Summary

The introduction of transportable reactors raises questions of whether they are within the scope of the current international safety, security, safeguards and liability frameworks. This paper focuses on the transport safety aspects to reflect the responsibilities of the author in the IAEA, but is also intended to stimulate a focused process to develop the necessary requirements in all disciplines as considered necessary by those with such responsibilities.

The development of a system to deliver energy to communities at a level not otherwise possible will be a significant factor to improve the health, wellbeing and overall quality of life of many people.

This discussion paper is not intended to cast doubt on the strategy of delivering energy by transportable reactors, it instead is intended to provide a stimulus to a discussion in the regulatory framework community that is necessary to ensure that transportable reactors fit into the frameworks which provide all of us with the confidence that agreed levels of safety have been set out and complied with when radioactive material is being transported anywhere around the world.

1. Introduction

The purpose of this briefing document is to stimulate discussion on the issues raised by the deployment of transportable reactors in the context of the safety infrastructures for nuclear power plants and transport.

Several Member States are developing concepts for transportable reactors and the first deployment by sea transport of 77MWt capacity using 19% fuel enrichment in two reactors is scheduled to take place in the near future with reports that another Member State is constructing a 200MWt capacity reactor on a ship which is scheduled for deployment within the next 5 years.

This emerging sector of NPP deployment is of interest in the context of the whole range of IAEA safety requirements which particularly for transport are promulgated directly into the international and Member State regulatory frameworks.

2. Nuclear Power Reactors and Transport; a new paradigm

The two universes of nuclear power plants and transport have understandably developed separate paradigms as traditionally the only interfaces were principally to deliver reactor fuel and export spent reactor fuel and radioactive waste from a nuclear power plant facility. There is the use of nuclear propulsion systems on ships which are discussed later in this paper.
Transporting nuclear power plants in the public domain creates a need to bring both parties together to explore and fully understand the requirements of the following three stages of delivery, operation and return, namely:

I. Transporting a new reactor, likely loaded with fuel, and possibly tested to criticality levels prior to delivery;
II. Operation of the reactor at the destination point;
III. Transport of the used reactor, possibly loaded with irradiated fuel, to another destination.

Repair, maintenance and disposal issues would be of interest to the nuclear reactor safety and waste management communities with appropriate interfaces with the transport sector.

The IAEA standards should take account of the deployment of transportable reactors by a State from anywhere by whatever route is chosen. It is therefore important to ensure that discussion and development of any new safety requirements and guidance remains at a global level thereby preserving the global nature of the IAEA documents.

3. IAEA SSR-6\(^{(ii)}\) Transport Safety Requirements

The requirements of SSR-6 apply to the transport of radioactive material by all modes on land, water, or air, including transport that is incidental to the use of the radioactive material. The requirements of SSR-6 are adopted by:

- the UN Model Regulations\(^{(g)}\)
- the globally adopted regulations ICAO Technical Instructions\(^{(i)}\) for transport by air
- the globally adopted regulations IMDG Code\(^{(4)}\) for transport by sea
- Regional Agreements such as ADR\(^{(5)}\) and RID\(^{(6)}\) for transport by road and rail respectively in Europe and some other Member States
- Directly by Member States into their national regulations for transport by road

SSR-6 definition of transport: Para.106, ‘... Transport comprises all operations and conditions associated with, and involved in, the movement of radioactive material; these include the design, manufacture, maintenance and repair of packaging, and the preparation, consigning, loading, carriage including in-transit storage, unloading and receipt at the final destination of loads of radioactive material and packages. …’
The transport safety regulations, SSR-6, requires spent fuel to be transported in Type B Fissile design packages that meet prescribed performance criteria for prescribed routine and accident conditions of transport which limit:

- the allowable release of its radioactive content;
- the rearrangement of its contents to ensure a criticality cannot occur;
- the surface and external dose rates to prescribed limits;
- the effects of heat from the radioactive contents and defined range for ambient temperatures;
- the effects of impact, fire and submersion resulting from prescribed accident test conditions and sequence of events.

SSR-6 provides the ability to transport fuelled and contaminated reactors under Special Arrangement Approvals which would be subjected to multilateral approval for international shipments. The package design safety report (PDSR), of which the Member State assessment and approval to transport would be based, would need to consider the reactor as an appropriate package type for its contents (fresh, used with spent fuel or used with spent fuel removed) and address the prescriptive package performance requirements for routine transport and transport accident conditions. This would involve consideration of the performance of the package to prescribed accumulation, impact, submersion and thermal assaults and the consequential performance characteristics relating to the containment, radiation shielding, effects of heat and prevention of criticality capabilities, for routine transport and accident conditions.

4 Equivalent safety, irrespective of classification

The graded approach used in IAEA SSR-6[^1] leads to a classification of the radioactive material and hence the type of packaging (package without radioactive contents) required for transport. The packaging is designed to ensure that each package type (a packaging loaded with a defined radioactive content and limit) meets prescribed dose rate limits and activity release criterion that result from prescribed performance criteria for routine and accident conditions. As a result of this approach the radiological effects of transporting any radioactive material in the appropriate packaging remains the same for routine transport conditions and any transport accident that is likely to occur.
5. Land transport - road or rail

Land transport of a nuclear reactor would be subject to the requirements of SSR-6[^1] enacted by Member States through their legislative processes into their domestic regulations directly or by the adoption of regional agreements such as ADR[^5] in Europe.

Consequently the approach described in section 3 of this report would apply.

6. Transport safety regulations - transport by sea

A summary of the existing global safety regulations for the transport of radioactive material by sea is shown in Table 1.

<table>
<thead>
<tr>
<th>Document</th>
<th>Purpose</th>
<th>Organisation</th>
<th>Chapter / Part</th>
<th>Reactor</th>
<th>Ship</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOLAS[^7]</td>
<td>To define ship requirements related to defined ship type</td>
<td>IMO</td>
<td>Entire document including Chapters VII (Dangerous Goods) and Chapter VIII (Nuclear Ship)</td>
<td>If not used for ship propulsion system, then defined as INF Cargo</td>
<td>Nuclear ship - New ship - Existing ship - INF Code[^8] requirements</td>
</tr>
<tr>
<td>Rules and Regulations for the Classification of Offshore Units – Parts 1 to 11[^1]</td>
<td>Classification of Offshore Units</td>
<td>Lloyds Register</td>
<td>Entire document</td>
<td>Not in scope</td>
<td>Surface Type Unit</td>
</tr>
<tr>
<td>INF Code[^10]</td>
<td>To define ship requirements for irradiated fuel, plutonium and high level radioactive waste cargoes</td>
<td>IMO</td>
<td>Entire document</td>
<td>Depending upon isotope inventory cargo is assigned INF 1, 2 or 3</td>
<td>INF-1 INF-2 INF-3</td>
</tr>
</tbody>
</table>

8. The adoption of ‘Nuclear Ship’ in SOLAS

The establishment of the nuclear ship concept is documented in IMO Resolution A.491 (XII)[^11] in which it is stated:

‘THE ASSEMBLY,

HAVING ADOPTED the Code of Safety for Nuclear Merchant Ships,

RECOGNIZING that the technology for nuclear powered merchant ships is evolving and that further experience will be gained as the application of nuclear power increases,'
AUTHORIZES the Maritime Safety Committee to amend the Code in due course as necessary in the light of future development in the field of nuclear powered merchant ships.

The Resolution also defines a ‘Nuclear ship’ as

‘Any merchant ship the normal mode of propulsion of which is based upon nuclear energy and whose characteristics are those of conventional displacement ships.’

The IMO website description of SOLAS Chapter VIII

Chapter VIII - Nuclear ships

Gives basic requirements for nuclear-powered ships and is particularly concerned with radiation hazards. It refers to detailed and comprehensive Code of Safety for Nuclear Merchant Ships which was adopted by the IMO Assembly in 1981.

9. Radioactive material as cargo on board ship

The SOLAS [7] Convention, Part A, Regulation 3 requires the carriage of dangerous goods in packaged form shall be in compliance with the IMDG Code [10], which reflect the SSR-6 [1] requirements.

The IMDG Code [10] requires unirradiated reactor fuel to be transported in a Fissile design package type which meets prescribed requirements and performance testing criteria, whilst irradiated reactor fuel is required to be contained in a Type B Fissile package which meets other requirements and performance testing criteria.

In addition, the SOLAS Convention Chapter VII, Part D requires irradiated nuclear fuel by:

- Regulation 14 defines irradiated nuclear fuel as INF Cargo
- Regulation 15 states that the INF Code does not apply to warships, naval auxiliary or other vessels owned by a Contracting Government and used on government non-commercial service
- Regulation 16 states a ship carrying INF cargo shall comply with the requirements of the INF Code [10] adopted by the Maritime Safety Committee of the IMO by resolution MSC.88(71)[10].

10. The use of a platform or barge that has no propulsion system carrying operational nuclear reactor

Platforms or barges that have no propulsion system are not covered by SOLAS [7], as cited in Chapter 1, Part A, Regulations 3(a) (ii).
11. Rules and Regulations for the Classification of Offshore Units

This document is produced by Lloyd’s Register in London in which Unit classification is regarded as the development and worldwide implementation of published Rules and Regulations in conjunction with proper care and conduct on the part of the Owner and Operator, will provide for:

- the structural strength of (and where necessary the watertight integrity of) all essential parts of the hull and its appendages;
- the safety and reliability of the propulsion and steering systems; and,
- the effectiveness of those other features and auxiliary systems which have been built into the unit in order to establish and maintain basic conditions on board whereby appropriate cargoes and personnel can be safely carried whilst the unit is at sea, at anchor, or moored in harbour.

Lloyd’s Register Group Limited (LR) maintains these provisions by way of the periodical visits by its Surveyors to the unit as defined in the Regulations together with a requirement to inform LR without delay of damage sustained between inspections. Similarly any modification which would affect the Class must receive prior approval by LR.

A unit is said to be in Class when the Rules and Regulations which pertain to it have, in the opinion of LR, been complied with, or when special dispensation from compliance has been granted by LR.

It should be appreciated that, in general, classification Rules and Regulations do not cover such matters as the unit’s floatational stability, life-saving appliances, pollution prevention arrangements, and structural fire protection, detection and extinction arrangements where these are covered by the International Convention for the Safety of Life at Sea, 1974[7], its Protocol of 1978, and the amendments thereto, nor do they protect personnel on board from dangers connected with their own actions or movement around the unit. This is because the handling of these aspects is the prerogative of the National Authority with which the unit is registered. A great many of these authorities, however, delegate such responsibilities to the Classification Societies who then undertake them in accordance with agreed procedures.

In Rules and Regulations for the Classification of Offshore Units, Part 1, Chapter 2, an appropriate definition is cited, namely:

- **Surface type units** are units with a ship or barge type displacement hull of single or multiple hull construction intended
However, the document goes on to describe these units in terms of their use such as drilling platforms and oil bunkers and therefore it would seem appropriate that this document should be reviewed in the context of a ‘surface type unit’ that carries nuclear power reactor(s).

12. Previous IAEA Study

A preliminary study of the Legal and Institutional Issues of Transportable Nuclear Power Plants was published by the IAEA in 2013[9] and this report makes a useful reading resource to inform discussion on this subject.

13. Concluding remarks

The introduction of transportable reactors has raised the issue of nuclear reactors in merchant ships. The advances made in the development of this new concept cannot compromise due consideration of the transport safety, security, safeguards and liability issues in the existing international frameworks and the formulation and introduction of new requirements considered necessary.

The development of a system to deliver energy to communities at a level not otherwise possible will be a significant factor to improve the health, wellbeing and overall quality of life of many people.

This discussion paper is intended to provide a stimulus to a discussion and agreement that is necessary to ensure that transportable reactors fit into the conventions and regulatory frameworks which provide all of us with the confidence that agreed levels of safety have been set out and complied with when radioactive material is being transported around the world.

Revision of the frameworks considered necessary will take time, but early agreement on the formulated changes will enable efforts to align the adoption of future changes in regulatory requirements within the delivery programmes for reactors. Such efforts could include consideration of implementing agreed changes by industry in advance of adoption into the transport safety framework thereby providing a possible mechanism for Member States to authorise deployment before the framework has been revised.

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March’ 2017
References

3. ICAO Technical Instructions,
4. IMDG Code, the International Maritime Dangerous Goods Code, International Maritime Organisation
5. ADR 2017 European Agreement concerning the International Carriage of Dangerous Goods by Road
6. RID 2017 Regulation concerning the International Carriage of Dangerous Goods by Rail
8. Rules and Regulations for the Classification of Offshore Units – Parts 1 to 11, Lloyd’s Register, London 2016