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UNITED KINGDOM EXPERIENCE IN PLUTONIUM TRANSPORTATION

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UNITED KINGDOM EXPERIENCE IN PLUTONIUM TRANSPORTATION

by UK Delegation

1 INTRODUCTION

British Nuclear Fuels Limited and the United Kingdom Atomic Energy Authority have been transporting plutonium to and from sites within the United Kingdom for 20 years and to destinations overseas since the early 1960s. Small quantities of this plutonium have been used for thermal reactor experiments but most of it has been for fast reactor research and development. In the United Kingdom, for example, considerable quantities of plutonium fuel have been transported overseas as a result of sales, for international projects and return to customers as the product from a reprocessing contract.

2 FORMS OF PLUTONIUM TRANSPORTED

2.1 Most plutonium has been transported as PuO_2 since this is the normal product of the reprocessing plant and is in convenient form for re-use.

2.2 Small quantities of plutonium nitrate have been transported.

2.3 Mixed oxide (MOX) has been transported for use in plutonium fuels. This form will probably be of more importance in the future because of possible requirements to increase the degree of physical protection.

2.4 Plutonium has been transported as fuel for both thermal and fast reactors.

2.5 There have been requirements to transport a multiplicity of plutonium-containing materials for research and development, and for recovery.

2.6 The transport of irradiated fuel elements is dealt with in a separate paper presented to INFCE Group 6 (Task 2).

3 REGULATIONS

3.1 There are UK and International regulations for all modes of transport: these are listed in Appendix 1. In general they are all based on the IAEA "Regulations for the Safe Transport of Radioactive Materials" (1967 and 1973 editions).

3.2 All these regulations are designed to protect the transport workers and the general public in both normal situations and accidents. This protection is achieved by the use of specially designed containers which can be safely transported around the world without further precautions other than for physical protection.

3.3 Stringent standards are applied to the design and use of these containers. All containers have to survive a series of tests which are designed to produce damage to the container equivalent to that which would be produced in a severe accident. These tests include the following:-

i. a 9 metre drop onto an unyielding target in the most damaging attitude

ii. a 1 metre drop onto a metal bar 15 cm diameter and at least 20 cm long

iii. a fire test of $800^{o}C$ for 30 minutes followed by natural cooling for 3 hours

iv. an external pressure test by immersion in 15 metres of water for 8 hours or water at a pressure of 1.5 kg/cm^2 (gauge).

The fire test has to be carried out after the two drop tests on the same container. Because of the unyielding nature of the target the G forces on the container in the drop tests are very high; a deceleration of 720 G was calculated in one test. Experience with fire tests has shown that the outside of the wood shielding chars very slowly and the build-up of gases of combustion reduces further charring.

Experience of testing such containers has shown that most of them have considerable safety margins over and above the requirements of the regulations (see also section 4.3). In 20 years there is no known incident of a plutonium container being damaged in a transport accident.

3.4 For fissile materials like plutonium a criticality safety assessment has to be submitted. Calculations or experiments are carried out on each design of container to show that under normal or accident conditions there is no possibility of a container becoming critical. The calculations also cover the "allowable number" of containers which can be carried in one consignment. The assessment considers full water reflection, eg if the container fell into a river and the container leaked. The criticality assessment will state the maximum plutonium content of the container and the form of the plutonium and may indicate a maximum hydrogen or hydrogenous material content.

3.5 Insurance

United Kingdom law requires insurance cover of third party liability which is dealt with in section 4 below.

3.6 Government Requirements for Plutonium Export

All plutonium shipments from the United Kingdom to other countries are subject to strict controls, and before an export licence is granted the Government has to be assured that all the appropriate obligations have been satisfied. The requirements include -

(1) An Inter-Governmental agreement for co-operation in the Peaceful Uses of Atomic Energy between the UK and the Government of the receiving country, and in addition clearance from countries through which the plutonium will be transported.

(2) An agreement between the IAEA and the receiving country specifying agreed Safeguards procedures, the acceptance by the IAEA that the material can be safeguarded by them, and where required assurances on physical protection.

(3) All commitments under the Euratom Treaty.

(4) All criteria laid down in Nuclear Suppliers' Guidelines for the export of Nuclear Material Infcirc/254 February 1978.

(5) US Government approval of the transfer (MB10) where material of US origin is involved and prior consent is required.

4 INSURANCE

4.1 The transport of plutonium from the UK to destinations overseas is a commercial operation normally requiring the following three main categories of insurance cover -

(1) Loss of or damage to the plutonium and its containers

(2) Compensation for costs of search and recovery

(3) Third Party Liability for Nuclear Risks, ie injury to persons or damage to property resulting from the radioactive properties or a combination of those and any toxic, explosive or other hazardous properties of the plutonium.

These are dealt with in turn below. Injury or damage as defined in (3) above is for convenience referred to as "damage".

Insurance is effected subject to the warranty that consignments are packed in accordance with the applicable national and/or international regulations.

4.2 Loss and Damage Insurance

This is effected under an "Open Cover" insurance policy for Marine, Air and War Risks. The particulars of each consignment, including its insurable value, are declared to the insurers before transport begins.

4.3 Compensation for Costs of Search and Recovery

Cover may be effected under the "Open Cover" policy, upon payment of a supplementary premium, for up to £5m for or towards the cost of search and recovery of material lost in transit.

4.4 Third Party Liability for Nuclear Risks

The UK is a contracting party to the Paris Convention on Third Party Liability in the Field of Nuclear Energy 1960 ("the Paris Convention") and the supplementary Convention of 1963 ("the Brussels Convention"). States which have ratified these Conventions are listed in Appendix 2.

4.4.1 Damage in Convention Countries

The Paris Convention, applied in the UK by Act of Parliament, introduced in Convention Countries (ie those which have ratified the Paris Convention) a system of sole and absolute but limited third party liability on the operator of a nuclear installation in respect of material leaving his installation or being brought to it from outside the Convention Countries with his written agreement. Except in certain limited circumstances involving the loss of the material, that liability ends, when carriage is to a Convention Country, normally when the material enters the consignee's installation, or, when carriage is to a non-Convention Country, on entry to that country.

The Paris Convention applies only to damage suffered in Convention Countries. As it is applied by the UK, the operator's liability is limited to the first £5m of damage suffered following an occurrence, and each operator is required to provide financial security for that amount. This requires UK Government approval and is usually arranged by way of commercial insurance under an "Open Cover" policy. The carrier must be provided with a certificate giving details of how the cover is provided for the consignments he is carrying.

Damages in excess of the operator's liability of £5m is covered by the UK Government from its own funds to an extent determined by the existing legislation or by Parliament and contributions from other contracted Brussels Convention States.

4.4.2 Damage in non-Convention Countries

Cover for damage suffered in a non-Convention Country is provided by commercial insurance under the "Open Cover" policy referred to above for the first £5m and by State-backed indemnity in respect of the excess.

5 CONTAINER DESIGN

5.1 In order that radioactive materials can be transported by the conventional means of transport it is a fundamental concept of the regulations that safety is built into the design of the container and thus is the responsibility of the consignor and

5.2 The principal factors to be borne in mind in designing plutonium containers are to prevent criticality and to maintain the mechanical integrity and fire resistance of the container in a severe transport accident.

5.3 The standard plutonium container consists essentially of a metal bottle sealed inside a plastic bag and then sealed in a metal can. Several sealed metal cans are then placed inside a wooden box lined with cadmium, and externally covered in steel. The box is made of specified hard woods which slow down incoming neutrons which are then absorbed by the cadmium. This prevents interaction (from a criticality viewpoint) between containers. The hard wood also provides excellent fire resistance. It chars very slowly and the charred carbon then acts as an insulator. The wood also provides good impact resistance, as it is one of the best energy absorbing materials known. As proof of the success of the design a container of this type was dropped 2000 ft (610 metres) onto a massive concrete target and the container still retained its integrity. From this height this container had reached its maximum velocity of nearly 200 mph (322 Km/hr), that is to say if it had been dropped from 50,000 ft the velocity on hitting the ground would be the same. The forces on the container at impact in this test were of the order of 2000-3000 G.

6 MODE OF TRANSPORT

6.1 Comparisons have been made between the safety of the various modes of transport; air accidents are more severe than surface accidents but are less frequent. Therefore, in transporting by air the critical factor is the resistance of the container to impact. Generally it was concluded that there is little to choose between modes of transport on safety grounds. The cost of different modes of transport is also not markedly different. From the point of view of physical protection it is difficult to generalise; however, the shorter time the material is in transit, the lower the risk. Therefore for long journeys at least, air transport is considered to be advisable.

6.2 It has been the practice in the past to deliver to a customer's site. However, with the increased emphasis on physical protection it is difficult to transport in another country where

where the detailed requirements of their governments may not be known. It is, therefore, preferred to deliver to the port or airport of entry in the customer's country.

7 VOLUME OF TRAFFIC

UK domestic (inter-site) shipments are over distances of 300-500 Km per movement and during the last 8 years there have been about 250 such movements into and out of Windscale, comprising 5000 kg Pu in various forms, including some 120 fuel assemblies for the prototype fast reactor at Dounreay.

Over the same period there have been about 50 overseas shipments, 30 of which were to destinations in Europe over distances of 800-1600 Km and 20 were movements over distances up to 10,000 Km (eg US, Canada, Japan). These shipments totalled some 2000 kg Pu.

8 PHYSICAL PROTECTION

Transport movements meet the recommended standards published by the International Atomic Energy Agency in Infcirc/225 "The Physical Protection of Nuclear Material".

Although the responsibility for the physical protection of nuclear materials within a State rests entirely with that State, international co-operation becomes necessary when such materials are transported across national frontiers. The Nuclear Suppliers' Group have agreed levels of physical protection to be ensured by competent national authorities in the use, storage and transportation of nuclear materials, and these are set out in Annex B of Infcirc/254 February 1978.

9 SAFETY ANALYSIS

Studies have been carried out on the effects on the environment if plutonium is released from a container in a severe accident. It is thought necessary to consider this eventuality even though a mechanism for release of plutonium from a container may not be conceivable. The studies first calculate the frequency of such an accident from available general accident statistics. These statistics will give a pessimistic figure as they are derived from all types of traffic, whereas plutonium is transported under closely supervised conditions and considerable care is taken both on the maintenance of the vehicles and the driving of them. A population distribution for the journey is worked out and assumptions made on weather conditions on the journey. The risk to the population from the release of plutonium can then be evaluated in terms of possible premature fatalities from cancer caused by the inhalation of plutonium. (It is emphasized that in the event of an accident releasing plutonium there would be no immediate fatalities, but cancers could develop 15 to 30 years later.) Generally this risk has been found to be very small, smaller than the risks from most other natural or man-made hazards. US work gave a figure of 7.4×10^{-8} premature fatalities per year from the transport of all radioactive materials. That is to say the risk to the individual is that 1 person in 10^{15} would die early from cancer (in a population of 75 million people) or that one person would die early every 13 million years. A UK study for a particular series of movements of plutonium found that the risk to an individual on the route was less than 3×10^{-8}/yr, a rate compatible with the USA one. Both these risks are much less than the risk from the nuclear reactors themselves (3×10^{-3}/yr from 100 reactors or 1 in 5,000 million). From most natural hazards the risk is greater; for example, there are on average about 5 deaths from lightning in the UK per year or a risk of 1 in 10 million.

10 COSTS

Costs of transport include the cost of design and manufacture of containers and packing, freight, insurance, nuclear indemnity, escorts and other physical protection requirements. These are small in relation to the costs of the rest of the nuclear fuel cycle.

For example, the cost of transport of one consignment of PuO_2 from the UK to Europe would be of the order of £10,000 in present-day costs. This cost is largely independent of quantity, ie it costs nearly as much to transport a small quantity of plutonium as a large one. The costs are mainly governed by the amount of physical protection required.

11 CONCLUSION

The foregoing details the extensive experience of BNFL and its predecessor in the transport of plutonium in various forms. A large number of movements to a wide range of destinations have been carried out over 20 years without any accidents.

The studies examined in the safety analysis (para 9) show that the risks associated with this traffic are very much less than those normally considered acceptable for the transportation of other materials, for example, compressed gases, organic and petro-chemicals. If the conclusions from these studies were more widely appreciated by the general public many of their fears would be alleviated.

This accident-free record together with the additional physical security procedures recently introduced suggest that this traffic could be expanded in the future without danger to the community or the environment. However, further investigations into possible steps to increase the safety and security of type of transport are being continued and will be examined under Task 5.

REGULATIONS AND CODES OF PRACTICE GOVERNING THE TRANSPORT OF RADIOACTIVE MATERIAL

INTERNATIONAL

International Atomic Energy Agency (IAEA) Safety Series No 6 Regulations for the Safe Transport of Radioactive Materials 1973 Edition.

Intergovernmental Maritime Consultative Organisation (IMCO) International Maritime Dangerous Goods Code Class 7 Radioactive Substances.

International Air Transport Association (IATA) Restricted Articles Regulations.

ROAD

Great Britain only. The Radioactive Substances (Carriage by Road) (Great Britain) Regulations 1974. SI No 1735: The Radioactive Substances (Road Transport Workers) (Great Britain) Regulations 1970. SI No 1827: The Radioactive Substances (Road Transport Workers) (Great Britain) (Amendment) Regulations 1975. SI No 1522: Code of Practice for the Carriage of Radioactive Materials by Road (1975 Edition) and the Code of Practice for the Storage of Radioactive Material in Transit (1975 Edition).

Europe only. European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR), Class 7.

RAIL

Great Britain only. British Rail publication BR 22426 (1977 Edition) Dangerous Goods by Freight Train and by Passenger Train or similar service - List of Dangerous Goods and Conditions of Acceptance - Class 7 Radioactive Substances.

Europe only. International Convention concerning the carriage of goods by rail (CIM). Annex I, International Regulations concerning the carriage of dangerous goods by rail (RID).

SEA

British ships registered in UK and other ships loading in UK ports or territorial waters only. The Merchant Shipping (Dangerous Goods) Rules 1965. SI No 1067: The Merchant Shipping (Dangerous Goods) (Amendment) Rules 1968. SI No 332: The Merchant Shipping (Dangerous Goods) (Amendment) Rules 1972. SI No 666 and the Report of the Standing Advisory Committee on the Carriage of Dangerous Goods in Ships 1966. (The "Blue Book") Class 7.

PORT

UK only. Code of Practice for the Carriage of Radioactive Materials through Ports - 1975 Edition.

AIR

UK only. The Air Navigation Order 1976. SI No 1783 and International Air Transport Association (IATA) Restricted Articles Regulations - Class 7 Radioactive Substances.

ACCESSIONS AND RATIFICATIONS TO THE PARIS CONVENTION ON THIRD PARTY LIABILITY IN THE FIELD OF NUCLEAR ENERGY

Turkey		10 October 1961
Spain		30 October 1961
United Kingdom		23 February 1966
France		9 March 1966
Belgium		3 August 1966
Sweden		1 April 1968
Greece		12 May 1970
Finland (accession)		16 June 1972
Norway		2 July 1973
Denmark		4 September 1974
Italy		17 September 1975
Federal Republic of Germany		30 September 1975
Portugal	(deposit)	29 September 1977

ACCESSIONS AND RATIFICATIONS TO THE ADDITIONAL PROTOCOL TO THE PARIS CONVENTION

Spain		30 April 1965
United Kingdom		23 February 1966
France		9 March 1966
Belgium		3 August 1966
Sweden		1 April 1968
Turkey		5 April 1968
Greece		12 May 1970
Finland (accession)		16 June 1972
Norway		2 July 1973
Denmark		4 September 1974
Italy		17 September 1975
Federal Republic of Germany		30 September 1975
Portugal	(deposit)	29 September 1977

ACCESSION AND RATIFICATIONS TO THE BRUSSELS SUPPLEMENTARY CONVENTION AND ITS ADDITIONAL PROTOCOL

United Kingdom	24 March 1966
France	30 March 1966
Spain	27 July 1966
Sweden	3 April 1968
Norway	7 July 1973
Denmark	4 September 1974
Federal Republic of Germany	1 October 1975
Italy	3 February 1976
Finland (accession)	14 January 1977