**Proceedings of the 18th International Symposium
on the Packaging and Transportation of Radioactive Materials
PATRAM 2016
September 18-23, 2016, Kobe, Japan**

Paper No. 1056

Following the Fukushima accident, additional assessment and management of consequences of beyond design basis events

Pierre Malesys
AREVA
Paris La Défense, France

Laurent Milet
AREVA TN
Montigny-le-Bretonneux, France

Abstract

In 2012, in the aftermath of the Fukushima accident, the IAEA reviewed transport of radioactive material activities. What emerged was that the accident did not justify any major changes to the "Regulations for the Safe Transport of Radioactive Material": the lessons learned mainly concerned emergency preparedness.

In 2013, the French competent authority called for a review of transport safety as regards low probability accidents with potentially significant consequences for persons or the environment.

Package designers delved into the behaviour of packages when faced with events that are more severe than or that differ from the regulatory tests. Consignors assessed their organizational and material measures in place to cope with an emergency during transport.

AREVA identified the casks of its own design associated with significant potential risk and analysed potential failure modes. This led to the definition of accident scenarios, which were applied to these cask designs. National and international existing studies, including AREVA's studies, were reviewed and confirmed that present regulatory tests cover actual identified accident situations, but also potentially more severe situations. Additional studies would nonetheless be useful for refining or confirming some of the safety distances in the France's emergency plans.

AREVA has developed a specific organization to support authorities in the event of a transport accident. This is incorporated into AREVA's general emergency management organization and is subject to regular drills. It is operational 24/7.

Following the Fukushima accident, the AREVA national emergency response force, FINA, was created. It allows to better organize the deployment of the internal support services in the event of a major emergency at one of AREVA's sites in France. FINA can provide support within 48 hours, with supplementary response personnel and equipment from other group's entities. There is still work to define and prioritize specific missions that could be allocated to FINA for a major transport event. However, FINA already has access to significant skills and resources required to address transport events and could be used as additional support should a large scale transport accident occur.

The paper details the assessment which was made (methodology and results) and provides information about the plan to cope with a large scale transport accident.

1. Introduction

In 2012, in the aftermath of the Fukushima accident, the IAEA reviewed transport of radioactive material activities. What emerged was that the accident did not justify any major changes to the "Regulations for the Safe Transport of Radioactive Material": the lessons learned mainly concerned emergency preparedness.

In 2013, the French competent authority called for a review of transport safety as regards low probability accidents with potentially significant consequences for persons or the environment. More precisely, the purpose was to evaluate the robustness within two levels of the defence in depth, when applied to the transport of radioactive material:

(i) the control of severe accidents, including some beyond design basis events, through the package performances, and

(ii) the ability to mitigate radiological consequences of significant releases of radioactive materials by making arrangements for planning and preparing emergency response to protect human life, health, property and the environment.

Package designers looked into the behaviour of packages when faced with events more severe than or differing from existing regulatory tests (malevolent actions are excluded). Consignors assessed their organizational and material measures in place to cope with an emergency during transport.

The involvement of AREVA in this review was twofold: as a designer and as a consignor. The paper details the assessment which was made (methodology and results) by AREVA for its package designs and gives information about its plans in place allowing to deal with a large scale transport accident.

2. Assessment of package designs

2.1 Methodology for the assessment of packages

Regarding the behaviour of the casks when faced with events that are more severe than or differ from the regulatory tests, AREVA TN, as a package designer, carried out an assessment including the following main steps:

- Identifying the failure modes which could lead to the most significant consequences for persons or the environment;
- Determining severe accident scenarios which could lead to the failure modes identified at the previous step;
- Sorting the packages with the highest potential hazards and grouping the packages;
- Applying systematically the accident scenarios to the groups of packages;
- Assessing the behaviour of the packages when subjected to the accident scenarios.

A flow diagram to represent this methodology is provided in Figure 1 at the end of this paper.

2.2 Failure modes

The IAEA Regulations for the Safe Transport of Radioactive Material states that protection of persons and the environment is achieved by requiring:

- Containment of the radioactive contents;
- Control of external radiation levels;
- Prevention of criticality;
- Prevention of damage caused by heat.

As the assessment targets accidents of low probability but leading to the most significant damage for the public and the environment, we concluded that only accidents which could lead to a major breach of the containment of a package need be considered.

2.3 Accident scenarios

A major breach of the containment of a package requires:

- the total or partial rupture of the wall(s), lid(s) or plug(s); or
- the loss of efficiency of the seals (welding seams, elastomeric gasket, metallic o-rings, etc.).

According to the design of the package, a major breach of the containment of the package may require in addition:

- rupture of the inner containment barriers, when present,
- rupture of the fuel rods, if the package is designed for the transport of fuel rods.

Considering the above, seven scenarios which could lead to a major breach of the containment of a package have been determined:

- drop from a height far in excess of that specified in the Regulations,
- drop onto a target quite different from the flat and horizontal surface or the punch bar specified in the Regulations,
- impact of a projectile on the package,
- immersion under a head of water in excess of that specified in the Regulations,
- explosion of gases generated by decomposition of the contents (radiolysis, thermolysis, etc.),
- fire with conditions (temperature and / or duration) more severe than those specified in the Regulations,
- burial of the package and its subsequent heating.

2.4 Selection of the package designs

The full list of the packages designed by AREVA TN, and approved by the French Competent Authority, was considered. The following package designs were excluded from further assessment:

- package designs which are approved but for which no package is currently transported on public roads or railways in France,
- package designs whose end of life is close,
- package designs used only for transport of Low Specific Activity (LSA) material, Surface Contaminated Objects (SCOs), or low activity material (a few A_2) [except packages containing uranium hexafluoride (UF_6), due to the specific risk resulting from the formation of hydrofluoric acid (HF)].

This resulted in identification of 17 package designs: one package containing uranium hexafluoride and 16 packages containing more than several thousand A_2 (though the threshold was a few A_2).

2.5 Grouping of the package designs

Based on the characteristics of the packaging designs (thick or thin walls, one or two containment barriers, cylindrical or cuboid geometry, etc.), the characteristics of contents (quantity of activity, subsidiary risk, inner containment, etc.) and the number of transports per year, the 17 package designs selected were grouped into eight families.

2.6 Application of the accident scenarios to the package designs

Many studies (theoretical, numerical and experimental) have already been performed regarding the behaviour of packages when subjected to beyond design basis events. These studies are reported in numerous papers which were presented in conferences, including the PATRAM symposium; two sessions were held on the topic of “Package Testing to Environments Different from Regulatory Test Environment” during PATRAM 2007. A synthesis of the tests and analyses which were performed on packages designed by AREVA TN is available in reference <1>.

A comprehensive review of the available literature has been performed.

Seven scenarios were identified earlier and have the potential to lead to major breach of the containment of packages. These seven scenarios were applied in a systematic way to the eight families of package designs: it was evaluated if they can trigger one or other of the failure modes described in paragraph 2.3. The evaluation took into account the actual conditions and environment of transport, on the one hand, and the results obtained from AREVA studies and available literature, on the other hand.

2.7 Results of the assessment

When comparing the expected behaviour of the eight groups of package designs when subjected to the seven scenarios, with due account taken of actual conditions of transport and environment, on the one hand, and the results obtained from AREVA studies and literature, on the other hand, three conclusions are possible.

- First, if it is demonstrated that the package design can withstand the accident postulated in the scenario, then the situation is acceptable. One of the levels of the defence in depth, consisting in controlling the release of the radioactive contents in the event of severe accidents including some beyond design basis events, is not degraded.
- Second, if it is not demonstrated that the package design can withstand the accident postulated in the accident scenario, but if the consequences are within the hypothesis taken into account when establishing the emergency provisions, the situation is also acceptable. The last level of the defence in depth, consisting in the ability to mitigate radiological consequences of significant releases of radioactive materials by making arrangements for planning and preparing emergency response to protect human life, health, property and the environment, is not jeopardize.
- Third, if there are uncertainties as regards the consequences of the scenarios which are considered based on the experience which is available in the literature, then additional studies might be needed.

The result of the assessment is that almost all cases fall in one of the two first categories, that is to say that either the packages can withstand the most severe accidents which can be conceived or the consequences of such accidents are already covered by existing emergency response provisions.

There is only one case which might deserve additional studies. It concerns packages made of thin plates containing transuranic (TRU) waste materials: the walls of these packages could be punched following some extreme accidents, and the dispersal of radioactive material following such events may needs further investigation to confirm that its consequences are properly taken into account in the emergency plan established by the relevant national and local organizations.

3. Emergency response organization

3.1 General organization for transport accidents

For more than two decades, AREVA TN has developed an organization to support the authorities in the event of a transport accident. It is incorporated into AREVA's general emergency management organization and is subject to regular drills: internal drills and large scale exercises with relevant governmental national and local organizations.

The organization includes several levels, which can be set up as necessary. They include:

- a local team which can be sent on the scene of the accident and / or liaise with the local authorities and emergency response organizations,
- an AREVA TN emergency response management team,
- a consignor emergency response management team,
- an AREVA headquarters crisis management team,
- an AREVA strategic management team.

Each management team interfaces with its corresponding level within the safety authorities and political authorities.

The organization is operational 24/7, with officers on duty.

3.2 National emergency response force FINA

Following the Fukushima accident, the AREVA national emergency response force, FINA, was created. It allows to better organize the deployment of the internal back-up in the event of a major emergency at one of AREVA's sites in France. FINA can provide support within 48 hours, with supplementary predefined response human and equipment resources from other group's entities. These resources can be adapted to the requirements.

The teams include specialist in cross-cutting fields such as measurement, logistics, radiation protection, cleaning. They free up local resources so that they can focus first and foremost on operating tasks. For its operations, FINA relies on volunteer reserves identified within AREVA entities. Periods of instruction and training are organized.

There is still work to define and prioritize specific missions that could be allocated to FINA for a major transport event. However, FINA already has the skills and resources to address transport issues and could be used as additional support should a large scale transport accident occur.

4. Conclusions

A review of available studies dealing with package behaviour when faced with events that are more severe than or that differ from regulatory tests was carried out. All studies carried out up to now show that the tests specified in the IAEA Regulations for the Safe Transport of Radioactive Material are, in general, more damaging than accident conditions actually encountered, but are also more damaging than conditions far more severe than those actually encountered. There is no need for further systematic investigations regarding the consequences of exceptional situations.

The assessment performed confirms that there is no need to revise the Regulations, as no generic gap concerning all package designs, has been identified.

If it is deemed necessary to enhance the safety of transport of radioactive material, this should be performed by improving those emergency provisions set up by relevant governmental local and national organizations, supported by industry. In this frame work, a few predetermined safety distances, for cordoned-off area, limited access area, evacuation area, sheltering area, etc. might need to be confirmed for a very limited number of couples accident scenario / package designs. As regards AREVA, **the national emergency response force FINA, which has been set up in the aftermath of the Fukushima accident, enhances AREVA capacity to support relevant governmental local and national organizations.**

5. References

<1> MALESYS, P. Package performance evaluation: our latest 30-year experience. *Proceedings of the 15th International Symposium on the Packaging and Transportation of Radioactive Materials*, October 2007, Miami, USA. (PATRAM 2007).

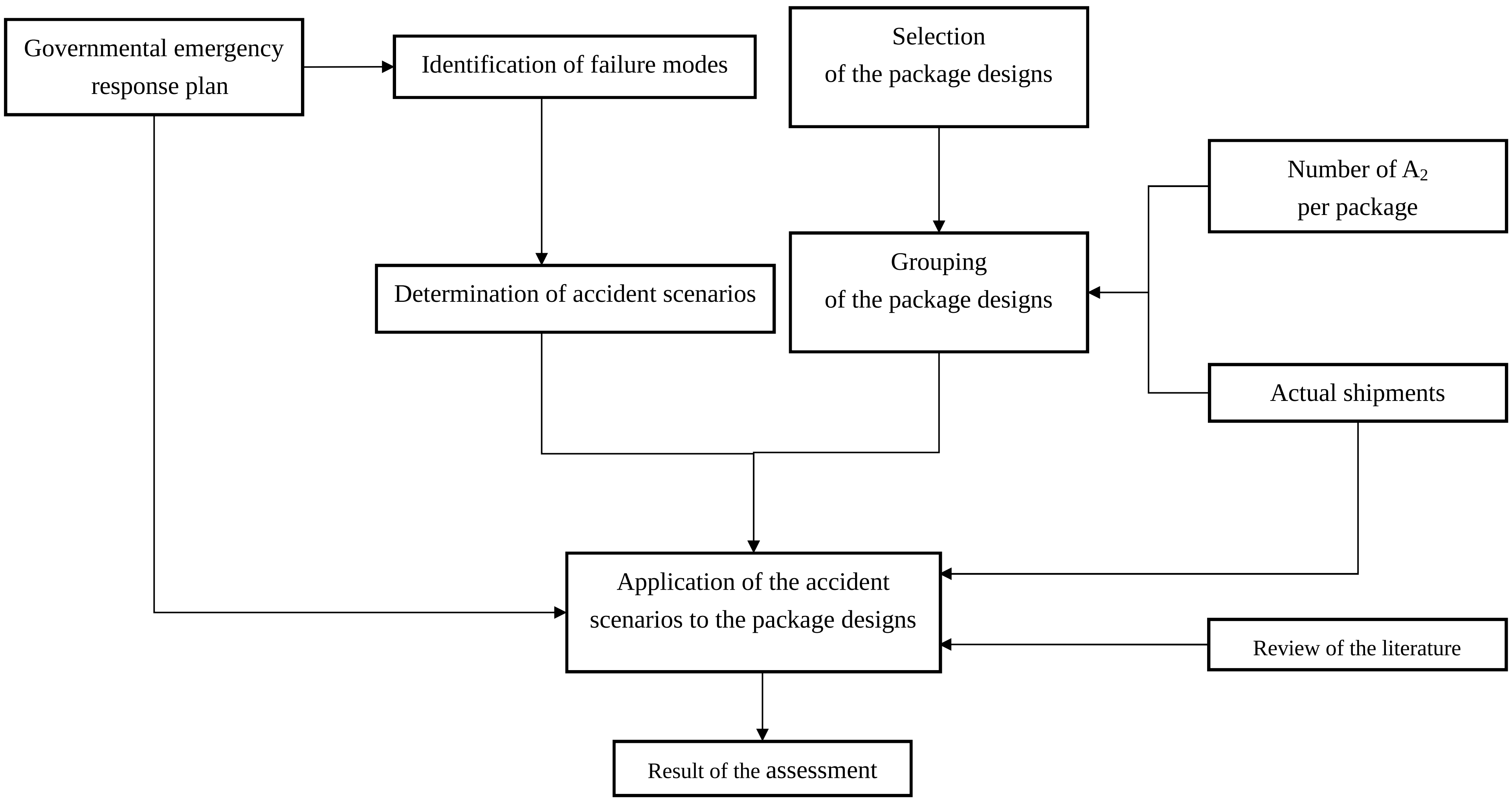

Figure 1 – Flow diagram for the methodology for the assessment of packages when faced with events that are more severe or differ from the regulatory tests