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TECHNOLOGICAL ALTERNATIVES FOR PLUTONIUM TRANSPORT

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TECHNOLOGICAL ALTERNATIVES FOR PLUTONIUM TRANSPORT - TASK 5

A Discussion Paper submitted by the UK Co-Chairman

1 INTRODUCTION

The previous paper on plutonium transport (INFCE/WG.4/43(B)) described the United Kingdom experience in transporting plutonium in different forms over 20 years and concluded that this experience suggested that this traffic could be safely continued. The CEC paper (INFCE/WG.4/41(B)) dealt with the environmental impact of plutonium transport within the European Community. However, under Task 5 Working Group 4B was asked to investigate possible alternative technologies which might be introduced in the future and this paper discusses the alternatives which may be envisaged and evaluates the impact factors as set out in Chapter VII of the provisional format of the Final Report.

(a) Proliferation resistance and safeguards

(b) Environmental and safety aspects

(c) Economic aspects.

Following the TCC guidance and considering which points in the fuel cycle can be particularly sensitive, it appears that vehicles transporting plutonium might be more vulnerable to sub-national threats than fixed facilities. For this reason the principles of improved physical protection measures which might be introduced in the future have been included in the scope of this paper even though national physical protection measures are outside the terms of reference of INFCE (INFCE/TCC/2/6 paragraph 11).

The paper considers transport of plutonium from a reprocessing centre to a store or a fuel fabrication facility and MOX fuel from the latter to a reactor. In the absence of written contributions from other participants the contents are based largely on United Kingdom experience together with our current thinking on future developments, and also include material drawn from US reports, particularly NUREG 0414 ES presented to INFCE as Co-Chairmen/WG.4/44(A,B).

It is presented as a discussion paper to the participants of WG.4B so that their contributions and comments can be incorporated in the first drafts of the transport section of Chapter VII of the Final Report.

2 ALTERNATIVE MODES OF TRANSPORT

The alternatives considered have been limited to conventional methods. The current thinking is that plutonium transport will be carried out as follows.

(i) Air - by dedicated charter aircraft

(ii) Sea - by large container ships

(iii) Road - by special security vehicles

(iv) Rail - by special dedicated trains.

The assumptions have been made that full international safeguards measures are in operation, all movements by any mode would be escorted, monitored by radio or by an automatic surveillance system, and arrangements exist for a speedy response by the contingency force.

(a) Proliferation Resistance and Safeguards

International safeguards procedures are generally the same for each method of transport. They include inspection and checking of the contents before shipment and after receipt, as well as prior notification for each transfer to the safeguards authorities.

The resistance to sub-national threats of the various modes of transport depends mainly on the ease of interception and time for the load to be removed compared with the response time for support forces. Judging the proliferation resistance of each mode by these criteria -

(i) Air Transport

Once an aircraft is in the air it cannot readily be diverted unless the crew have been subverted, and the small number of crew gives rise to less problems from the point of view of security clearance. Air transport is the most rapid so that the time the material is at risk outside a secure site is at a minimum. Thus, air transport could prove to be the most resistant mode particularly for longer journeys.

(ii) Sea Transport

Considerable resources in the way of ships, aircraft and manpower would be needed by a sub-national group attempting diversion of a fast container ship, but with a larger crew it is somewhat more vulnerable to subversion than air transport. However, if protection by radiation necessitates the use of heavy shielded containers sea transport could prove to have advantages for long journeys.

(iii) Road Transport

With specially designed containers, secure penetration-resistant transport vehicles capable of immobilisation, a good communication system and escorts, road transport can be regarded as secure for short to medium distance journeys in reasonably populated areas like Western Europe. The material is outside the security site for a longer time but external reinforcements can be made quickly available.

(iv) Rail Transport

This also is suitable for medium distance journeys but being less flexible than road transport is marginally more open to diversion. If protection by radiation requires the use of heavy shielded containers rail transport could prove to have advantages for carrying these weights at speed.

(b) Environmental and Safety Aspects

The environmental aspects of plutonium transport have been studied in many countries and were mentioned in the base case papers by the UK and the CEC. The general conclusion has been that the effects on the environment would be small. In support of this GESMO NUREG 0002, 1.3.1.5 concluded that, "The plutonium oxide containers are doubly sealed and the special vehicle to be used for plutonium oxide transportation is designed to withstand unusual efforts of penetration. Thus the probability that there would be any release of radioactive material from a plutonium oxide shipment following any credible accident is not considered significant". However, the relative consequences of an accident for each mode of transport are considered below.

(i) Air accidents are likely to be more severe but less frequent than accidents on land or sea. However, as stated in INFCE/WG.4/43(B) - United Kingdom Experience in Plutonium Transportation - the containers at present used by UK transporters are tested to withstand the ground impact which would result from a mid-air accident. Further designs of containers are now being considered and these will incorporate improvements including - increased ease of handling, remote loading and unloading, the capacity to dissipate additional heat arising from increased fuel irradiation targets, and the ability to transport mixed oxide if required. With these containers and the additional protection of the reinforced freight containers in which they will be carried it is highly improbable that there could be a significant release of plutonium.

(ii) In the case of accidents at sea, which may be more frequent, the consequences of a release to that environment are likely to be less. Here also the reinforced freight containers will be designed to resist penetration; and offer considerable additional protection in an accident. The problems of recovery in the unlikely event of a container being lost at sea are at present being investigated.

(iii) For road and rail the transport vehicles and plutonium containers are expected to withstand the consequences of the most severe accident.

(c) Economic Aspects

In general for the transport of large quantities of plutonium (100 kgs or more) there is not a wide difference between the cost of different modes of transport. For the conventional methods considered the cost would be from $15,000 to $20,000 per movement. The resources for conventional modes of transport are already available. Although the recent requirements for physical protection both for equipment and manpower have made the transport of plutonium very much more expensive, the costs are still small, being quoted as of the order of 2% of the irradiated fuel transport costs (NUREG 0002 Vol 4) and therefore the contribution to the total fuel cycle costs is very small.

3 ALTERNATIVE FORMS IN WHICH PLUTONIUM CAN BE TRANSPORTED

Consideration is being given to the form in which plutonium should be transported in order to afford increased resistance to diversion. There will be a continuing need for the transport of small amounts of plutonium between sites and countries in whatever form is essential for particular R & D purposes. Consideration will need to be given to an appropriate ceiling for these shipments. However, in practice they will probably be infrequent because of the high costs associated with individual shipments.

The following alternative forms are those generally being discussed but this method of protection is mainly significant against sub-national threats as in any national action aimed at diversion it is probable that separation facilities would be readily available.

I Plutonium oxide

II Plutonium oxide mixed with uranium oxide

III MOX fuel

IV Protected by radiation.

(a) Proliferation Resistance and Safeguards

I Plutonium Oxide

The normal starting point for the manufacture of high performance nuclear explosives is plutonium metal and this will be the basis of comparison for other forms of the material. To produce metal from plutonium oxide requires a number of chemical processing steps and thus there is a gain in proliferation resistance by the transport of the oxide.

II Mixed Oxide

Lower plutonium content materials are likely to be more secure because they increase the weight of material to be diverted to make a weapon, introduce a further chemical separation step in the bomb-making process, and require the acquisition of separation equipment. If it is feasible to co-locate the fuel fabrication plant with the reprocessing plant the transport of mixed oxide as well as plutonium oxide can be avoided and the problem limited to that of finished fuel transport.

III <u>MOX Fuel</u>

Fuel is marginally more diversion resistant than mixed oxide. The additional steps to bomb-making are somewhat more difficult to achieve than in the case of mixed oxide.

IV <u>Protected by Radiation</u>

This could be accomplished by

(i) Insertion of a gamma source in the transport container

(ii) Spiking the plutonium during manufacture with a gamma emitter, eg cobalt 60

(iii) Pre-irradiating the plutonium fuel.

A source in the plutonium container could be removed by the terrorist by the same method with which it was installed, but it would entail him acquiring remote handling equipment and techniques.

Similarly, gamma emitters as in (ii) would entail a difficult reprocessing operation under shielded conditions to remove them before making a nuclear weapon. In the context of national proliferation it would add to the timescale and resources needed and in the case of a sub-national threat would provide a significant additional barrier to a terrorist. However, there is difficulty in ensuring that the activity present will not separate out during final processing operations and therefore the resulting dose might not be sufficient to provide the full protection required. This type of proposal has so far only consisted of early studies without the backing of full-scale developments.

Pre-irradiation of the fuel would require co-location of the reprocessing plant, the fuel fabrication plant and complex irradiation facilities and when all factors are considered this does not appear to be a practicable solution.

(b) Environmental and Safety Aspects

There are no significant differences in the safety of transport of PuO_2, MOX or MOX fuel but marginal improvements are offered by sintered material. The addition of gamma emitters by the methods discussed in the previous paragraph would increase the risk of radiation doses to the employees involved in fuelling, transporting and emptying containers as well as those at the fuel fabrication plant and the reactor loading. It could also affect many plutonium monitoring instruments, thus complicating both safety and safeguards measurements.

(c) Economic Aspects

Transport as mixed oxide involves shipping more material than with plutonium oxide but new containers specifically designed for mixed oxide could reduce the proportional increase in cost.

There could be economic advantages in transporting the mixed oxide at the specification required by the fabricator, thus reducing the requirements for further blending operations.

Transport as fabricated fuel marginally increases the degree of protection but this would require co-location of the reprocessing plant and the fuel fabrication plant and would raise many technical and commercial problems, eg the multiplicity of designs and changing requirements of a large number of customers, the access to the detailed design know-how and the financial implications of guarantees of fuel performance in the reactor.

Shipment with gamma emitters present would require heavy shielded containers similar to those needed for irradiated fuel (80+ tons). This would greatly increase the cost and virtually rule out air transport. In addition, if the gamma irradiation is provided by spiking, the necessary additions and alterations to reprocessing plants and reactors would involve very high costs. In the case of fabrication plants the technology of remote handling and maintenance is not yet available and when developed would add considerably to the cost of the fuel.

4 IMPROVED PHYSICAL PROTECTION MEASURES

By the nature of the material the transport of plutonium is a sensitive operation and heavy reliance must be placed on physical protection in order to reduce the risk of diversion.

Factors should be built into the overall system to extend the time between the mounting of a diversionary attack and the conversion of the material to a weapon. The material therefore should be in a form not directly usable in an explosive device in order that the chances of recovery are maximised. Delays may be achieved by modifying the chemical form or providing protection by radiation. Even when this has been done further protection must be given by the transport container or vehicle. Ideally, the vehicle must be capable of total immobilisation and the container able to resist penetration until contingency forces arrive. In all cases there should be communication systems which can indicate that the transport is under attack and give its precise position at all times.

The third element of protection will be provided by escort. The material, in addition to being transported in a penetration-resistant container vehicle, must travel under escort. The function of the escort should primarily be to provide communications for the nuclear convoy to ensure that the movement is tracked throughout and in an attack situation ensure that this fact is communicated to a point from where rapid assistance can be afforded. Whilst the escort will act as a deterrent it is essential that the overall system provides back-up services to ensure prompt response in the emergency.

Developments in physical protection, particularly in the construction of the transport vehicle and container and in communication between base and escort, should be kept under review with the objective of continued improvement.

5 INSTITUTIONAL ASPECTS

All movements of safeguarded plutonium are subject to strict controls and fall into two main categories.

5.1 National movements within States when all safeguarded plutonium is subject to national controls, international safeguards and the relevant safety procedures laid down by individual governments.

5.2 International movements: before any plutonium can be exported to another country the several authorities concerned have to be satisfied that the following requirements have been met.

(i) An inter-governmental agreement for co-operation in the peaceful uses of atomic energy is in force between the two countries.

(ii) An agreement exists between the IAEA and the receiving country satisfying agreed international safeguards procedures including sealing and inspection in each country and the acceptance by the IAEA that the plutonium can be safeguarded by them in the receiving facility.

(iii) All criteria laid down in Nuclear Suppliers' Guidelines for the export of nuclear material (INFCIRC/254 February 1978).

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

5.3 In addition to the above requirements the IAEA is considering the establishment of an International Convention on the physical protection of nuclear material which would cover transport regulations between national boundaries.

6 SUMMARY AND RECOMMENDATIONS

From the limited discussions within INFCE and the experience to date the following recommendations appear to be emerging.

(i) Based on present experience, the transport of plutonium could continue by air or sea where long distances are involved, and by road and rail over shorter distances. These methods of transport would appear to be acceptable from the non-proliferation, environmental impact and economic aspects.

(ii) Development should continue to increase the protection against diversion offered by the vehicle and container.

(iii) In order to strengthen the protection over long distances, developments on improved communication systems and shortened response time should continue.

(iv) It is hoped that the IAEA proposals for an International Convention on the physical protection of nuclear materials will improve the control of movements between national boundaries.

(v) There appear to be advantages in protection if plutonium is transported in the form of mixed oxide.

(vi) The degree of protection increases marginally with the extent to which the MOX approaches the form of finished fuel.

(vii) The transport of MOX fuel from a fabrication plant to a reactor would not involve additional problems from the non-proliferation or other aspects, but to limit the transport of plutonium to this form would present technical and commercial problems.

(viii) Protection of material by radiation has been proposed but details of these processes have not yet been fully developed, nor are the technologies available. The use of these methods would appear to entail increased risk of exposure to radiation by operators and incur heavy cost penalties. There is also difficulty in ensuring that the activity present will be sufficient to deliver the incapacitating dose necessary.