14th International Symposium on the Packaging and ransportation of Radioactive Materials (PATRAM 2004), Berlin, Germany, September 20-24, 2004

Paper # 190

Authorised radioactive contents of packages: how to maximise simultaneously safety and flexibility?

Pierre MALESYS
Greg FIELD

COGEMA LOGISTICS (AREVA Group), Saint-Quentin-en-Yvelines, France
Packaging Technology, Inc. (AREVA Group), Tacoma, USA

ABSTRACT / INTRODUCTION

Packages for the transport of radioactive material are required to comply with national and / or international regulations. These regulations are widely based on the requirements set forth by the International Atomic Energy Agency (IAEA) in the "Regulations for the Safe Transport of Radioactive Material".

"The objective of these Regulations is to protect persons, property and the environment from the effects of radiation during the transport of radioactive material. This protection is achieved by requiring:

(a) containment of the radioactive contents;

(b) control of external radiation levels;

(c) prevention of criticality; and

(d) prevention of damage caused by heat."

Some of the package designs require an approval by the applicable Competent Authority(ies). The application for package approval includes "a specification of the authorised radioactive content, including any restrictions on the radioactive contents which might not be obvious from the nature of the packaging".

The required "specification of the authorised radioactive content" must include assurance that the material that is actually transported meets the four above-mentioned requirements. For that purpose, the choice of the parameters of the specification is crucial: they should be of such a nature that they can be checked before shipment to allow demonstration of compliance with the above-mentioned requirements. From our experience, it is appropriate to consider parameters that have the most direct influence on the compliance with the requirements. It is worthwhile to consider, for instance and when possible, direct measurement for the assessment of compliance with a requirement. A typical example is measurement of radiation exposure: it can provide a confident level of verification of the external radiation level, regardless of other parameters such as the activity.

The paper presents our experience, particularly in France and in the USA, to demonstrate that it is possible to adequately define the authorised radioactive contents in order to maximise simultaneously the allowable contents and the demonstration of the compliance with the safety goals.

1. GLOBAL APPROACH

A first approach consisting in a detailed and comprehensive specification of the content is very often retained. This specification contains all the parameters that describe the radioactive contents. They are sufficient to confirm that the package meets the regulatory requirements dealing with the containment of the radioactive contents, the control of external radiation levels, the prevention of criticality, and the prevention of damage caused by heat.

1.1 First example: definition of the authorised radioactive contents for the transport of spent fuel

The definition of the radioactive contents for the transport of spent fuel assemblies could include parameters such as:

- the geometry of the fuel assemblies, with
  - the type of the array (16 X 16, or 17 X 17, or 9 X 9, or …),

- the number of fuel rods,
- the number and location of the guide tubes,

- the length of the fuel assembly,
- the size of the cross section of the array,
- the active length of the fuel rods,

- the pitch between the rods,

- the diameter of the rods,
- the thickness of the cladding,
- the diameter of the pellets,

▪ the weight of the fuel assemblies,
▪ the weight of the fissile material,
▪ the density of the fissile material,

▪ the initial enrichment in uranium 235,

▪ the irradiation history, with

  - the number of cycles,
  - the length of each cycle,
  - the duration between each cycle,
  - the burn-up at the end of each cycle,
  - the cooling time,

▪ the total activity,

▪ the residual heat power …

Generally, this specification will be based on the typical (and / or bounding) fuel assemblies to be loaded in the flask. For the specified contents, all the parameters will be considered with their maximum or minimum values, whichever is the most restrictive.

Under this approach, it is generally only feasible to consider rather small variations around the typical loading. It can be very difficult to include non-typical spent fuel assemblies with a quite shorter cooling time and a quite lower burn-up. Such assemblies could probably also be loaded in the same packaging, but it is difficult to accommodate in the same definition assemblies with so different characteristics. One solution is to present a curve (burn-up versus cooling time) to define the acceptance criteria. This solution is quite feasible, but can involve a lot of calculations.

The situation becomes still more complex when considering fuel assemblies with an "exotic" irradiation history. We already faced such situations, with fuel assemblies with a high burn-up and a short cooling time, but which were acceptable as far as safety was concerned. This was due to the fact that these fuel assemblies had a classical beginning of irradiation history, then were stored during a long time, and finally were submitted to a very short additional irradiation. How to deal, on an administrative point of view, with such irradiation history is not an easy matter, considering the large number of situations we can meet.

Through this first example, it appears that such a global approach, with a generic comprehensive description of the material to be transported may not provide the flexibility necessary to efficiently transport non-typical spent fuel assemblies. To then accommodate all the situations that exist, application for revisions of the package design approval would be required, each time a non-routine situation occurs.

1.2 Second example: definition of the authorised radioactive contents for the transport of fresh MOX fuel

The definition of the radioactive contents for the transport of fresh MOX (uranium and plutonium mixed oxide) fuel assemblies could include parameters such as:

- the geometry of the fuel assemblies, with

  - the type of the array (16 X 16, or 17 X 17, or 9 X 9, or …),
  - the number of fuel rods,
  - the number and location of the guide tubes,

  - the length of the fuel assembly,
  - the size of the cross section of the array,
  - the active length of the fuel rods,

  - the pitch between the rods,

  - the diameter of the rods,
  - the thickness of the cladding,
  - the diameter of the pellets,

- the weight of the fuel assemblies,
- the weight of the fissile material,
- the density of the fissile material,

- the enrichment in uranium 235 for the uranium matrix,
- the plutonium content in the mixed oxide,
- the isotopic composition of the plutonium,

- the total activity,

- the heat load …

As for spent fuel assemblies, generally, this specification will be based on the typical fuel assemblies to be loaded in the packaging. For the specified contents, all the parameters will be considered with their maximum or minimum values, whichever is the most restrictive.

Nevertheless, once again, it is generally only possible to consider rather small variations around the typical loading. It will be very difficult to take into account fuel assemblies with a quite different isotopic composition and quite different plutonium content. Such assemblies could probably be also loaded in the same packaging, but it is difficult to accommodate in the same definition assemblies with so different characteristics.

2. TOPICAL APPROACH

Considering the difficulties that are described above, it is interesting to analyse, not the parameters that are <u>sufficient</u>, but those that are <u>necessary</u>. And for that purpose, it is of primary importance to consider the possibilities of inspection before shipment.

As mentionned earlier, the International Atomic Energy Agency (IAEA) "Regulations for the Safe Transport of Radioactive Material" define requirements in four fields, namely:

- containment of the radioactive contents;
- control of external radiation levels;
- prevention of criticality; and
- prevention of damage caused by heat.

We will assess the key parameters in these four fields, considering the example of the transport of spent fuel assemblies.

2.1 Containment of the radioactive contents

As regards containment of the radioactive contents, on one hand, it is not easy to make a direct measurement of this phenomenon. On the other hand, in most cases, this matter is not the critical one. Therefore it is possible to allow large variations from the typical fuel assemblies to be loaded and transported. A typical analysis of the source term will take into account:

- the maximum weight of the fissile material,
- the most penalising enrichment in uranium 235,
- a continuous irradiation with the maximum burn-up and the highest theoretical specific power (this will allow to eventually consider the burn-up as the only key driving parameter, and to avoid any specification about the number and length of cycle, as well as about the duration between each cycle),
- a very short cooling time, lower than all the reasonable cooling times that can be met.

2.2 Control of external radiation levels

External radiation levels that are met in routine conditions of transport can be measured before shipment. As a consequence, the specification of the radioactive contents for that topic can be very limited.

For the specification of the radioactive contents, an efficient way to cope with the regulatory requirements dealing with the external radiation levels is not to rely specifically on the irradiation history, but to specify appropriate measurements after loading the cask / before shipment.

The calculations in the application for approval will then be useful:

- to determine the location of the most sensitive area of the package where the measurement should be performed,
- to confirm that, if the regulatory criteria dealing with the external radiation levels for the routine conditions of transport are met, then the criteria for the accident conditions of transport are also met (for most of the designs, the increase of dose rates between the routine conditions of transport and the accident conditions of transport is lower than the difference of criteria between those two conditions).

This approach provides a high degree of flexibility in the authorised radioactive contents, and in the meantime a high level of safety. It is not dependent strictly on a long list of parameters that are checked before shipments, parameters that are the <u>cause</u> of the phenomenon of concern, namely the external radiation level. It is, however, directed at the parameter of concerns, its <u>effect</u>, which is measured and checked.

2.3 Prevention of criticality

Criticality is also a hazard that cannot be easily measured. The most efficient procedure to prevent criticality is to make reliable calculations, with suitable parameters for the definition of the authorised radioactive contents. In the case of spent fuel assemblies, particular care will be taken to the geometry of the fuel assemblies (due to its influence to the moderation) and to the quantity of fissile material. For that purpose, the key data are the followings:

- the geometry of the fuel assemblies, with
  - the type of the array (16 X 16, or 17 X 17, or 9 X 9, or …),
  - the number of fuel rods,
  - the active length of the fuel rods,
  - the pitch between the rods,

  - the diameter of the rods,
  - the thickness of the cladding,
  - the diameter of the pellets,

- the density of the fissile material,

- the initial enrichment in uranium 235.

Should the criticality safety assessment be performed on the basis of burn-up credit, additional parameters can be needed, regarding the irradiation history. It is then interesting to take into account conservative values for the parameters that do not strongly influence the result. That will allow to limit the number of parameters to control before shipment (this is beneficial for safety, by limiting the risk of errors), without reduction of the capacity of the package.

2.4 Prevention of damage caused by heat

The key parameter to prevent the damage caused by heat is the residual heat power of the fuel assemblies.

The irradiation history has a strong influence on the heat load. Efficient calculation tools are available to assess the residual heat power of the fuel assemblies, knowing the actual irradiation history. It must be recalled that, when implementing the general approach described in the paragraph 1 of this paper, starting from the comprehensive list of parameters which can characterise a fuel assembly, the residual heat power is calculated first, before assessing the temperatures in the package and their consequences.

Considering that, before shipment, all the data dealing with the irradiation history are available for each fuel assembly to be transported, it is possible to calculate before shipment the actual residual heat power of the loading.

Therefore, specifying the authorised heat power, independently of the irradiation history of the fuel assemblies, provides a high degree of flexibility, without jeopardising safety in any instance.

3. CONCLUSION

According to the requirements set forth by the International Atomic Energy Agency (IAEA) in the "Regulations for the Safe Transport of Radioactive Material", some of the package designs require an approval by the applicable Competent Authority(ies). The application for package approval includes "a specification of the authorised radioactive content, including any restrictions on the radioactive contents which might not be obvious from the nature of the packaging".

An approach that is generally followed is to list all the parameters that could be useful and to specify values for these parameters. Though this can be safe, this approach induces limitations in the flexibility that is necessary in the day-to-day operations.

According to our experience, it is highly beneficial to assess the driving parameters for the four types of requirements which are defined in the regulations, namely containment of the radioactive contents, control of external radiation levels, prevention of criticality and prevention of damage caused by heat. We have shown that it is possible to consider parameters that have the most direct influence on the compliance with the requirements. It is worthwhile to consider, for instance and when possible, direct measurement for the assessment of compliance with a requirement. A typical example is measurement of radiation exposure: it can provide a confident level of verification of the external radiation level, regardless of other parameters such as the activity, or the irradiation history. This last series of parameters is probably the place where most flexibility can be achieved.

The examples that have been developed in this paper were mainly related to the transport of spent fuel assemblies. The same methodology can be easily implemented to other types of content, with once again the aim to simplify the definition of the authorised radioactive contents. For instance for fresh MOX fuel, simplifications can be obtained on the definition of the isotopic composition of the plutonium. For waste, the restrictions on the activity of the various radionuclides can also be limited.

Doing such an analysis allows to increase the level of safety by focusing on the important and most reliable parameters, whilst providing flexibility in the operations.