropriate construction, systemic errors in calculations and low reliability/insufficient longevity (see Fig. 6).

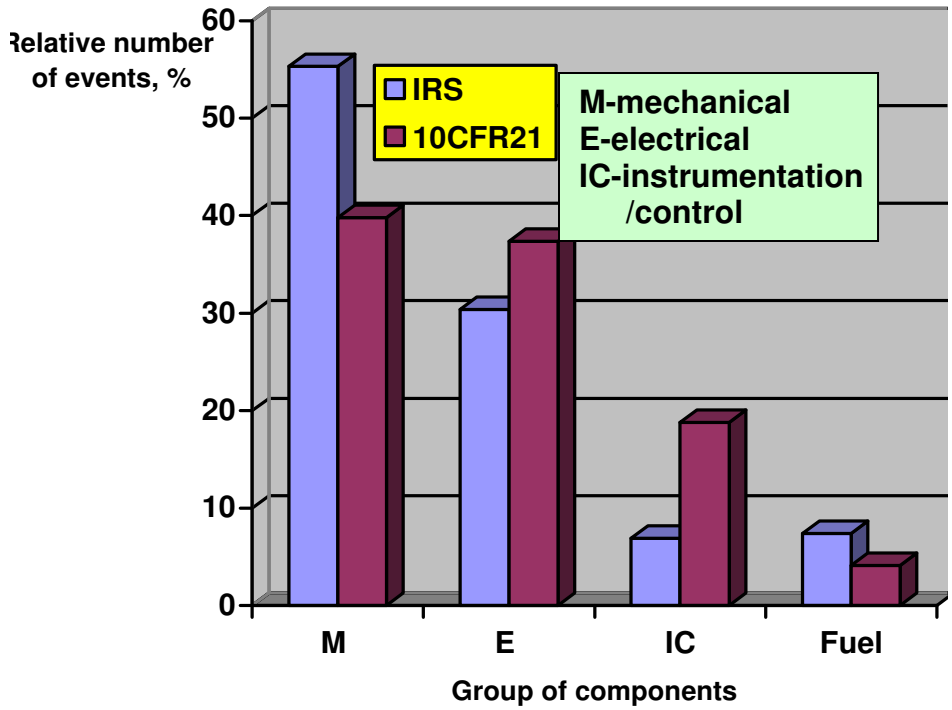


Figure 3. Distribution of events related to the supply of components in regard to specific groups of components failed

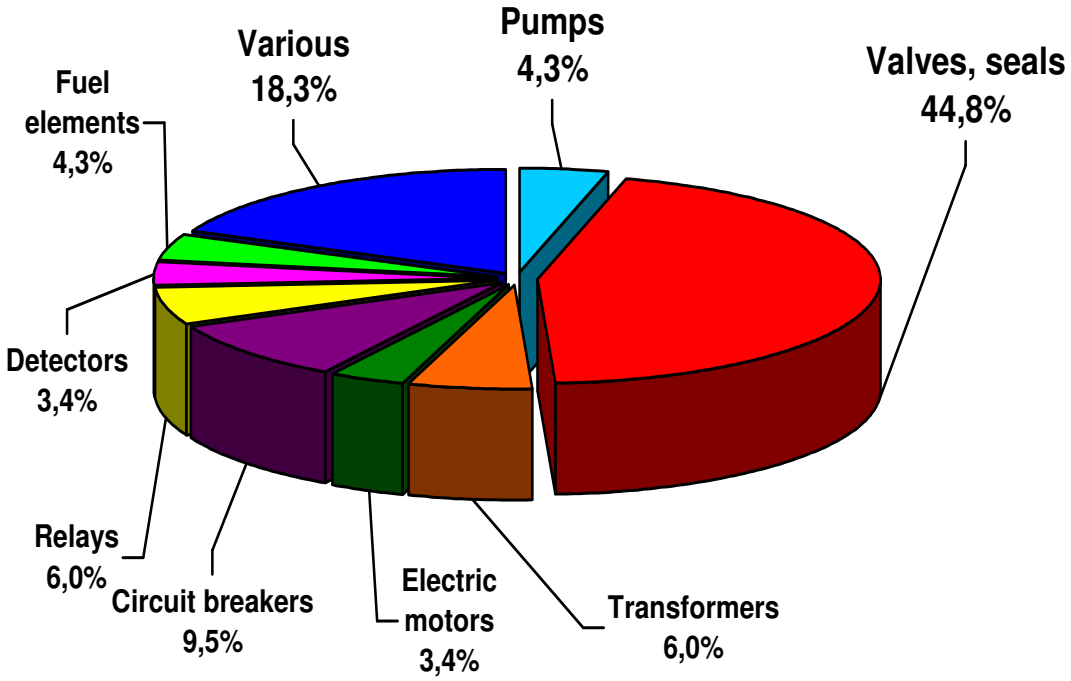


Figure 4. Distribution of failed components which caused events related with design

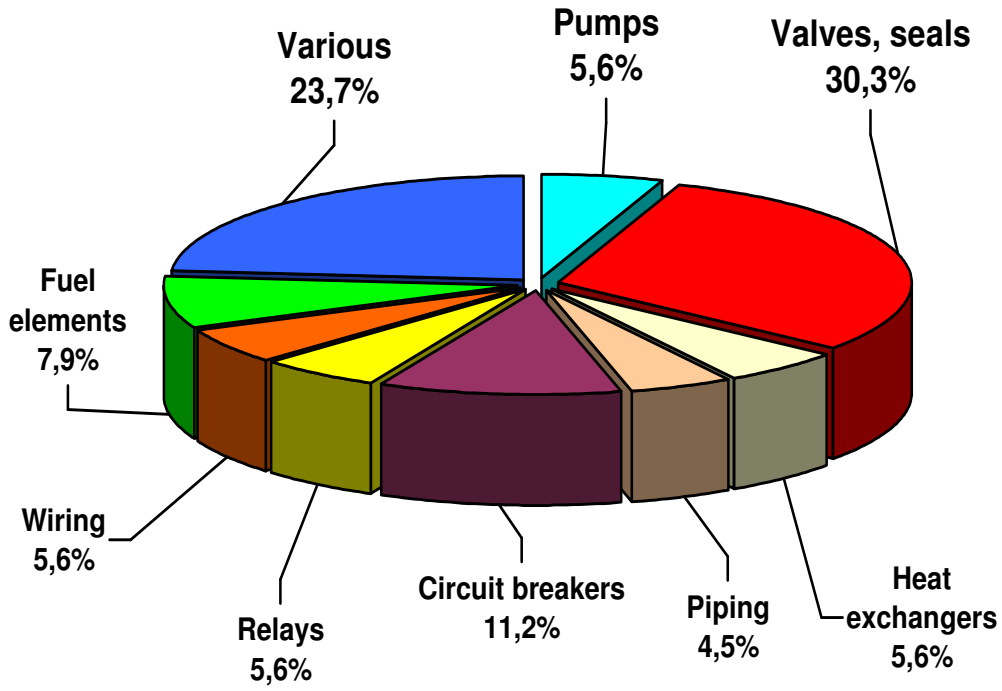


Figure 5. Distribution of failed components which caused events related to manufacturing

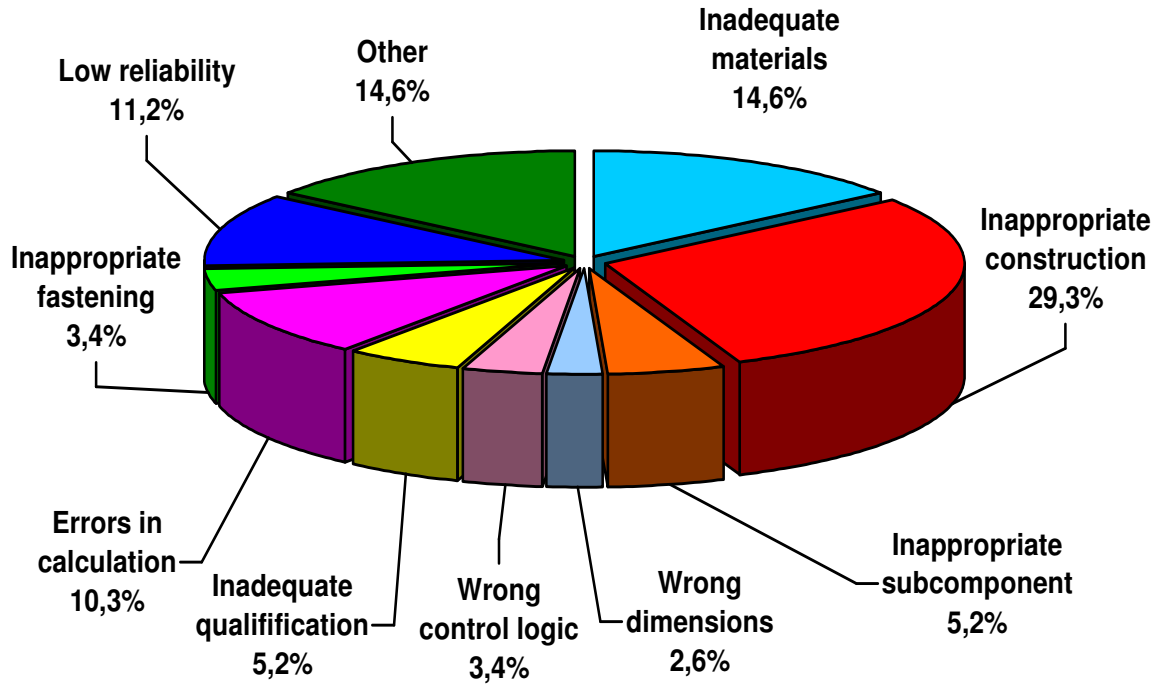


Figure 6. Most frequent design errors identified after events related with design

Defects of technical nature also are the most commonly mentioned as causes of events related to manufacturing. Generally they are related to inadequate material used and/or heat treatment applied, inadequate or not followed technological procedures, inappropriate assembling, wrong dimensions, and welding defects (see Fig. 7). Only in a few cases human factors, organizational or management problems are mentioned as complementary causes.

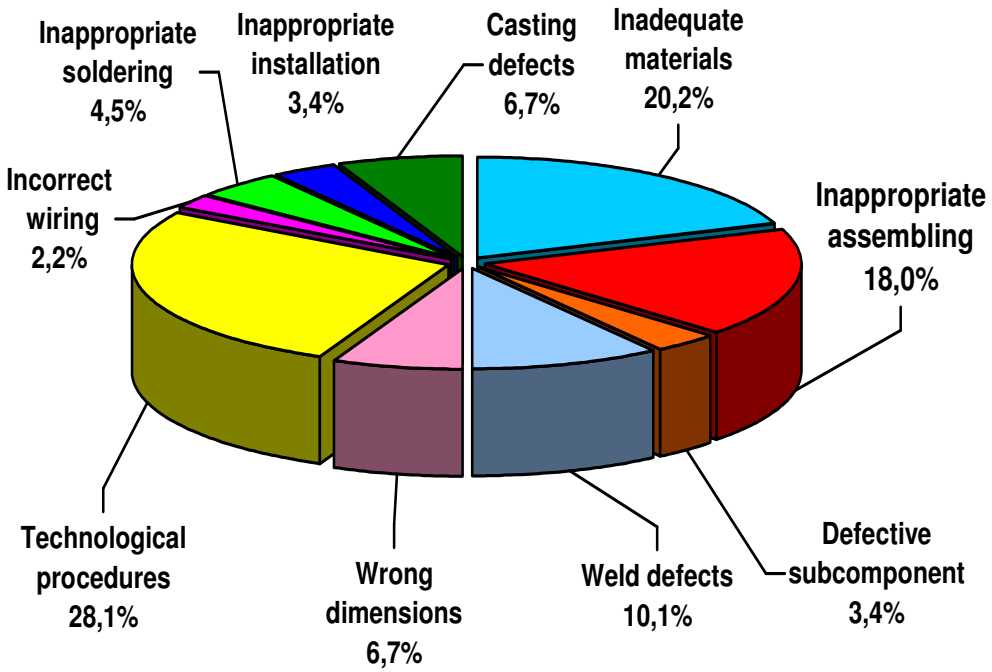


Figure 7. Most frequent deficiencies identified after events related with manufacturing

It is worth to stress that real root causes of events seem to be not properly identified in a considerable part of the analyzed event reports, especially when they are related with processes managed by suppliers (design, manufacturing). For example, most popular findings such as “design weaknesses” or “manufacturing deficiencies” actually are not root causes of events. Real root causes of such events are hidden deficiencies in the management systems or low quality/safety culture of adequate design or manufacturing organization and are probably remaining latent. These organizational weaknesses later materialise in design or manufacturing errors or failures to detect products of inadequate quality in a due time. Unidentified root causes of events lead up to putting in place ineffective corrective actions and prevent learning from operational experience, creating wrong belief that problem is solved while high probability for recurrence of analogous events still remains.

The safety significance of events caused by substandard components is relatively high. Up to 50% of events of different subfamilies resulted in some real undesirable consequences: unplanned reactor shutdown, unanticipated release of radioactive materials, damage of fuel etc. The remaining part of the analyzed events had no real identified consequences or no effect on operation of a plant; however, most of these events had potential to cause real more serious consequences under other circumstances due to loss, degradation or weakening of safety functions or potential unavailability or inoperability of safety related systems or equipment.

Prevailing corrective actions which are usually put in place or planned following the majority of events are of reactive nature: most of them are targeted to replacing, repairing or recovering of failed component or system and restoring its functionality, i.e. to eliminate direct causes of the incident or troubleshooting. However, they do not seem sufficient to remove latent root causes of incidents and are often ineffective to prevent their recurrence.

# 4. RECOMMENDATIONS

Scrutinizing the lessons learned from the analyzed events and looking beyond the component-specific or condition-specific issues it is possible to formulate some generically applicable recommendations for preventing or decreasing the probability of supply to NPPs of inappropriate products and components.

## 4.1. General recommendations

These recommendations could be addressed both to vendors/suppliers (including designers, manufacturers, distributors), licensees and regulators:

1.1. Besides formal putting in place of state-of-the-art quality management systems, their practical implementation and maintaining operational, effectiveness and continuous improvement should be ensured in all organizations participating in nuclear supply chain.

1.2. Maintaining strong safety (quality) culture at all organizational levels: quality and safety should be the highest priority prevailing over costs and schedule.

1.3. In order to detect deviations in components' quality with higher sensitivity, it is worth organizing the several examination/inspection sessions of components' quality and quality management systems, carried out by designers and manufacturers itself, by vendor/supplier, independent 3rd party, licensee and regulator.

1.4. Regulatory bodies must effectively communicate the current regulations to vendors supplying nuclear components and services, so that they are well informed about their obligations. Regulations should include obligations for vendors, designers and manufacturers to report defects identified or otherwise fully assure that safety-related components will perform adequately in service.

1.5. Regulators should conduct routine as well as proactive inspections of domestic and foreign vendors' supplying safety-related parts and services to nuclear power plants according to approved vendor's inspection program. In order to detect substandard components timely, frequency and scope of inspections should be increased. Vendor's status of implementation and current level of compliance with relevant quality assurance regulations and other requirements should be checked during these inspections.

1.6. Aiming to facilitate regulatory oversight of suppliers (especially located in foreign countries), international cooperation between national regulatory bodies should be expanded and adequately coordinated.

1.7. Regulatory approach to counterfeit, fraudulent, and misrepresented items (CI) should be strengthened. In the context of increasing occurrence of CI in nuclear and other industries the currently existing reactive approach should be enhanced by introducing in suppliers' inspection program the formal strategy and plan to monitor and evaluate potential CI.

1.8. In order to address the counterfeiting issue in a proactive manner, a specific international data base (DB) for gathering and sharing information about incidents related to substandard components should be developed and maintained. This data base should contain the adequate information about suppliers and their products. All participating organizations should provide relevant data to this DB about substandard components, products, services detected before or after installation or use at the plant.

1.9. A modification to the existing event reporting criteria should be considered. The legal system of each country should contain requirements for all entities acting in the nuclear supply chain (including suppliers/vendors, designers, manufacturers and distributors) to inform national regulatory body and/or some international or regional responsible organization and the end user (NPPs) about any defects or non-compliances discovered in the components supplied to nuclear facilities.

1.10. Quality, comprehensiveness and thoroughness of the event investigations should be improved. Specifically, root causes of events should be correctly identified, especially for events caused by inadequate activities of vendors/suppliers, designers, manufacturers, distributors.

### 4.2. Recommendations for vendors/suppliers, designers, manufacturers, distributors

2.1. For ensuring good management of the subcontracting chains, it is important that in each call for tender on sub-contracts the vendor clearly indicates and emphasizes the nuclear specific practices and requirements. These could include:

- a requirement to provide design documentation in an early stage for getting manufacturing approval from the licensee and regulatory body,
- a requirement on multiple quality controls and regulatory inspections, to be conducted during and after manufacturing, and
- expectations on safety culture.

2.2. Improvement of design quality seems to be the most effective mean for preventing or decreasing probability of supply to NPPs of inappropriate products and components. A special attention should be given to the quality of the design of nuclear power plant components important for safety, especially for valves, seals, circuit breakers, relays.

2.3. Apart from mandatory enforcement to meet all applicable design requirements, standards, codes and specifications (including procurement requirements), every efforts should be applied to avoid the most frequently noticed design errors (creating inappropriate constructions, selection of inadequate materials etc).

2.4. Design assumptions and calculation methods should be consistently considered and updated (if applicable), taking into account operational experience feedback, lessons learned and results of studies and research programs performed considering specific design related phenomena, especially concerning design of most problematic components such as valves.

2.5. Improvements in quality management of manufacturing seem to be an important instrument for preventing or decreasing probability of supply inappropriate products and components to NPPs. The common most frequently noticed manufacturing errors such as deviations from technological procedures, use of inadequate materials, inappropriate assembling should be avoided. A special attention should be given to quality of manufacturing of components important for safety, especially valves, seals, circuit breakers, relays.

2.6. The supplier's documentation for delivered components should contain the detailed latest available information on the important parameters and characteristics. It should be checked and compared against the relevant information in originally supplied documentation or assumed in the original design, especially during replacement of obsolescent components by new ones during modifications or refurbishment.

2.7. Any deviation from procurement requirements, change of design specifications or any characteristics/parameters defined by design that were introduced by other participants in the supply chain (e.g., by manufacturer) should be carefully considered in advance,

harmonized with the designer and the licensee, appropriately documented and approved.

**3. Recommendations for licensees**

3.1. A verification of vendor's and sub-contractors' real competencies and capabilities should be made before making purchase. The licensee needs to have means to ascertain that the issues specific to nuclear safety and quality management are adequately addressed, and the respective controls are properly agreed in each contract between the vendor and its sub-contractors. The actual competence of manufacturers and sub-contractors is not easy to judge through auditing only. Capabilities need to be assessed not only in case of sub-contractors that are newcomers to the nuclear field. Besides the records about earlier experience the current capabilities of manufacturer should be verified, including its actual control on quality management at the shop floor level.

3.2. A licensee's capability to identify products or components susceptible to be substandard can be improved by:

- wider involvement of engineering staff having an adequate qualification and experience in the procurement and product acceptance process;
- establishment of well organized, adequately equipped, properly managed and effective source inspection, procurement, receipt inspection, and testing programs.

# 5. CONCLUSION

The results gained during this study once more validated the possibility to extract useful information from operational experience. They revealed that considering of a nuclear supply chain as whole combined with continuous analysis of events related with supply of components provides important insights for further improvement of safety.

Findings of this study highlighted that nuclear supply chain's management system is not effective enough to prevent the increasing proliferation of substandard (especially counterfeit) components to the safety related systems of NPPs. Overwhelming majority of the supply-related events seems to be caused by the same group of common fundamental reasons – inadequate quality/safety culture and deficiencies or ineffectiveness of management systems, quality management or quality assurance either of supplier/vendor - designer, manufacturer etc. - or of customer (NPPs). Consequently, the main opportunity for preventing or decreasing the probability of events caused by inappropriate supplied components lies in the improvement of management systems, including management of nuclear supply chain and management of NPPs.

# 6. LIST OF ACRONYMS

| | |
|---|---|
| CFR | Code of federal regulations (US) |
| CI | Counterfeit, fraudulent, and misrepresented items |
| DB | Data base |
| GRS | Gesellschaft für Anlagen und Reaktorsicherheit mbH, Germany |
| IAEA | International Atomic Energy Agency |
| IRS | Incident Reporting System |
| IRSN | Institut de Radioprotection et de Sûreté Nucléaire, France |
| NPP | Nuclear Power Plant |
| NRC | Nuclear Regulatory Commission (US) |
| OECD NEA | Organisation for Economic Co-operation and Development, Nuclear Energy Agency |
| OEF | Operational experience feedback |

# 7. REFERENCES


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**ABSTRACT**
This report presents the essential results of study performed by European Clearinghouse on Operational Experience Feedback in cooperation with IRSN and GRS aiming to analyze the impact of inappropriate components supplied to NPPs on safety. Study has been performed by means of extracting, systematizing and analyzing of adequate operational experience related information from event reports stored in the relevant data bases. Methodology of study includes identifying, highlighting and examining of circumstances, precursors, causes and safety significance of said events, as well as of most important corrective actions, lessons learned and recommendations. Trying to evaluate impact of different potential sources causing incidents the entire nuclear supply chain as a whole is covered, and all stages of this system including design, manufacturing, storage, transportation are taken into account in the developed system of 7 subfamilies. The main defence lines of the licensee designed to prevent penetration of substandard components such as thorough preparation of the procurement documentation, source inspection prior to authorizing release for delivery and inspection/testing of items on receipt are considered as well.
Based on the results of performed analysis major contributors to the existing problem were identified. Among the analyzed subfamilies deficiencies in design cause about 42% of selected events and manufacturing faults cause 32%. The most frequently failing are mechanical (including hydraulic/ pneumatic) components (40 - 55% of relevant events) and electrical elements – they take 30 - 37% of total events number respectively. The worst vulnerable specific types of components are also identified: they are valves and seals among mechanical components, circuit breakers and relays among electrical components. Scrutinizing the lessons learned from the analyzed events and looking beyond the component-specific or condition-specific ones some generically applicable recommendations for preventing or decreasing the probability of supply to NPPs of inappropriate products and components are formulated.

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