Marine transportation of irradiated nuclear fuel, plutonium and radioactive wastes: the continuing debate on regulatory measures

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Abstract

The prospect that the maritime transportation of irradiated nuclear fuel (INF), plutonium and radioactive wastes can be expected to continue for the foreseeable future, together with widely expressed concern that an accident may occur to a ship carrying such cargo, has meant that regulatory safeguards have come under intense scrutiny in recent years. The paper describes the actions taken by the International Maritime Organisation (IMO) aimed at ensuring the safety of ships engaged in such activity, culminating in the decision of its Maritime Safety Committee (MSC) in May 1999 to make compliance with the INF Code mandatory. In relating the above progress, the paper draws attention to a number of issues raised by Governments in the IMO which have so far gone unaddressed, these issues having also been highlighted in responses to a questionnaire circulated to coastal states. The paper reviews the legal issues associated with the right of emergency access to a foreign port by a ship transporting nuclear materials, the availability of a safe haven being crucial in the event that critical repairs or salvage operations are necessary. Finally, the paper considers whether seabed characteristics should be assessed in determining the routing of such ships, bearing in mind that ocean floor topography and water depth will be crucial in determining whether recovery of nuclear materials would be practicable in the event of sinking of a ship.

Keywords: Irradiated nuclear fuel; Radioactive wastes

1. Introduction

1.1. The importance of nuclear energy

The development and utilisation of nuclear power in combination with nuclear fuel recycling, is already playing an important role and may increasingly do so, in meeting society’s energy needs. In promoting this utilisation of nuclear power, the transportation of radioactive materials is essential.

This transportation involves shipment of spent fuel from nuclear power plants to reprocessing plants, shipment of plutonium recovered through reprocessing and shipment of high-level vitrified residues to storage facilities.

Moreover, new countries with nuclear reactors have appeared all over the world, and may eventually need to transport materials to reprocessing plants prior to storage of residues. Furthermore, the break-up of the Eastern block in 1989 may mean that nuclear wastes dumped at sea, and elsewhere, by the USSR may also require reprocessing, and hence transportation before suitable land-based means of disposal can be arranged.

Finally, nuclear energy is also important in the sectors of medicine, industry and agriculture, and it is reasonable to expect that international sea transportation will be increasingly involved, especially if the maritime industry can prove that it conducts itself in a safe and reliable manner.

1.2. Sea transportation of irradiated nuclear fuel

The main trade of such material is between Japan, Europe, and the United Kingdom. In the UK, British Nuclear Fuels Ltd (BNFL) has established a subsidiary...
transport company Pacific Nuclear Transport Limited (PNTL) for this purpose. For France, the company concerned is COGEMA. Since 1969, from Japan to Europe and between European countries, 291 ship movements involving irradiated nuclear fuel took place by sea; this involved the carriage of 8061 t of such material in 2856 flasks.

According to the source of this information [1], this was achieved without a single incident resulting in the release of radioactive materials.

Another important movement of such material has taken place between Swedish ports since 1985. Every year about 20 transports were made containing 4–5 casks. Sweden has a purpose-built ship, the M/S Sigyn. Between 1985 and 1996 some 2200 t of irradiated nuclear fuel and 18,000 m³ of reactor waste were transported by the Sigyn [2]. France has transported more than 24,000 metric tons of heavy metals (MTHM). MTHM is a unit pertinent to nuclear fuel used in reactors. Fuel rods are enriched with heavy metals to avoid melting in the reactor due to high temperatures. This involved 6800 shipments of light water reactor (LWR) and gas-cooled reactor (GCR) fuels and reportedly caused no personal injury or property damage. Regarding spent fuel, more than 16000 metric tons as uranium (MTU), corresponding to 4258 casks, have reportedly been safely transported by France since 1966. MTU is a unit associated mainly with nuclear wastes whose purpose is to normalise measurements of materials with different characteristics due to their origins and the nuclear reactors in which they were used. In 1994, 326 casks were transported representing 1498 MTU of both pressurised water reactor (PWR) and boiling water reactor (BWR) fuels [3].

This paper is concerned with the sea transportation of irradiated nuclear fuels and substances arising from reprocessing, and not with the routine movement of packages of other radioactive materials, which involve hundreds of thousands of shipments per year.

IAEA has acknowledged the usefulness of data on shipments of radioactive materials, accidents, etc., and is currently developing five databases [4]:

- Competent authority package approval certificates (PACKTRAM).
- Events in the transport of radioactive material (EVTRAM).
- Shipments of radioactive materials (SHIPTRAM).
- Radioactive exposure from radioactive material transports (EXTRAM).
- Research and development in radioactive material transportation (REDTRAM).

In May/June 1998 one of the authors (BST) endeavoured to obtain more comprehensive data on shipments of irradiated nuclear fuel from the IAEA. In reply he was informed that the Agency had invited its Member States to provide shipment data (i.e. SHIPTRAM database) for the nuclear fuel cycle for the calendar year 1990 but the response rate was so low that it was only feasible to prepare an administrative report on the subject. Information, as summarised above, submitted to the Special Consultative Meeting convened by IMO in 1996, would therefore appear to give the best available indication of the scale of sea transportation of such material. From the viewpoint of international accountability, it seems IAEA is being frustrated in meeting the expectations placed upon it in this respect.

1.3. International safety regulation of marine transportation of nuclear materials

The carriage of dangerous goods is dealt with in Chapter VII of the International Convention for the Safety of Life at Sea, 1974 (SOLAS) which, *inter alia*, contains provisions for the classification, packing, marking, labelling and placarding, documentation and stowage of dangerous goods in packaged form. The classification follows the system used by the UN for all modes of transport, but adaptations have been made for the marine situation and the provisions are in some cases more stringent. To assist governments in issuing instructions at the national level IMO, in cooperation with the United Nations Committee of Experts on the Transport of Dangerous Goods, drew up the International Maritime Dangerous Goods (IMDG) Code which was adopted by the IMO Assembly in 1965. The IMDG Code has undergone many changes and revisions and so far 52 countries representing over 85% of the world’s merchant tonnage are applying the code.

Radioactive material falls under Class 7 of the classification system recommended by the UN Committee of Experts. The responsibility for drawing up regulations for such material lies with the International Atomic Energy Agency (IAEA) in so far as radioactive and fissile properties are concerned and IMO has incorporated IAEA regulations covering Class 7 into the IMDG Code. It should be noted, however, that consignments of radioactive materials may possess hazardous properties other than those falling within IAEA’s mandate, and any additional precautions form part of the various modal regimes, this need being explicitly referred to in paragraph 105 of IAEA Safety Series No 6 (SS6).

IAEA requirements are mainly directed at the packaging, marking and labelling of radioactive material, as well as test procedures to demonstrate compliance with package regulations. On the question of whether the transport of such materials should be subject to routing restrictions, it is implicit in paragraph 106 of SS6 that it is

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1 Personal communications from J. Russel and M.T. Brittinger of the Transport Safety Unit, Division of Radiation and Waste Safety, IAEA, Vienna, Austria.
IAEA’s belief that the present level of safety is such that measures of this kind are not generally necessary. That is, it can be assumed that packages complying with IAEA safety requirements are in principle acceptable for all types of transport and routing, and that any consideration of special routing schemes should focus on hazards requiring measures falling outside the scope of the IAEA regulations.

This distinction between transport issues falling within the scope of IAEA regulations, and those which do not, has in practice gone beyond the illustrative point of routing. For instance, the potentially more severe consequences of an aviation accident are reflected in the performance requirements of packages that can be transported by air. Similarly, the use of non-purpose-built vessels for the transport by sea of irradiated nuclear fuel and related substances has led to the adoption of complementary carriage requirements by IMO.

Recent regulatory developments in respect of sea transport, as manifested by adoption of the Code for the safe carriage of irradiated nuclear fuel, plutonium and high-level radioactive wastes in vessels (INF Code) by IMO’s 18th Assembly, while undertaken with IAEA’s co-operation, constitute an erosion of IAEA’s formerly exclusive position relative to regulation of nuclear transport. Notwithstanding the merits of bringing IMO’s maritime expertise to bear upon what many in the wider community would regard as an extremely hazardous operation, IMO’s growing involvement means that IAEA no longer has exclusive control over operations crucial to the functioning of the nuclear industry. This has opened up possibilities for entities not engaged in civil nuclear power programmes to express their concerns on sea movements of radioactive cargoes transiting sea areas adjacent to their coastlines and to demand that these concerns be reflected in framing IMO requirements. This, in itself, is a significant development with the potential for the imposition of further regulation and control.

1.4. Aims of the present paper

The purpose of this paper is to examine the evolving regulatory regime associated with the sea transport of nuclear materials at the same time as seeking to understand the precepts upon which such trade is conducted. The outcome is described of a questionnaire sent to some 30 coastal states inviting them to identify their concerns on this issue. The legal issues associated with the right of emergency access to a foreign port by a ship transporting nuclear materials are reviewed, bearing in mind that the availability of a safe haven could be crucial in the event of accidental damage. Finally, some initial consideration is given to whether it would be feasible to include an assessment of seabed characteristics in determining the routing of such ships, in the knowledge that topography of the ocean floor and depth of water will be crucial in determining whether recovery of nuclear materials would be practicable in the event of the foundering of a ship.

2. Development of the INF CODE

A comprehensive review of this subject may be found in the presentation by Young to the Special Consultative Meeting convened by IMO in March 1996, which itself was condensed from Hesse and Young’s paper to the PATRAM ‘95 Conference [5]. Background events significant to development of the Code are related below.

Until May 1999, when amendments where made to chapter VII of SOLAS, 1974 making the INF Code mandatory, no special requirements concerning the construction and equipment of ships had been included in SOLAS for radioactive material, although such provisions had been made for other classes of dangerous goods, for example in respect of fire protection equipment (see Chapter II-2). This perceived lack of special carriage provisions for Class 7 materials together with the expectation that such trade would increase, gave initial impetus to development in this regard.

This question was first raised (by Italy) at the 52nd session of the Maritime Safety Committee of IMO in 1985, Italy’s concern being that non-purpose-built ships could engage in unrestricted carriage of INF material without sufficient thought having been given to the adequacy of fire protection or damage stability. Following initial focus on non-purpose-built ships, the scope of the MSC’s work was eventually widened to include purpose-built ships, covering such subjects as hold cooling, ventilation and radiation protection equipment. In response to a request that definition be made of the maximum quantities of INF material to be permitted for carriage on non-purpose-built ships, the relevant MSC sub-committee proceeded to draw up requirements for three classes of ships according to the aggregate quantity of INF to be carried, a stage that was reached in 1990.

Fundamental differences of opinion now emerged between IAEA and IMO, with the former taking the view that safety could be ensured through package design while IMO was convinced of the need for quantity

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2 Resolution A.748(18), November 1993.

3 Resolution MSC 87(71) of 27/5/99: Adoption of amendments to SOLAS 74 as amended, concerning mandatory application of the INF Code from 1/1/2001.

4 Resolution MSC 88(71) of 27/5/99: Adoption of the text of the INF Code referred to in Footnote 8.
limitation, and for specific ship design or fire protection requirements to be applied when transporting INF material in large quantities. So as to move the issue forward, a joint IAEA/IMO working group was established with terms of reference:

(a) to study the adequacy of existing provisions for the safe transport of irradiated nuclear fuel by sea. To take into account the impact of marine casualties, such as fire, explosion, or breach of the hull, on packaging integrity. To assess the probability of such casualties occurring;
(b) within the purview of the tasks specified under (a), to make recommendations for any action deemed necessary; and
(c) to consider whether the marine transport of other radioactive material should also be studied.

The joint working group met in December 1992 and April 1993. One of the main conclusions of the first meeting was to include nuclear materials of similar potential hazard to INF in any new provisions. Thus plutonium (Pu) and high-level radioactive wastes were subsequently considered alongside INF in future considerations of the group. The second meeting of the group agreed on the text of a code for the safe carriage of INF, Pu and HLW in Flasks on Board Ships (hereinafter referred to as the “INF Code”) with a view to its submission to IMO’s Assembly in October–November 1993 for formal adoption. The contents of the Code reflect the work done by various IMO bodies on safety-related questions affecting the ship and its crew, as referred to earlier. The aim of other conclusions of the second meeting of the working group would seem to public reassurance, rather than an expression of confidence in its assessment of the probability of risks occurring, viz.

- no information or data submitted to the joint sessions cast doubt on the adequacy of IAEA regulations;
- papers supported the existing experience and knowledge of IAEA/IMO members, which indicated low levels of radiological risk and environmental consequences from the marine transport of radioactive material; and
- any further consideration of packaging standards should be pursued through the established revision process of IAEA.

The group did, however, identify matters requiring further consideration, such as emergency response plans, notification of coastal States about shipments of nuclear materials, positive tracking of vessels transporting substantial INF quantities, and the fitting of transport containers with a device to assist their location and recovery should they be lost at sea. It also recommended that a policy of compulsory package retrieval be considered, and the responsibility for the action be predetermined (in conjunction with the development of the convention on liability and compensation for damage in connection with the carriage of hazardous and noxious substances by sea — the “HNS Convention”).

In respect of matters such as emergency response and package retrieval, the group recommended that this should be considered as complementary to the INF Code. It further proposed that each shipment of INF, Pu and HLW should have a “Voyage Plan”, including:

- sufficient material and packaging specific information which can be provided to coastal States into whose waters the ship enters in an emergency;
- an emergency response plan for the package(s); and
- an emergency response plan for the ship, to include information on salvage capabilities and ports with ship repair capabilities.

It was recognised that the question of whether coastal States should be notified of shipments of INF, Pu and HLW should be referred to IMO, taking into account the need for physical protection of nuclear materials.5 The decisions already taken under the auspices of IAEA to ensure the physical protection of nuclear material undoubtedly conflicts with the desire by some IMO members for greater openness in respect of prior notification of shipments and voyage planning. For example IAEA’s publication on the physical protection of nuclear material states in paragraph 6.1.1 that transport is the operation most vulnerable to an attempted act of unauthorised removal of nuclear material or sabotage. Protection provided should be “in depth” and particular attention should be given to the recovery system. The following points are listed in paragraph 6.1.2:

- minimising the time in transit;
- minimising the number of transfers, i.e. from one conveyance to another;
- protecting material in temporary storage;
- avoiding the use of regular movement schedules;
- requiring predetermination of the trustworthiness of all individuals involved in transport of nuclear materials;
- limiting advance knowledge of transport information to the minimum number of persons necessary.

Paragraph 6.1.3 states that measures should be taken to protect the confidentiality of information relating to transport operations, including detailed information on the schedule and route. This requires great constraints in the use of open channels for transmission of messages concerning shipments of nuclear material.

Reference in made under Section 3.2 headed “Regulations” to a prerequisite that the sending, receiving and any transit States should be Parties to the Convention on Physical Protection of Nuclear Material (INFCIRC/274) or have concluded a formal agreement which ensures that physical protection arrangements are implemented. Other alternative arrangements are also possible, and these are set out.

Notwithstanding the above commitments, made within IAEA, there was disappointment among some IMO Members that the above-mentioned complementary issues had not been covered by the INF Code, as reflected by the reservations recorded by Belgium, Egypt, Fiji, Iceland, Malaysia, Sierra Leone and Solomon Islands at the time of the IMO Assembly’s deliberations on the Code prior to its adoption.6

To assuage these concerns, the Assembly called upon the relevant IMO Committees to give high priority to these issues, taking into account the joint working group’s recommendation, and to report to the 19th IMO Assembly on progress made.

The following brief summary of the contents of the INF Code illustrates its present scope. As from 1 January 2001 the Code will apply to all new and existing ships, including those below 500 gross tons.

For purpose of the Code, the following definitions apply:

1. irradiated nuclear fuel means material containing uranium, thorium and/or plutonium isotopes that has been used to maintain a self-sustaining nuclear chain reaction;
2. plutonium means the resultant mixture of isotopes of that material extracted from irradiated nuclear fuel from reprocessing;
3. high-level radioactive wastes means liquid wastes resulting from the operation of the first stage extraction system or the concentrated wastes from subsequent extraction stages, in a facility for reprocessing irradiated nuclear fuel, or solids into which such liquid wastes have been converted.

The Code assigns ships to three classes viz. Classes INF 1, 2 and 3, depending on the total radioactivity of INF cargo which is carried on board. Regulations vary according to the class of ship, the first two classes being limited as to the aggregate radioactivity, while the third class has no restrictions of this kind. This reflects a situation whereby passenger and cargo ships in ordinary service may transport the limited quantities specified for Classes INF 1 and 2 while Class INF 3 vessels are purpose built for such cargoes.

All ships, regardless of size, should comply with SOLAS 1974 and, in addition, requirements concerning:

- damage stability;
- fire protection;
- temperature control of cargo spaces;
- structural considerations;
- cargo securing arrangements;
- electrical supplies;
- radiological protection equipment;
- management, training and shipboard emergency planning.

Following the 18th Assembly in 1993, a number of issues were assigned to IMO bodies, such as:

| Emergency response including salvage and recovery | Marine Environment Protection Committee (MEPC) |
| Route planning and notification and consultation with coastal States, and of possible restrictions and exclusion of certain routes | Sub-Committee on Safety of Navigation (NAV) |
| Equipment and devices that would facilitate location and salvage of a ship and/or cargo | Sub-Committee on Carriage of dangerous Goods (CDG) and Sub-Committee on Radio communications (COM) |

In connection with the MEPC’s brief, a consultant was contracted to undertake a desk study, involving a literature survey and interviews with consignors, carriers, regulators, coastguards and salvors, the outcome being reported in June 1995.7

Pacific Nuclear Transport Limited (PNTL) and the American National Standard for barge transportation of radioactive material were the consultant’s main sources.

PNTL, which operates a fleet of 6 purpose-built ships to transport Class INF3 quantities of radioactive materials has:

- extensive emergency response procedures, properly documented, checks on communications and regular drills;
- satellite tracking allows ship’s positions to be monitored throughout the voyage;
- equipment enables vessel to be located in the event of sinking.

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6 As recorded in document A18/5(b)/2 dated 3/11/93: Report of the Technical Committee to the Plenary.

American National Standard calls for:
- radar reflectors to make the barge more visible;
- sonic signalling device (“pingers”) to enable location of sunken barge;
- routeing service, providing weather and sea state forecasts;
- skipper must provide operational information (normal and emergency);
- each shipment must be accompanied by communications and, if required, in-transit security and physical protection instructions, route and alternative route information.

The consultant was critical of IAEA’s failure to advise on what should be done if a ship is disabled or in danger of sinking. IMO’s IMDG Code also failed to consider possible recovery of radioactive material from the seabed. Loss of cargo in deep water had not been clearly defined. Risks associated with attempted recovery, as against leaving cargo on the seabed, had not been considered. Flash failure following sinking; disablement of ship rendering it unsuitable for towing; and refusal of a port to accept entry had not been considered.

The consultant reported:

From the perspective of the salvor, if radioactive cargo is involved then burial of the wreck in sediment would be preferred. Advice would probably be to leave the ship where it is if possible. Radioactive cargoes are considered less hazardous than other dangerous goods which are more readily dispersible from a wreck.

After two years of consideration, NAV could not decide whether the INF Code should include provisions for route planning, notification and consultation with coastal States and restrictions and exclusions of certain routes in the case of INF cargoes. It agreed to consider whether the existing IMO provisions for voyage planning should be extended to cover extraordinary measures for the carriage of INF Code materials by providing for prior consultation with coastal States that may be affected.

Thus the 19th Assembly in November 1995 was unable to report progress on any of the supplementary issues, viz. emergency response, route planning and notification/consultation with coastal States, and equipment that would facilitate location and salvage of ship and/or cargo. As a consequence, the Assembly drew up another list of 11 tasks, incorporating the points of unfinished business from the previous Assembly. To facilitate progress, a suggestion by the IMO Secretary General to convene a Special Consultative Meeting to discuss these issues was accepted. In the authors’ view, the suggestion to convene a special consultative meeting had arisen because of impatience with the tardy progress made in developing measures complementary to the INF Code during the previous two years, which itself had been a reflection of the seeming attitude of IMO Members engaged in the marine transportation of INF, plutonium and HLW that present arrangements were adequate and therefore did not need to be improved upon. This rather naive view, as seen from the IMO context, is perhaps insignificant compared with the complex diplomatic and legal challenges being made to such trade in the world at large, which had undoubtedly produced a more profound impact upon the countries directly concerned, resulting in their rather “touchy” and defensive attitude to the status quo. The concern of these countries with what IMO might come up with in terms of complementary provisions to the INF Code must also be seen in the context of the international law of the sea, which sets out the rights and obligations of States whose vessels are engaged in transporting cargoes of INF, Pu and HLW and of States whose interests might be affected.

These issues have been analysed by Van Dyke [6], and Kwiatkowska and Soons [7]. It is not the authors’ intention to reiterate the arguments discussed by these authors, but only to observe that governments might naturally be reluctant to engage in the development of guidelines on such matters as prior notification to coastal States of the intended passage of INF ships which infringe in any way upon the rights of passage through the territorial sea, the exclusive economic zone, straits and archipelagic waters, as set out in the law of the sea. Such developments would quite likely be seen as a challenge to these rights and ultimately as leading to restrictions on what vessels can, and cannot do, in going about their legitimate business. Governments will, in the present context, also have in mind the physical protection commitments entered into under the auspices of IAEA, as described above.

The Special Consultative Meeting referred to above took place from 4 to 6 March 1996. While assisting participants to understand the issues involved, the meeting’s list of unfinished business was little different from that drawn up by the 19th Assembly in its resolution adopted in November 1995,8 which is largely a repetition of the previous list of unaddressed issues.

Events then move forward two years to the 20th Assembly in November 1997, at which progress during 1996/97 was reported.9 The NAV Sub-Committee continued to focus on whether the existing regulations on voyage planning for ships in general should be extended to cover extraordinary measures for the carriage of INF

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Code materials. This could be covered by the further development of “principles, criteria and guidelines” on voyage planning, upon which proposals were invited from Member States. The Sub-Committee subsequently reported that preliminary guidelines had been drawn up for its future consideration, but the earliest that this could be adopted would be at the 21st Assembly in 1999.

The Sub-Committee was opposed to prior notification to coastal States because:

- it could endanger the physical protection of INF Code materials;
- States might try to veto or prevent the passage of such ships through their territorial sea or EEZ;
- establishing a precedent might lead to prior notification being required for all classes of ships.

No action was taken on measures to locate and identify a sunken ship or flasks which might have been lost.

On emergency response, the Assembly adopted

10 “Guidelines for developing shipboard emergency plans for ships carrying materials subject to the INF Code.”

Some key points in the Guidelines are:

- it is the consignor or shipper’s responsibility to comply with regulations and to deal with all potential difficulties anticipated when shipping by sea;
- states are generally entitled to define techniques and measures to be taken against a marine pollution incident in accordance with the Protocol relating to Intervention on the High Seas in Case of Pollution by Substances other than Oil, 1973.
- Paragraphs 29 and 30 of the INF Code (amendment adopted at the 20th Assembly) provide that the nearest coastal State should be notified of an actual or probable release (see reference to resolution A.853 (20) below).
- A report to the nearest coastal State is required (by Chapter VII of SOLAS, 1974) whenever there is any release of INF Code Material.
- The emergency plan should outline a decision process that will aid the master in determining when salvage assistance should be obtained, including determination of the nearest capable assistance and response time (i.e. time for tug to get on scene and secure the tow). When an incident occurs that reduces manoeuvrability, the master needs to determine the “window of opportunity” considering the response time of assistance, regardless of the estimated time of repair.

A second Assembly resolution11 adopted amendments to the INF Code calling for every ship, after 1 July 1998, to carry on board a shipboard emergency plan, and for such plan to be approved by the Administration (of the Flag State), and setting out the requirement to notify the nearest coastal State of any loss or likely loss of INF cargo.

In the authors’ opinion, the action taken by IMO since 1993 on the supplementary issues connected with INF transport has progressed very little. The INF Code has been amended to the extent that ships must carry shipboard emergency plans approved by the Administration, and calling upon the ship to notify the nearest coastal State of any loss or likely loss of INF cargo. There is still no requirement for countries engaging in such transport to provide advanced notification to coastal States of their intention, or to consult them concerning the intended passage of the ship, or to enter into any prior agreement concerning access to ports for repairs or with respect to emergency response or possible salvage assistance. No provisions have been adopted by IMO in respect of the fittest of devices which could assist in locating lost or sunken containers, or INF ships for that matter, although it is known that ships operated by PNTL and barges used in the US are so equipped.

3. Outcome of Cardiff University Questionnaire to Coastal States and consideration of issues followed-up

In June 1997 a questionnaire was circulated to 35 Coastal States with the object of ascertaining their views on the issues being debated by IMO at that time, such as voyage planning and emergency arrangements. More specifically, governments were asked to indicate, from the following list, those aspects of the marine transportation of INF, plutonium and radioactive wastes on which they were especially concerned:

(a) prior consultation in determining the preferred route(s) of such voyages;
(b) advance notification of voyage plan;
(c) emergency arrangements:
   (i) Prior identification of suitable ports where repairs could be carried out
   (ii) Arrangements for recovering packages lost at sea or for salvaging vessels containing such packages
   (iii) Mandatory use of devices in such packages and vessels facilitating their location (for recovery purposes)
   (iv) Others (to be indicated by respondent).

Responses from the seven governments replying to the questionnaire are summarised in Table 1. Column headings refer to the issues listed above.

In order to gauge the views of a wider group of countries than those responding to the questionnaire, the opinions of representatives of Argentina, Brazil, Chile, Ireland and South Africa, as expressed at the Special Consultative Meeting at IMO in March 1996, have been collated, as shown in Table 2.

Table 1
Summary of Government’s response to Questionnaires

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<thead>
<tr>
<th>Country</th>
<th>Aspects of concern</th>
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<tbody>
<tr>
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<td>(a)</td>
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<td></td>
<td>(i)</td>
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<tr>
<td>Columbia</td>
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<tr>
<td>Peru</td>
<td>✓</td>
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<tr>
<td>Solomon islands</td>
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</tbody>
</table>

*Greece, in response to item (iv), indicated that there should be passage planning for ships carrying INF materials.

3.1. Emergency arrangements

It is apparent from discussions in IMO and responses to the questionnaire that governments believe that there should be arrangements in place for recovering packages lost at sea or for salvaging vessels containing such packages. There is also support for the mandatory use of devices in such packages and vessels facilitating their location for recovery purposes. Concern over this subject is clearly shared by British Nuclear Fuels plc, as reflected in the paper by Cheshire and Boyers [8] which describes a salvage location and telemetry system to assist in vessel location and to provide information to a salvage team regarding the condition of the ship and cargo. The paper includes a plan view of a ship (now operated by Pacific Nuclear Transport Limited) equipped with such a system illustrating the position of radiation detectors, hatch detectors, data acquisition units, power supply unit and transponders. Further details of on-board equipment was given by Miller [9] of BNFL plc who stated that all PNTL vessels are fitted with a sonar location and telemetry system which consists of four acoustic transponders wired to a number of onboard detectors. The sonar system is capable of operating in water depths in excess of 6000 m and has a range of up to 20 km. The system can transmit the following information back to the surface:

1. the depth of the vessel;
2. the radiation level from duplicated sensors in each hold;
3. the angle of the ship;
4. whether the hatch covers are in place;
5. the temperature;
6. whether the ship is distorted or broken up.

Miller goes on to describe the contractual arrangement between BNFL and Smit International salvage, for Smit to provide advice on procedures and equipment which would facilitate salvage assistance and to continuously review the latest applicable technology. Twice-yearly meetings of a joint committee of the two companies have given rise to the following arrangements:

1. BNFL Emergency Procedures contain 24-h contact arrangements with the Smit International Radio Room in Rotterdam and with key Smit personnel.
2. Smit towing brackets and matched lengths of towing chains have been fitted to the forward and aft ends of all PNTL/BNFL vessels.
3. Exercises both at sea and in port are conducted to practise making towing connections to the vessels.

Table 2
Concerns expressed by Government representatives at Special Consultative Meeting, IMO, 4–6 March 1996

<table>
<thead>
<tr>
<th>Country</th>
<th>Ships’ routing</th>
<th>Complementary preventive measures (co-operation, information)</th>
<th>Provision for salvage/repairs</th>
<th>Exclusion of vessels from sensitive areas</th>
</tr>
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<tbody>
<tr>
<td>Argentina*</td>
<td>✓</td>
<td>✓</td>
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*Argentina expressed concern on the safety of cargo and containers.

*Chile and Ireland called for the development of an ‘international responsibility regime’.

*Ireland drew attention to the need for hazard evaluation.
4. Hand operated emergency lifting gear fitted to each vessel enables pumps and other salvage equipment to be lifted on to vessels even if the ship does not have power.

5. Brackets which could be welded on to the hull of the vessels to assist righting have been pre-designed for each ship.

6. Salvage inspection tours are made periodically by a joint BNFL/Smit team to renew contacts and investigate the availability of equipment along the routes taken by PNTL/BNFL vessels.

BNFL also engages the services of a specialist company which provides information, updated monthly, on the availability and disposition of all types of salvage equipment world-wide.

3.2. Right of access to foreign ports

Four countries (Greece, Panama, Peru and Solomon Islands) highlighted the prior identification of suitable ports where repairs could be carried out when responding to the earlier mentioned questionnaire.

However, papers describing the commercial transportation of INF cargoes, for example of Pacific Nuclear Transport Limited, make no reference to problems that might occur should a ship loaded with an INF cargo seek to make an unscheduled port call en-route to its destination, perhaps necessitated by a breakdown of the ship or its equipment requiring urgent repair. PNTL’s contractual arrangement with Smit International Salvage might prove an important source of emergency assistance, but would not necessarily avoid the need to enter a port for essential work or dry-docking.

The concerns expressed by coastal states in IMO, particularly regarding the need for prior consultation on the intended routes of INF ships, may stem from the fear that, should such a ship encounter difficulties during a voyage, it would need to make an emergency call at one of their ports. The risks associated with admitting entry of such a ship, or at least the public perception of such a risk, and the political outfall of allowing (or refusing) entry, have the potential to escalate into a major international incident. If a safe haven is provided, the government rendering assistance would probably face severe criticism on the domestic front; if the ship is refused entry, such a government would inevitably come under pressure from the flag State and others directly involved in the INF transportation.

The question may therefore be legitimately asked, could a State refuse access to its port by an INF ship? Or might it be acceptable for it to refuse access under some circumstances?

The authors’ interest in this question was triggered by the wording of Articles 7(e) and (f) of the 1960 Paris Convention on Third Party Liability in the field of Nuclear Energy as amended by the Protocols of 1964 and 1982, which read as follows:

(e) A contracting Party may subject the transit of nuclear substances through its territory to the condition that the maximum amount of liability of the foreign operator concerned be increased, if it considers that such amount does not adequately cover the risks of a nuclear incident in the course of the transit; provided that the maximum amount thus increased shall not exceed the maximum amount of liability of nuclear installations situated in its territory.

(f) The provisions of paragraph (e) of this Article shall not apply:

(i) to carriage by sea where, under international law, there is a right of entry in cases of urgent distress into the ports of such Contracting Party or a right of innocent passage through its territory; or

(ii) to carriage by air where, by agreement or under international law there is a right to fly over or land on the territory of such contracting Party.”

Thus, it appears from paragraph (f)(i) that under international law there may be a right of entry in cases of urgent distress into the ports of another state. Further enquiry led the authors to Brown’s textbook (1994) [10] on the International Law of the Sea, in particular the section dealing with jurisdiction over internal waters. As Brown has pointed out, the distinguishing feature of internal waters, as compared with the territorial sea, is that the sovereignty of the coastal State in internal waters is not limited by an obligation to grant a right of innocent passage to foreign shipping. It is indicated, however, that such limitations may arise under international customary law or pursuant to treaties entered into by the coastal State. Although there is some doubt about the existence under international customary law of a general right of access to foreign ports, there appears to be no doubt about a right of entry for vessels in distress, though the precise scope of the right is less than clear, especially when hazardous cargoes are carried. Leaving such customary law aside and focusing instead on the possibility that a coastal State may have accepted obligations concerning passage through internal waters and access to ports pursuant to treaties it has entered into, it would seem that in the present context the Geneva Convention and Statute on the International Regime of Maritime Ports, 1923 [11] is the most relevant instrument, Article 2 of which provides that:

Subject to the principle of reciprocity and to the reservation set out in the first paragraph of Article 8, every Contracting State undertakes to grant the vessels of every other Contracting State equality of treatment with its own vessels, or those of any other State whatsoever, in the maritime ports situated under its sovereignty or authority, as regards
freedom of access to the port, the use of the port, and the full enjoyment of the benefits as regards navigation and commercial operations which it affords to vessels, their cargoes and passengers. The equality of treatment thus established shall cover facilities of all kinds, such as allocation of births, loading and unloading facilities, as well as dues and charges of all kinds levied in the name or for account of the government, public authorities, concessionaries or undertakings of any kind.

If a Contracting State refused entry to its port of an INF ship of another Contracting State in need of urgent repairs, one repercussion might be that the Flag State might retaliate by refusing access to its ports of ships of the Contracting State concerned, as allowed by Article 8 of the Statute, viz.,

Each of the Contracting States reserves the power, after giving notice through diplomatic channels, of suspending the benefit of equality of treatment from any vessel from a State which does not effectively apply, in any maritime port situated under its sovereignty or authority, the provisions of this Statute to the vessels of the said Contracting State, their cargoes and passengers.

Clearly, such suspension could inflict economic damage upon a Contracting State refusing entry to an INF ship, and might well deter it from such action.

On the other hand, a Contracting State refusing entry to an INF ship seeking emergency repairs may invoke Article 16 of the Statute, which allows deviation from Article 2 in the case of measures taken in case of an emergency affecting the safety of the State or the vital interests of the country, viz:

Measure of a general or particular character which a Contracting State is obliged to take in case of an emergency affecting the safety of the State or the vital interests of the country may, in exceptional cases, and for as short a period as possible, involve a deviation from the provisions of Articles 2 to 7 inclusive; it being understood that the principles of the present Statute must be observed to the utmost possible extent.

This would mean, of course, the coastal State arguing that allowing access to its port of an INF ship seeking emergency repairs would affect the vital interests of the country, for example through the risk of exposure to radioactive contamination.

Similar provisions to the Geneva Convention and Statute are included in bilateral treaties under which ships of Contracting States have liberty of access to all ports, waters and places open to international commerce and navigation in each other’s territory.

For a full understanding of the obligations of specific States one would have to ascertain the current status of the Geneva Convention and Statute and the extent to which bilateral treaties contain such provisions. This is beyond the scope of the present paper. It may be surmised, however, that treaty provision in this respect is somewhat patchy. For this reason, the development of treaty provisions, perhaps in the context of the 1974 SOLAS Convention, setting out States’ obligations in respect of the provision of port access to INF ships for emergency repairs, would remove the present ambiguity surrounding this issue. For example, giving the INF Code mandatory status under SOLAS could have made it a requirement that consultations take place between flag States and coastal States in respect of emergency arrangements along the routes followed by INF ships, covering such issues as port access for emergency repairs. It may be noted in this context that a resolution of the 1995 IMO Assembly which called for a review of the INF Code in various respects, requested that consideration be given to the “establishment of bilateral or multilateral agreements in relation to emergency preparedness and response arrangements in the event of an accident in international waters involving cargoes subject to the INF Code”. Clearly, such agreements could include provisions on port access for emergency repairs. However, until now there is no evidence of IMO having assisted in drawing up such agreements; nor was any reference to port access made in the resolution of the IMO Maritime Safety Committee in May 1999 making compliance of the INF Code mandatory under SOLAS, or in the latest text of the code adopted at that time (see Footnotes 8 and 9).

3.3. Comparison with provisions made by IMO on the use of ports by nuclear merchant ships

From the viewpoint of potential for radioactive exposure, there may be some similarities between situations pertaining to emergencies involving INF ships and nuclear merchant ships. Although no ships of the latter type presently exist, considerable work was done by IMO in the expectation that nuclear-propelled ships would be built. The technology is, in practice, limited to submarines and ice breaking ships.

Chapter VIII of SOLAS, 1974 sets out the safety requirements of nuclear ships, in which the following regulations are of interest in the present context:

“Regulation 6 — Radiation safety: The Administration of … shall take measures to ensure that there are
no unreasonable radiation or other nuclear hazards, at sea or in port, to the crew, passengers or public, or to waterways or food or water resources.

Regulation 7 — Safety assessment: (a) A safety assessment shall be prepared to permit evaluation of the nuclear power plant and safety of the ship to ensure that there are no unreasonable radiation or other hazards, at sea or in port, to the crew, passenger or public, or to the waterways or food or water resources. The Administration, when satisfied, shall approve such safety assessment which shall always be kept up to date. (b) The safety assessment shall be made available sufficiently in advance to the Contracting governments of the countries which a nuclear ship intends to visit so that they may evaluate the safety of the ship.

Regulation 11 — Special Control. In addition to the control established by regulation 19 of Chapter I, nuclear ships shall be subject to special control before entering the ports and in the ports of Contracting Governments, directed towards verifying that there is on board a valid Nuclear Ship Safety Certificate and that there are no unreasonable radiation or other hazards at sea or in port, to the crew, passengers or public, or to the waterways or food or water resources.”

That is, so far as special control is concerned the Safety Recommendations on the Use of Ports by Nuclear Merchant Ships should be followed. The Recommendation was drawn up by the joint IMO/IAEA Technical Committee on Port Entry Requirements for Nuclear Merchant Ships and covers in considerable detail the precautions which should be taken by ports, such as the designation of suitable ship anchorages, berthing, fire fighting and administrative arrangements for emergencies.

While acknowledging that a ship powered by a nuclear reactor and a ship transporting irradiated nuclear fuel are engaged in quite different activities, giving rise to hazards of a different kind, there may nevertheless be situations such as resulting from a fire on board, which require similar responses in terms of radiological protection, etc. It would therefore seem appropriate to keep in mind the work of IMO and IAEA on nuclear merchant ships when developing further the regime for INF ships, particularly in respect of access to ports and related safety precautions. The preparation of a safety assessment, as required for SOLAS for nuclear merchant ships, would seem particularly relevant to INF ships.

3.4. Deep ocean salvage scenario

Whilst it is an unlikely event, it is indisputable that every vessel has the potential for sinking. In the route between Japan and Europe, two key variables in potential deep ocean salvage would be the ocean floor topography and water depth.

Since the mid 1980s, developments in deep ocean technology have been instrumental in finding an increasing number of shipwrecks on the deep ocean floor in deliberate search plans, including rms Titanic and mv Derbyshire, both at about 4000 m depth.

The disposition of wreckage on the ocean floor will be governed by:
- loss scenarios (cause of sinking and immediate structural damage at the surface);
- structural damage and rotation incurred during the descent phase;
- impact damage on the ocean floor.

In an assessment of the sinking of mv Derbyshire (Donaldson, 1995) various loss scenarios were listed: structural failure, loss of hatch covers, flooding, cargo movement, loss of directional stability, explosion, fire, pooping, abnormal wave action, and Master’s action. A more universal list would include collision and sabotage as well. Irrespective of the loss scenario, shipwrecks on the deep ocean floor are usually considerably more damaged than those encountered on continental shelves, principally as a result of the fall distance and impact on the ocean floor, as well as the effects of hydrostatic pressure upon void spaces. Much would be dependent upon the extent of pressure compensation, i.e. extent of water ingress, before the sinking ship left the surface. Intact void spaces would be susceptible to implosion/explosion damage within 20–50 m of the surface.

Whereas PNTL has extensive response procedures in place and has incorporated various features in their ships aimed at facilitating vessel location and condition monitoring, the loss of a vessel and the eventual shape and dispersal of wreckage on the ocean floor cannot be anticipated. Taking the OBO vessel mv Derbyshire as an example, irrespective of the fact that it was a much larger vessel and of a different type from the PNTL ships, the remnants ended up in a debris field of 1.5 km² with just under 3000 pieces of disparate wreckage, including 290 pieces larger than 10 × 5 m. In this case, the wreckage fell onto oceanic ooze, 4200 m down, and most of the damage and dispersal were caused by the first two factors given above.

Whatever the route from Europe to Japan, there are regions of ocean floor which could be classed as “problematic” with respect to increased impact damage to sinking vessels. With respect to the voyage of mv Pacific Pintail in 1995, which was shadowed by the Greenpeace vessel mv Solo, the Cape Horn route is considered in greater detail below. Critical ocean floor areas in this route would be:
- Crossing the Atlantic Ridge near Lat.01°N, Long.30°W;
Scotia Arc and Drake Passage south of Cape Horn;
- East Pacific Rise in the vicinity of Lat.28°S, Long. 114°W;
- French Polynesia between Lats. 15°–25°S, Long. 140°–150°W;
- Northwest Pacific basin between the Hawaiian Islands and Japan.

These are areas where the ocean floor consists primarily of exposed volcanic rocks of very irregular topography, with minimal sediment cover. For this route, these areas cannot be avoided and have to be crossed. The hard nature of the floor greatly increases potential impact damage and wreckage dispersion. Elsewhere, much of the passage occurs over sediment-covered abyssal plains.

Whereas services like weather routing have existed for several decades, the concept of seabed routing could be considered in safety management, and for the Cape Horn route, it would involve only minor changes to the route taken. Seabed routing would consist of two aspects: identification of (1) unavoidable seabed risk areas, and (2) avoidable areas. With the expansion of bathymetric measurements of ocean floors, chart series such as general bathymetric chart of the oceans (GEBCO), published under the authority of the International Hydrographic Organisation, enable the delineation of unavoidable and avoidable areas of ocean floor. For example, in the Northwest Pacific Basin, only slight deviations from the normal route would take the passage away from ocean floor areas of exposed volcanic rock in several belts of seamounts towards more basinal or abyssal plain areas of thicker sediment cover, thereby reducing the level of potential impact damage.

Water depths in excess of 6000 m are classed as ocean deeps (Fig. 1). Ocean deeps have to be crossed whichever route from Europe to Japan is taken.

**Cape Horn route:** No major deeps in the Atlantic Ocean along this route. The track would pass well inside the Argentine Abyssal Plain (6000 m), which is located some 450 n miles NE of the Falkland Islands. Much of the South Pacific Basin is 3500–4000 m deep, but consists of a relatively flat, sediment-covered floor. However, the Northwest Pacific Basin has extensive areas deeper than 6000 m, and finally, there is the narrow Japan Trench to cross before the track reaches Japan.

**Cape of Good Hope route:** Again, there are no major deeps in the Atlantic Ocean along this route. Skirting around the tip of Africa, the track runs north of the Southwest Indian ridge, but then encounters substantial irregular, volcanic crustal floor in the Central Indian ridge and parts of the Southeast Indian, before passing over Ninety East ridge and then the deep (6000 m +) region of the Wharton Basin. If the route crossed through the smaller islands of Indonesia via the Lombok Straits or adjacent straits, the track would run across the narrow Java Trench into the Java Sea. Passing south of the Philippines, the route crosses the Philippine Trench, then deep areas of the Philippine Basin.

**Panama Canal route:** From Europe, this route would have a protracted crossing of the volcanic crustal floor of the Atlantic Ridge, then an area of deeps between the Sohm and Nares abyssal plains, southeast of Bermuda. Before encountering the Caribbean Sea, the Puerto Rico Trench is crossed. In the Pacific Ocean, much of the route runs over the relatively flat North Pacific Ocean in depths of 3500–4000 m before the extensive deeps of the Northwest Pacific Basin, and Japan Trench.

Salvage from ocean deeps is not without its problems. Determining the location of a wreck fitted with transponder equipment in the ocean deeps is not a major problem, as there are abundant sidescan sonar systems with ocean depth capability. One of the principal tools used in marine salvage is the remotely operated vehicle (ROV). However, the development of the ROV industry has followed developments in offshore oil and gas industry and its water depth requirements, which are predominantly less...
than 200 m. Liddle (1997) [13] mentions that there were less than a dozen ROV systems in the mid 1970s, increasing to about 300 in the mid-1980s and ~ 3000 in the mid-1990s.

“Hands on” contact with wreckage on the deep ocean floor could be problematic in that there are only a few ROVs with 6000 m + depth capability. Examples include the US Navy Supervisor of Salvage’s CURV III (< 6100 m) and Oceanicering Technologies’ Magellan 725 (< 7000 m) and Magellan 825 (< 8000 m). Hence, it is clear that salvage from these depths operates at present-day technological limits.

3.5. The authors’ conclusion in respect of the above described marine transportation issues

In the event that accidental damage occurs to a ship engaged in this type of transportation activity, there could well be circumstances in which the ship would seek refuge in a port to shelter or undertake emergency repairs. It is not clear that such a ship would have undisputed right of entry to a port for this purpose, and it would seem essential that emergency arrangements should include prior consultation and agreement with coastal States on ports where repairs could be undertaken without posing risks to the safety of the adjacent population. In the unlikely, though not impossible, event of sinking of a ship, it is to be expected that there would be considerable public pressure for recovery of cargo from the seabed, and some consideration should be given to the practicability of routing a ship so as to avoid the greatest depth of water, and the roughest sea-floor, so enhancing the likelihood of eventual recovery. A recovery operation at depth of greater than 6000 m would, however, be at the limits of current technology. It might be concluded from this paper that Governments, through the International Maritime Organisation, should continue to seek agreement on such matters as prior consultation on the routes taken by such ships, on passage planning and on emergency arrangements including access to ports for emergency repair. The technical feasibility of recovering flasks from the sea-floor, including simulated exercises and operational trails, should be more fully considered.

References