EVOLUTION OF TRANSPORT REGULATIONS FOR SPENT FUEL

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Abstract

The paper presents an overview of the evolution of the IAEA transport regulations for spent fuel since their inception in 1961. The challenges expected in the future for the transportation of spent fuel are highlighted. Besides compliance with the regulations, there is an additional need to assure for the 'transportability' of packages that are stored for extended periods before shipment for processing, conditioning, disposal of the spent fuel.

1. INTRODUCTION

The IAEA Regulatory Infrastructure and Transport Safety Section leads the development of IAEA Safety Standards related to regulating the safety of radiation sources and the safe transport of radioactive material. It supports Member States in their application of these Standards and of the Code of Conduct on the Safety and Security of Radioactive Sources.

The primary responsibility of the Transport Safety Unit is SSR-6 regulations which are adopted into the UN Model Regulations which in turn are adopted into the globally implemented International Dangerous Goods Regulations (IMDG Code) by the IMO[1] for transport by sea, and the globally implemented ICAO[2] Technical Instructions for transport by air. Land transport regulations are written and implemented by Member States. In 2018 IAEA issued a latest revision of the SSR-6 regulatory requirements which are currently in the process of being adopted by the UN Model Regulations, IMDG Code and ICAO Technical Instructions and Member States are aware of the appropriate actions regarding their land transport regulations.

2. THE HISTORY OF TRANSPORT REGULATION FOR SPENT FUEL

Since their inception in 1961, the transport regulation evolution can be illustrated by few examples, but the main question relates to the challenges in the future.

The Agency's Statute was approved on 26 October 1956 at an international conference held at United Nations headquarters, New York, and the Agency came into being when the Statute entered into force on 29 July 1957. The first session of the General Conference was held in Vienna, Austria, the permanent seat of the Agency, in October 1957.

In July 1959, the Economic and Social Council of the United Nations prepared a resolution entrusting the IAEA with the drafting of recommendations on the transport of radioactive substances. In May 1961, the Safety Series Number 6 (SS-6 regulations) on the safe transport of radioactive materials were produced. The timeline of these events demonstrates the importance of developing regulatory requirements for the safe transport of radioactive material

Section 15.3 of the Chapter on Fissile Materials introduces the general requirements for the carriage of fissile materials (including unirradiated and irradiated fuel) and further on, the section expands on the fissile materials in the form of nuclear fuel elements/ assemblies. Furthermore, in evaluating the inherent safety of the shipment of nuclear fuel elements, the following requirements were prescribed of which at least one had to be followed:

[1] International Maritime Organization
[2] International Civil Aviation Authority

- The effective neutron multiplication factor (k_{eff}) of the system shall not exceed 0.9;
- where mass is the controlling factor, the permissible value in any single package must not exceed 80% of the critical mass under the conditions of packing;
- if the geometry is the controlling factor, the permissible value for each controlling dimension must incorporate a 10% safety factor.

The IAEA publication on the regulations for the safe transport of radioactive materials has been revised several times since 1961 with its document number changed from Safety Series No. 6 to TS-R-1 and then SSR-6 to reflect the changes in document numbering systems used by the IAEA.

One of the major revisions was accomplished in 1964 when for the first time, the mechanical test requirements for Type B packages were introduced. In the first edition (1961), it was stipulated that a package must withstand maximum credible accidents, but no parameters were stated, and the concept was not very clear. Three years later in 1964, the test requirements that are intended to take into account a large range of accidents, which can expose packages to severe dynamic forces, although severity levels indicated by test criterion are not intended to represent a worst-case accident scenario.

Other examples of changes made in the IAEA regulations include:

- the introduction of the Criticality Safety Index (CSI) in the 1996 Edition;
- Type C package was introduced for air transport in 2005;
- Recently, in the 2018 Edition, ageing management became an explicit requirement for packages stored before shipment and the SCO-III category was introduced for the transport of very large decommissioning components that cannot be packaged.

Over the past 20 years there has been continuous increases in the computing power in terms of increased speed and modelling capabilities technical analyses codes. As a result, more parametric calculations in criticality assessment can be made with corresponding impact analyses to provide fuel assembly geometries and pin containment failure which can be used in the criticality assessments of the package design to ensure the package design remains sub-critical under normal transport and transport accident conditions. The objective of advanced computational analysis is to reduce uncertainties in the impact analyses and criticality assessments.

3. FUTURE OPPORTUNITIES AND CHALLENGES

Fuel designs for longer reactor cycle time and higher burnups is one of the objectives of the nuclear industry as these increase reactor performances by reducing outage time and improved utilization of the fuel. However, this will impose challenges for the transport of spent fuel in which it will be necessary:

- To demonstrate the structural integrity of the high-burnup fuel under prescribed transport impact accident conditions (geometry / pin containment);
- This data will be required for criticality assessment, which directly may affect the payload or indeed, in some instances, the fuel itself may not be transportable if the fuel assembly design suffers unacceptable failure of the fuel pins.
- Fuel designs (after irradiation) must be designed to withstand prescribed transport impact accidents; practical tests on spent fuel rods/ assemblies is not possible due to the lack of facilities to accommodate such testing. Still there is a need to know the mechanical properties the fuel assembly has after irradiation and what is the impact that causes decelerations of 120g, 130g or more depending on the package design.

These points illustrate that reactor operation is only one part of the nuclear fuel life cycle process and the controlling parameters will increasingly become transport regulatory requirements as the uncertainties of the structural performance of the spent fuel increases as a function of burnup.

Another challenge is the long term storage of spent fuel in Dual Purpose Casks (DPCs) which is gaining more prominence as an interim storage solution; reactor operation and storage of spent fuel are combined activities in most nuclear power programmes. The strategy to store spent fuel for decades until decisions on the next steps in the fuel cycle are made has storage time limitations and therefore the progressive increases in planned storage times originally ranging from 20 - 50 years is now cited in some discussions to be storage periods of 50 - 100 years.

The growing trend towards using the DPC for interim storage was recognized by the recent 2018 Edition of the SSR-6 regulation document which specifies that for packages designs that are intended to be transported after storage, there is now a requirement to have an ageing management system in place approved by the competent authorities as part of the Package design Safety Report upon which the package design approval certificate is based..

DPCs are often considered to solve the increased interim storage capacity and to provide a safe storage environment which can also be used for its future shipment. However, the challenges associated are multiple and have to be further addressed:

- It introduces a disconnect between an activity (transporting spent fuel) and its ongoing interaction with the public.
- As storing of spent fuel pending future decisions on the next step in the fuel management cycle becomes the norm, future generations will have little to no experience of transporting spent fuel in the public domain. The effects of this will be time-dependent. The longer the spent fuel is stored, the more influence the disconnect is likely to have.
- There is a need to develop a mechanism to evaluate ‘transportability’ which is more than solely compliance with the transport regulations. Transportability will remain unproven until preparations are being made for the first shipments of DPCs from storage in the future.
- Transportability may in itself provide a limit to the interim storage period
- One alternative that may provide longer interim storage periods may be to use a shielded container that is subsequently loaded into a transport cask that is designed, approved and manufactured nearer the time of the intended shipment programme of the shielded containers from the storage facility.

The further in the future we plan for subsequent shipments of long term stored DPCs, more consideration should be given to the wider issues that may influence the ability to complete those shipments; wider than regulatory compliance. It is important to include such considerations in the strategic planning to minimize the possibility of significant costs, delays, uncertainties and loss of credibility could be incurred to complete what would then be a near term planned shipment programme.