

**HUMAN AND ORGANIZATIONAL FACTORS IN THE TRANSPORT OF  
RADIOACTIVE MATERIALS**

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**ABSTRACT**

The analysis of events related to the transport of radioactive materials shows that most of them are not only due to technical issues, but also involve human and organizational factors as a root cause. Indeed, human and organizational factors, such as competences, work environment, task characteristics and organization, have an effect on the safety of transport activities. In this regard, the analysis of the transport related events performed by the French Institute for Radioprotection and Nuclear Safety (IRSN) takes into account these factors in order to identify the causes of the most significant events occurred in France and to assess the actions put in place by consignors and carriers in order to prevent their recurrence. These analyses can focus on the organization implemented for the transport activities, including the operators training program and the means to take into account the operational feedback. In addition, on-site visits and interviews with operators and managers enable a better understanding of the organization (interfaces, roles and responsibilities), the working conditions and the possible difficulties related to the applicable procedures. In 2018, such an assessment has been performed by IRSN after the declaration of an event involving the loading operations of packages designed to transport spent fuel. The paper will describe the methodology applied for this analysis and present the main conclusions drawn from this assessment. The paper will also describe the major human and organizational factors that need to be taken into account in the safety of transport of radioactive materials. In fact, IRSN considers that the design process of packages and associated tools must include human factors engineering (co-design and validation with users addressing the future operating conditions). Furthermore, the safety functions ensured by the safety related components should be explained to the package users to improve their understanding of the different operations that should be performed at each step of the package transport, including loading and unloading.

**INTRODUCTION**

In accordance with the rules applicable in France, consignors or carriers of packages containing radioactive materials must declare online to the French nuclear safety authority (ASN) and to the French Institute for Radiation Protection and Nuclear Safety (IRSN), its technical support, every event affecting a transport, whether it has led to radiological consequences or not. This covers all events that occur during transport operations, i.e. during the shipment itself, as well as during the maintenance of the package, the loading and unloading operations or during the inspection of the package before and after its

transportation, on public roads as well as on a nuclear site. When the event is considered as “significant” (the criteria for classifying an event as “significant” are defined in a guide published by the French nuclear safety authority), the declarant must also submit a detailed report presenting the analysis of the causes of the event and the actions put in place in order to prevent the recurrence of similar events. The feedback of these analyses shows that most of the events involve human and organizational factors among the root causes. In this regard, the ways these factors are taken into account by the consignors, the carriers and the package designers in their analysis of the most significant events are assessed by IRSN in order to ensure that the possible root causes have been identified and that the corrective actions are appropriate.

## **OVERVIEW OF EVENTS INVOLVING THE TRANSPORT OF RADIOACTIVE MATERIALS IN FRANCE**

As described in [REF 1], about 120 events involving the transport of radioactive materials for civilian use are reported each year in France, representing one event per 8,000 packages shipped. Only half of these events are considered as “significant” and, consequently, are the subject of a detailed report analyzing their causes. The vast majority of the reported significant events are related to type B or industrial packages shipped by companies working in the nuclear fuel cycle sector.

The most frequent types of events are related to transport documentation (errors in transport documents or package labelling), radiological issues (exceedance of the regulatory limits for the radiation level around the package or contamination on the surface of the package or the transport vehicle), tie-down defects (especially for surface contaminated objects or low specific activity material in containers), package non-compliances (use of package in conditions not provided for in the user manual) and non-conforming contents (presence in the packaging of objects or materials not authorized for loading).

## **IMPORTANCE OF THE HUMAN AND ORGANIZATIONAL FACTORS**

The human and organizational factors can be defined as a set of scientific and professional disciplines related to the working conditions and task characteristics, the human behavior, the work organization and management, that could have an impact on the safety of an industrial activity. In all industrial activities, incidents and accidents rarely happen as a result of one single technical malfunction, but are more likely the result of an accumulation of both technical problems, human and organizational failures or weaknesses. It is nevertheless important to highlight that human performance also have a significant positive contribution to safety, as human operators are able to detect technical problems and to mitigate their consequences and that organizations can significantly reduce the possibility of harmful outcomes.

Based on the feedback of the most severe accidents related to nuclear installations that occurred over the past decades, the International Atomic Energy Agency (IAEA) published in 2018 a technical document [REF 2] that underlines the importance of taking into account the

human and organizational factors for the safety assessment of nuclear activities and for events investigation.

During recent years, such analyses have been conducted by IRSN for some of the most significant transport related events reported in France, either upon the request by the competent authority or within the framework of the released of its public reports dedicated to the feedback drawn from the analysis of transport events [REF 3]. Some of the analyses performed by IRSN and considerations on this topic are described hereinafter.

## **EVENT INVOLVING THE LOADING OPERATIONS OF PACKAGES DESIGNED TO TRANSPORT SPENT FUEL**

### Context

Several type B packages are used in France to transport irradiated fuel assemblies from nuclear power plants (NPP) to the Orano reprocessing plant in La Hague. These packages are made up of a cylindrical shell equipped with impact limiters at their extremities. Their cavity and the orifices allowing access to the cavity are closed by plugs equipped with elastomer gaskets that ensure the leak-tightness of the containment envelope. Before transport, a leak-tightening test is performed on each gasket in order to ensure that the maximum allowable leak rate specified in the safety analysis report is not exceeded.

In May 2017, the French national NPP Company (EDF) reported an event following the finding that the final leak-tightness test of the cavity plug of one of these packages was not included within the operating documents used by operators and describing each step that has to be realized before shipment of the cask. This deviation from the package user manual instructions has concerned 199 shipments of spent fuel assemblies performed since 2004 from the two most recently commissioned French NPP. In this regard, this event was classified at level 1 on the INES scale by the French nuclear safety authority.

The analysis of this event realized by the consignor shows that the operating document used for the package preparation was initially adapted from a similar one used in another NPP. During the writing of this document, the final leak-tightness test of the cavity plug, required in the safety analysis report, has been omitted. The reason of this omission was not clearly identified, but this test may have been seen as redundant with the “pre-test” of the same gasket which has to be realized before the drain of the cavity and its filling with an inert gas, with the same leak-tightness criterion than the final test. The role of the pre-test is to ensure that the gasket has been put in place correctly, but only the final test result is relevant to demonstrate the leak-tightness of the containment envelope in the transport conditions. After this event, an exhaustive comparison between the package user manual and the operating documentation was realized by the consignor, and several other discrepancies, presenting less important safety issues, were identified and corrected.

Considering the generic nature of this event, the French competent authority asked IRSN to analyze the assimilation by the consignor of the safety concerns related to the transport operations on public roads, its ability to translate them into appropriate technical tasks and to draw lessons from the feedback of use of the packages.

### Methodology for the analysis

The analysis performed by IRSN focused on the organization implemented by the consignor in order to ensure that the operations realized for the shipment of spent fuel assemblies are consistent with the package user manual and the certificate of approval. This analysis included a review of the content of the operating documents, the operators training program and the organization put in place to take into account the operational feedback. In this regard, IRSN conducted on-site visits and performed interviews with operators, their managers, central services executives and personal in charge of the operators training in order to better understand the organization put in place by the company for the shipment of packages loaded with spent fuel assemblies (interfaces, roles and responsibilities), the working conditions and the possible difficulties related to the applicable procedures. This analysis implied specialists in the field of human and organizational factors and experts in charge of the transport safety assessment.

This analysis was limited to the reactors concerned by the above-mentioned event. Indeed, the dispositions implemented by the consignor are generally the same for all the NPP but have specific features for each power level. In particular, operational documents used for the shipment of spent fuel are common to each type of reactor.

### Main conclusions drawn from the analysis

The process put in place by EDF to develop a new operating document or to update an existing one requires several months because of the numerous exchanges between the consignor and the package designer, the number of accompanying documents and the possible modifications to be made on the tools used by the operators. Within this framework, a specific analysis of the impacts of these modifications in terms of working organization and operators training is realized by the consignor. In this regard, the company is currently reinforcing the competences of the managers in charge of this analysis in terms of human and organizational factors, which is a positive point.

The analysis conducted by IRSN shows nevertheless that the complex organization related to the validation of updated operating documents and that the number of entities involved allow little time, at the end of the process, for the validation by the NPP of the operating documents used by the operators before shipment. This constraint can sometimes lead to the use of unclear, incomplete or temporary documents, which do not integrate all the modifications made by the package designer on the user manual, for the shipment of spent fuel. In this regard, IRSN considers important to reinforce the provisions aiming to ensure that the safety requirements are correctly mentioned in the operating instructions before shipment and that the operating documentation is systematically validated by operators' representatives.

The competences of operators rely on an initial training course that includes practices of technical gestures on a package specimen, followed by a mentoring period. Their knowledge of the operating processes is kept up-to-date through information of the modifications made on operating documents. Nevertheless, they do not follow any refresher training, whereas the operations, tools and safety criteria can change over time. IRSN considers that such courses should be put in place in order to take into account the evolution of practices and the operational feedback.

The operating documents used for the preparation of the cask before shipment are shared by similar NPP (same power level, same type of loading). However, some criteria or tool references can differ between sites. For instance, the criterion used for the leak-tightness tests of the containment envelope gaskets of packages used to transport spent fuel is different in the two most recently commissioned French NPP because of the use of two different tools (the leak rate is measured by rise of pressure through the gaskets and the associated criterion depends on the expansion volume of the tool used for this measurement). Therefore, the operating document displays two different criteria and two different associated tool references for the same test. This situation can be a possible source of error, especially for operators taking part in shipments from several NPP. In this regard, the ergonomics of operating documents could be improved. Moreover, a standardization of the tools used in similar NPP should be planned in order to prevent confusion and to make the operating documents easier to use.

At the end of each shipment, a debriefing meeting is organized with all the involved operators and their managers in order to identify the needs in terms of evolution of the process or documentation. The proposed evolutions have to be validated by another similar NPP before transmission to the central services and possible integration within the operating documents. This process allows the operators to be fully involved in the evolution of the process that defines their activity, which is a positive factor for the respect of safety requirements related to the shipment of spent fuel.

## **INTEGRATION OF SAFETY REQUIREMENTS IN OPERATING DOCUMENTS**

The feedback drawn from the analysis of transport events reported in recent years shows several non-compliances between the package user manual and the operating documents such as the one studied hereinabove.

For instance, another discrepancy related to the leak-tightness test of the gaskets equipping packages used to transport irradiated fuel assemblies has been reported following the observation, by the consignor, that the criterion related to the maximum allowable rise of pressure through the gaskets defined in its operating documents was incorrect. In fact, the criterion is defined by the package designer in the user manual and is based, on one hand, on the leakage rate considered in the safety analysis and, on the other hand, on the conditions under which the tests are realized (ambient pressure and temperature in the facility and volume of the tool used to perform the test). As mentioned above, there is no standardization of the tools used in the different NPP to perform the leak-tightness tests. As a consequence, the package's user manual displays several criteria for the rise of pressure, depending on the volume of the tool used for the test. However, the volumes considered by the package designer in its calculations did not cover all the tools used by the consignor in the different NPP. The event analysis showed that the consignor did not inform the package designer of the tools renewals and of their characteristics. After this event, the leakage criteria have been corrected by the package designer and some of the tools used by the consignor have been replaced.

Between 2011 and 2016, several events have been reported in France after the observation, during unloading operations of packages used to transport spent fuel assemblies, that one or several impact limiters fastening bolts could be loosened "by hand". The analysis of these

events highlighted the importance of human and organizational factors in their occurrence [REF 4]. Corrective actions put in place by the package designer and the consignor included an increase of the tightening torque, an update of the operating documents and the implementation of additional controls realized before shipment, such as a dual inspection of the bolt tightening using two different torque wrenches and performed by two different operators. These actions enabled a significant decrease in the occurrence of this type of events. Nevertheless, a few similar events have been reported thereafter. One of these events was due to a lack of information from the package designer to a package user, located abroad, about the changes made on the torque value to apply for tightening operations. This non-compliance shows the importance for the package designer to inform the package users of any modification of the package design or of the instructions for use. Another event was related to the use, by a consignor located in France, of an operating document that was not updated to take into account the change on the torque value made by the package designer in the user manual. This event underlines the importance of an efficient integration by the consignor of the modifications made in the user manual into its own operating documents.

Other examples of similar non-compliances between the operating documents and the package design, the user manual or the certificate of approval, can be mentioned. They were for instance related to the use of components which characteristics (dimensions of gaskets and bolts, mechanical properties) were inadequate after being changed by the package designer, generally to improve the package safety level, but without information towards the package users. In some other cases, the consignors have been well informed of the changes by the package designer but failed to integrate them in their own operating documents.

The events presented in this paragraph highlight the need to ensure an efficient communication between the package designer and the package users, especially in case of changes involving the safety parameters by the package designer or related to the conditions of use of the package by the consignor. An analysis of the impact of any modification affecting an element important for safety on the instructions of use of packages, on the working organization and on information given to the operators, has to be made by taking into account the human and organizational factors. Such analyses have to be conducted by both the package designer and the consignor, who must keep each other informed of the implications of these changes on their own operating documents.

## **CONSIDERATIONS REGARDING THE DESIGN PROCESS OF PACKAGES AND ASSOCIATED TOOLS**

The feedback of reported transport events highlights the importance of taking into account human factors engineering for the design process of packages and associated tools. Within the framework of the development of a new packaging aiming to replace the packages currently used to transport spent fuel assemblies, the package designer and the French NPP company have put in place common working groups to improve the integration of safety requirements and to allow the consideration of organizational and human constraints early in the design of the new packaging. This kind of cooperation should facilitate the application of the safety requirements in the user's operating documents and enable a better anticipation of the needs of the consignors in terms of tool design, working organization and operator's training. Moreover, the package designer should be able to take into account in the early stages of the design the suggestions made by the users, based on the specificities of their facility and their

equipment as well as the feedback of past events they have experienced. Such initiatives are conducive to safety through a better integration of human and organizational factors into the implementation of transport activities.

## **UNDERSTANDING OF THE SAFETY ISSUES BY THE PACKAGE USERS**

The compliance with safety requirements for cask preparation relies on the quality and completeness of the operating documents, but also on the reliability of the actions realized by the operators. On this subject, their understanding of the safety issues related to their activities is an important condition to enable them to carry out the different operations in accordance with the safety requirements. Indeed, some transport events highlight a lack of knowledge by the operators of the safety issues related to their activities. For instance, a recent event rated level 1 on the INES scale by the French competent authority was due to the fact that an operator withdrew a protection plate on a package, which had been damaged during handling, without informing his hierarchy and without being aware that this component was identified as an element “important for safety” in the package safety analysis report. Making operators aware of the safety issues associated with each of the operations they carry out and with the main components of the packages is therefore an important element in order to limit the risk of human errors. In this regard, among the corrective actions proposed after the event involving the leak-tightness of the containment envelope gaskets described above, EDF has initiated an update of its operating documents in order to identify, among all the tasks to be performed before shipment, those with the most important safety issues. This kind of initiative is likely to help operators to increase their vigilance when carrying out actions important for the transport safety.

## **CONCLUSION**

Human and organizational factors play a major role in the safety of the transport of radioactive materials. Indeed, the experience feedback shows that they are often identified as a root cause in the occurrence of discrepancy towards the regulatory requirements, incident or accident involving a transport. Therefore, consideration of these factors is essential for package designers, consignors and carriers in order to ensure full compliance with the safety requirements and the transport regulations. These aspects are increasingly taken into account by the companies working in the nuclear industry in the context of event analysis, for the design of new packaging and new tools, the edition of operating documents and the training of operators. The awareness of other users of packages loaded with radioactive materials, especially in the “small-scale” nuclear sectors such as the non-nuclear industry and the medical sector, should also be promoted.

## **REFERENCES**

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