R -v- MARTIN GRANT FORWOOD

STATEMENT

BY

JOHN H LARGE

LARGE & ASSOCIATES

CLIENT: GEOFFREY CLAPP, SOLICITOR

REPORT REF NO R3104-A1.DOC

REVISION Nº	APPROVED	1ST ISSUE	PRESENT ISSUE
R2		30 August 2003	28 JULY 2013

Large & Associates , London

The Gatehouse 1-2 Repository Road Ha Ha Rd Woolwich London SE18 4BQ ☎ 44[0]181 316 4236 – 317 2860 fax 44[0]181 317 2859

R -V- MARTIN GRANT FORWOOD

Here I summarise my statement:

- I am a qualified and experienced Consulting Engineer able to provide a statement and opinion on this matter.
- In a professional and business capacity I have had past communication and contact with Mr Forwood – through these dealings, I find him to be of honest and forthright character.
- In setting down evidence I have assumed that Mr Forwood's alleged actions were prompted by his concerns over specific activities relating to BNFL operations at Sellafield, these being the:
  a) risks and hazards arising from the transportation of spent nuclear fuel
  b) environmental and health impacts from reprocessing spent nuclear fuel
  c) safe and secure management of the radioactive wastes and materials generated by reprocessing spent nuclear fuel

I have made these assumptions so that I might channel my expert evidence to specific issues of what is a very complex and technological industry. Moreover, since Mr Forwood's alleged action of 15 April, 2003 were specifically directed at the transportation of spent fuel, I have concentrated on this aspect of Mr Forwood's broader concerns.

My findings are that:

- Irradiated or spent nuclear fuel is very hazardous because it is intensely radioactive and, as I would term it, extremely radiotoxic.
- Like in any human endeavour, the risks involved in the transportation of spent nuclear fuel cannot be entirely eliminated
- Whereas the risk and severity of <u>accidents</u> (but not all accidental situations) might be projected *a priori*, but for terrorist acts, a very real threat following events of 11 September 2001, the intentions are determined by complex behavioural factors that are not amenable to the risk assessment techniques and rationale developed and practised by the nuclear industry – in other words, the risk of terrorist act cannot be reliably forecast.
- If the transport flask was severely damaged, either by accident or by terrorist attack, then the ensuing release of radioactive fuel particles and gases could result in significant environmental contamination and health harm, in the short, interim and longer terms.
- Depending of the circumstances of the incident, particularly the flask location, its relative proximity to urban population, the prevailing meteorological conditions, etc., then the health harm could include fatalities in the short, interim and longer terms – I have given examples of the probabilities and numbers of casualties (fatalities) that might occur in the aftermath of a radioactive release from a spent fuel flask.
- Whereas for its transportation safety case, the nuclear industry relies to a great extent on the design of the flask being sufficient for it not to rupture during all reasonably foreseeable accidents, there seems to be no account (in both the flask design, the management and protocols adopted for the transport itself and the nuclear industry's own emergency response plan) of the utterly ruthless type of international terrorist act characterised by the events of 11 September 2001 – so far as I can ascertain, the nuclear industry has done little to implement a meaningful defence against such acts of terrorism.

In this regard, I can understand and, to some extent, share Mr Forwood's concern over the safety of the transportation of spent nuclear fuel to the BNFL plant at Sellafield. Since the transportation of spent nuclear fuel involves risk, Mr Forwood's actions if intended to stop the transportation would, if successful, have removed that element of risk to the public.

I also briefly reviewed other aspects of Mr Forwood's concerns, on these:

- Because of the intentional delays in moving the fuel from the nuclear power stations to BNFL Sellafield, typically twenty of more years, halting such shipments would have no safety implications because the nuclear power stations themselves have adequate long-term spent fuel storage facilities.
- Mr Forwood's actions to halt the transport from Barrow for a few hours, that is by his interference with a section of the track that was remote from the flasks held at Barrow docks, would have no nuclear safety implications for the spent fuel within the flasks.
- There is no certainty, particularly in light of BNFL's ailing economic performance of late, that the Garigliano fuel (the subject of Mr Forwood's alleged actions) will ever be processed by BNFL. However, the general nature of the BNFL fuel reprocessing contracts suggests that the fuel may be 'hypothetically' reprocessed and an equivalent amount of radioactive waste returned to Italy under the terms of the contract – if so, risks associated with handling, transporting and storing the fuel at Sellafield, and the risks of returning the equivalent radioactive wastes to Italy, would have been entirely unnecessary and thus additional risks placed upon local and regional communities, in the United Kingdom and abroad.
- At this time the regulatory body authorising the discharges of radioactivity from BNFL's reprocessing operations seems to be satisfied that the risk of health harm to the British public is acceptably low when economic and social factors (benefits) are taken into account – the regulator's reasoning is that the benefits outweigh the detriments. This composite may or may not apply to the British public as a whole, but continuing radioactive discharges from Sellafield must disproportionately apply to communities local to Sellafield who will, by virtue of their close proximity, receive higher radiation exposures and hence carry greater risk of health harm, particularly in the longer term.
- Those communities abroad, who also receive radiation exposure from the discharges at Sellafield, particularly the Republic of Ireland and Norway (via the radioactively contaminated marine environment), receive no benefit from the operation of Sellafield so, to their disadvantage, the regulatory composite of *detriment -v- benefit* cannot apply.
- BNFL Sellafield continues to reprocess spent nuclear fuel on the absence of a UK national radioactive waste management strategy – at this time all radioactive wastes processes and packaging is being undertaken without knowledge of how these diverse waste streams are to be stored and/or disposed of in the interim and longer terms. I consider the continuing operation of Sellafield and the generation of diverse wastes streams in the absence of how these are to be managed in the future to be unsustainable and entirely converse to HM Government's commitment to the principle of Sustainable Development which it committed to at the Rio de Janeiro and subsequent Earth Summits.

Now I give my statement in the main:

R -V- MARTIN GRANT FORWOOD

1 QUALIFICATIONS AND EXPERIENCE

1.1 I am a Consulting Engineer, a Chartered Engineer, Fellow of the Institution of Mechanical Engineers, Graduate Member of the Institution Civil Engineers, Member of the British Nuclear Society and a Fellow of the Royal Society of Arts.

1.2 From the mid-1960s through to the late-1980s I was a full-time member of the academic staff of Brunel University, throughout which I undertook research for the United Kingdom Atomic Energy (UKAEA) on nuclear reactor systems and other nuclear devices.

1.3 Since 1986 I have headed the firm of Consulting Engineers, Large & Associates. In this capacity and relating to civil and military nuclear technology I have given evidence to the House of Commons Environment and Energy Committees, and at several Public Inquiries in the United Kingdom. In much the same military-nuclear topics, I have also advised a number of overseas governments, including Japan, Italy, South Africa, Bulgaria and the Russian Federation, and state and county authorities in Australia, New Zealand and the United States.

1.4 Recent work undertaken in the nuclear area includes advising the Government of Gibraltar throughout 2000 on the repairs to *HMS Tireless*, a nuclear powered submarine that emergency berthed at Gibraltar for repairs to its reactor plant. Throughout much of 2001, I formed and headed a team of UK experts advising the Russian Federation Government and the salvers Mammoet-Smit of the hazards and risks associated with the nuclear reactor plant and weapons on board the sunken nuclear powered submarine *Kursk* during the preparation and salvage operations – I was awarded a commemorative medal by the Russian Federation Government for my contribution to the successful salvage of the *Kursk*.

1.5 Specifically relating to this matter, I have advised a number of UK local authorities (Greater Manchester, the GLC, Kent County Council and others) on the risks and hazards of the transportation of irradiated or spent nuclear fuel; I acted as the retained consultant to the Fire Brigades Union (FBU) from the mid 1980s through to the mid-1990s, advising the Union on radiological matters during which I attended as an invited observer on behalf of the FBU a number of irradiated fuel rail transportation accident exercises, including an exercise at Millom; and I have prepared and given evidence to the New Zealand Parliamentary Foreign Affairs Committee on the sea movement of unirradiated (fresh) MOX fuel en route to Japan via the Tasman Sea. My most recent involvement in this area was that I attended the International Atomic Energy Conference on the transportation of nuclear materials in Vienna in July 2003 as an invited observer and Rapporteur on behalf of Greenpeace International.

1.6 I consider myself adequately qualified and experienced to provide a statement and to give opinion on this matter.

2 INSTRUCTIONS

2.1 I received instructions by letter of 4 August, 2003 from Geoffrey Clapp, Solicitor.

2.2 Essentially, Mr Clapp ask me to prepare a comprehensive statement on a number of issues so that the Defence might be informed when dealing with Mr Forwood's line of defence *'that he was attempting to protect the public and, given the nature of the material, he did what he could do in the circumstances'*.

2.3 I should note here that I have known Mr Forwood for a number of years in a business capacity, wherein he has sought my advice from time-to-time, and I am aware that he is involved with a Cumbria based organisation known as *Cumbrians Opposed to Radioactive Environment* (CORE). In this respect I acknowledge that Mr Forwood might be regarded as an anti-nuclear campaigner or lobbyist.

2.4 On a personal note, in my dealings with Mr Forwood, I have always found him to be of honest, forthright and of very amenable character. Although he is strongly opposed to the activities undertaken at Sellafield and the nuclear industry generally, to my knowledge he has never expressed this opposition by demeaning those employed by BNFL at Sellafield and he is able to debate without hostility to those holding converse viewpoint.

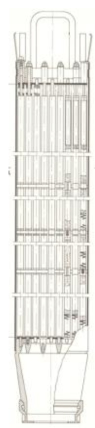
2.5 That said, my prior business acquaintance with and part knowledge of Mr Forwood's views will not, in any way, prejudice the statement of facts and opinion that I present here.

3 THE IRRADIATED FUEL SHIPMENT INTO BARROW ON 15 APRIL 2003

3.1 Before addressing Mr Forwood's issues, it might be useful if I provide some information on the fuel shipment that was at the subject of Mr Forwood's alleged actions of 15 April 2003.

3.2 This batch of irradiated nuclear fuel originated from a boiling water reactor (BWR) at Garigliano located on the mid-west of Italy which was first commissioned to power operation in 1964 and which was permanently shut down in 1982.

3.3 Over its operating lifetime of eighteen years, this relatively small nuclear power plant would have accumulated about 250 to 300 tonnes (uranium weight - tU) of irradiated fuel accumulated from annual discharges of fuel elements from the reactor core. This fuel would have been discharged to and stored in the power station fuel ponds and, subsequently, 60 tonnes or more were transferred to the national radioactive waste facility at Avogadro near Milan.



Garigliano Single Element
81 UO_2 fuel pins ~200kg U

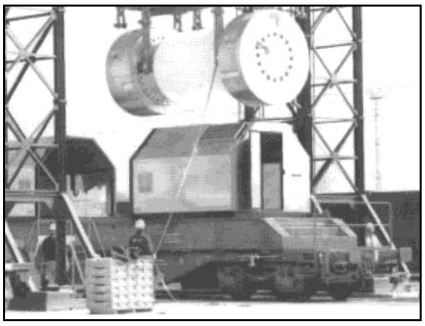
3.4 In or about 1975 (and perhaps later in January 1980) the Italian state company ENEL (now the responsibility of another state enterprise- Società Gestione Impianti Nucleari – SOGIN) entered a contract with British Nuclear Fuels (BNFL) to chemically separate (reprocess – see later) 259 spent fuel elements (in all about 53 tU) from the Garigliano power station.[1]

1 *Allotntanamento di Combustibile Irraggiato dal sito Saluggia*, Ing Angelo PAPA, SOGIN, Trino, 13 March 2003

3.5 The batch of irradiated fuel landed at Barrow on or about 15 April 2003 was the first of thirteen shipments of Garigliano fuel from Avogradro. My understanding is that a total of 13 shipments of Garigliano irradiated fuel are to be landed at Barrow, with each batch comprising two type NTL 3MA flasks each carrying 10 fuel elements, about 2 tU, of irradiated fuel.

3.6 The NTL (Nuclear Transport Limited) 3MA is a cylindrical flask of approximately 2.25m diameter by 4.85m long, weighing about 54 tonnes.

3.7 The main body of the flask is externally ribbed to improve the dissipation of heat from the heat-emitting spent fuel within,[2] the flask is lined to shield β-γ radiation and coated with a resin to absorb neutron activity from the fuel. A basket or bottle holding the 10 fuel elements is sealed inside the flask and the flask is water filled when the fuel is loaded. When transported overland by rail, the flask is loaded onto a specially adapted flatrol wagon and usually concealed within a lightweight, slide back cover.



NTL 3MA Fuel Flask being loaded onto a rail flatrol with slide back covers open

3.8 The flask is hauled by dedicated train from the Barrow Ramsden Dock, moving up the freight branch line to Salthouse Junction where it joins the main Barrow to Carlisle line, thence travelling northwards to Seascale where it branches to the BNFL Sellafield works. The Barrow to Carlisle line serves both passenger and mixed freight rail traffic, and passes through a number of centres of population, including Askam in Furness, Millom and Seascale.

3.9 Upon arrival at BNFL the train is uncoupled and the flask lifted from the flatrol, it is then water spray cleaned and immersed in a fuel reception pool where the flask is pressure equalised before being opened for the fuel assembles to be withdrawn and transferred to the main fuel storage pond.

3.10 Some time later, depending upon scheduling, batches of the fuel are (re)processed in the BNFL Thermal Oxide Reprocessing Plant (THORP).

3.11 Essentially, reprocessing is the train of processes that i) mechanically breaks down, ii) chemically dissolves, iii) chemically separates the depleted uranium, plutonium and fission (waste) products into distinctive streams, and iv) treats and packages these separate products for long term storage (depleted uranium), eventual disposal (fission product waste), and possible reuse (uranium and plutonium for uranium based and mixed oxide fuels).

3.12 Operating alongside the reprocessing plant are a number of purging, cleansing and treatment processes all intended to maintain the discharges of radioactivity to within the regulator's authorised limits.

---

2 The fuel elements continue to emit heat by virtue of the continuing natural radioactive decay of the intensely radioactive fuel – heat dissipation continues for many decades following fuel discharge from the reactor core.

3.13 I do not have details of the original contracts signed between BNFL and ENEL (these are typically very confidential) although, generally, BNFL contracts to return to the customer the plutonium yield of reprocessing its fuel, together with an equivalent amount of radioactive waste.

3.14 The plutonium yield would be, for 59 tU of Garigliano irradiated fuel, between 50 to 70kg – when processed this could be in the form of a neat plutonium oxide powder (PuO_2) or the same amount blended with uranium in the form of mixed oxide fuel (MOX) that can be used to fuel specially adapted and licensed nuclear power reactors.

4 MR FORWOOD's CONCERNS

4.1 As previously noted, Mr Clapp has advised me that Mr Forwood's line of defence is *'that he was attempting to protect the public and, given the nature of the material, he did what he could do in the circumstances'*.

4.2 The *'material'* referred to here is irradiated or spent nuclear fuel, so I can reasonably assume[3] that Mr Forwood's actions on 15 April arise from his concerns relating to the reprocessing of this fuel at the BNFL THORP at Sellafield. These concerns might centre on the safety of the reprocessing activities, both in THORP and its related plants; and with the discharges of radioactive effluents and gases to the marine and atmospheric environments.

4.3 Mr Forwood might also relate and link this concern to pre-reprocessing activities, particularly the docking and unloading of the spent fuel arriving from Italy at Barrow-in-Furness, and to its onward rail journey to Sellafield. Here his concern is likely to relate to the risk and consequences of accident of sufficient severity to challenge the surety of the flasks. Also, he might consider the docking and rail transportation phases and, indeed, the Sellafield plant itself, to be vulnerable to terrorist attack or sabotage

4.4 Similarly, he is likely to draw into his concern the post-THORP management and use of the products separated from the spent fuel by BNFL. His concerns might range over the sustainability of interim and longer term management of the radioactive waste products of reprocessing; the potential for proliferation of the fissile plutonium-239 isotopes to use in nuclear weapons; and the use of plutonium in mixed oxide fuel (MOX) as fuel in especially adapted thermally moderated reactors.

4.5 In summary, I suggest that there are three areas of nuclear activity that relate spent nuclear fuel to Mr Forwood's actions on 15 April. These are the:

a) **risks and hazards of the transportation of spent nuclear fuel**

b) **environmental and health impact of reprocessing spent nuclear fuel**

c) **safe and secure management of the radioactive wastes and materials arising from reprocessing of spent nuclear fuel**

---

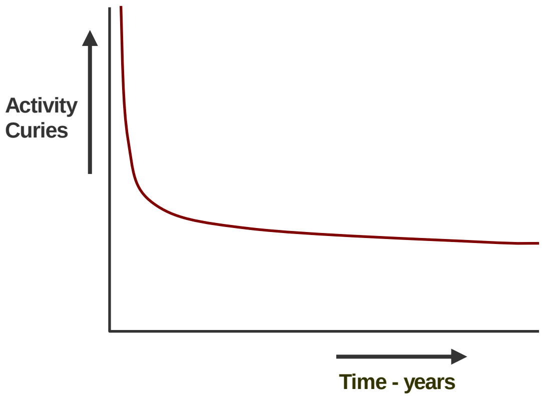
3 These concerns are drawn together from the CORE website at http://www.corecumbria.co.uk/

4.6 Because the alleged offence attempted to disrupt the transport system used for the movement of the fuel from Barrow to Sellafield, I shall concentrate my comments on this aspect of Mr Forwood's concerns.

5 HAZARD OF IRRADIATED FUEL, PARTICULARLY WHEN IN TRANSPORTATION

5.1 Irradiated or spent nuclear fuel is intensely radioactive. This is because the nuclear processes undertaken in a nuclear reactor destabilise the atomic structure of the uranium based fuel by fission, that is splitting the atoms, leaving fragments of unstable fission products of the uranium to radioactively decay (stabilise) over time.

5.2 The radioactive nature of spent fuel is complex, comprising many different chemo-radioactive species. When the fuel is withdrawn from the nuclear reactor and in the absence of further radioactivity being generated by nuclear fission and irradiation, the initial bout of radioactive decay is rapid and exponential-like until it attains a decay characteristic dominated by the longer-live radioisotopes, where the continuing decay is long term, over tens, hundreds and thousands of years.



5.3 As example, the (radio)activity spent PWR fuel at about 6 months withdrawal from the reactor core is about 4.10^6 Curies per tonne of uranium (that is 4 million Ci or ~150,000 million million Becquerel per tonne). After 5 years, this radioactivity has reduced by natural radioactive decay to about $0.75.10^6$ Ci/tU or about one-fifth of its 6 month post core value.[4]

5.4 As previously noted, each flask contains 10 fuel element assemblies or about 2 tU, so the radioactive worth at 5 years would be (2 x $0.75.10^6$=) $1.5.10^6$ Ci. As I have noted the Garigliano reactor closed down in 1982 so, in account of the further natural radioactive decay, I would expect the fuel to have decayed by about one-third again, say at about 1.10^6 or one million curies per flask.

5.5 So if the fuel within the transport flasks is i) adequately shielded and ii) prevented from spilling or releasing from the flask containment then, although the spent fuel within the flask is highly hazardous, there is no or almost negligible health detriment or consequence to the public.

5.6 On its part the nuclear industry is confident that the transportation flasks are sufficiently well engineered and robust to ensure that in all reasonably foreseeable accidents and incidents there will be no release of radioactivity to the environment. It does so by referring to what it claims to be the excellence of design, its past history of

---

4 It is difficult to provide a gauge of how harmful exposed (unshielded) spent fuel would be – a person standing close by, say within 1m of an unshielded spent fuel rod, would incur a lethal radiation exposure within less than one or a few seconds. However, the expected exposure route would be where the fuel break-down into fine particles and the release is via a plume of cloud of radioactivity, so that the dose uptake might be from immediately received external radiation and, immediately and in the longer term, by internal uptake of fuel particles and fission product gases. This type of release and exposure would be expected to result in short, interim and longer term exposures and the corresponding risk of health harm and fatality over many years.

transportation without major radioactive mishap, and upon the compliance of the flask with the standards established by the International Atomic Energy Agency (IAEA).[5]

5.7 The nuclear industry also claims that its emergency planning is entirely adequate to deal with all reasonably foreseeable accidents, that effective countermeasures can be implemented in good time, and that the health and safety of the public can be safeguarded.

5.8 I personally do not subscribe to this 'absolute' confidence that the system of transportation of irradiated fuel (including the road, ship and rail legs of the journey) is entirely safeguarded against all (realistically) possible accidents and incidents.

5.9 **COMPLIANCE WITH IAEA (ST 1 & TS-R-1) RECOMMENDATIONS**

5.9.1 These recommendations are adopted in the UK for flask compliance for which the flask has to maintain surety and containment through a series of somewhat arbitrarily derived tests. Essentially, these regulations (being nationally and internationally adopted) stipulate that Type B(U)/F packages (ie spent fuel flasks) maintain containment of the nuclear material; shield against radiation emissions (beta, gamma and neutrons); preserve subcriticality conditions; and dissipate residual heat, all when subject to both normal and accidental conditions of transport.[6]

5.9.2 However, there is much to be argued against the adequacy of this test regime and approach to safety:[7]

- **Adequacy of the IAEA Test Regime:** There is much criticism of the entirely empirical approach of the IAEA flask compliance regime, particularly in that for accident (or sabotage) scenarios the conditions encountered by the flask may be more severe and, indeed, substantially different from those applied in the IAEA tests. Indeed, the first of the drop tests (9m) solely determines the ability of the flask not to leak during and following the very specific impact conditions of the test and the thermal test, with the flask engulfed at 800°C for 30 minutes, is not considered a realistic simulation of complex chemical fires, particularly when occurring in confined spaces such as rail tunnels.

- **Limitation of IAEA Test-Based Approach:** Another very significant weakness is that the IAEA approach provides the opportunity for flasks to be designed to be test-specific, particularly now with very advanced computer-aided design

5 There is a plethora of regulations and statutes relating to the transportation of Category 1 materials in addition to the IAEA regulations (ST 1 & TS-R-1) for the safe transport of radioactive materials, including mode-specific regulations such as the *European Agreement for the International Carriage of Dangerous Goods by Road* (ADR - EC Directive 94/55/EC – *The Radioactive Material (Road Transport)(Great Britain) Regulations 1996*) and *The International Maritime Dangerous Goods* (IMDG) Code (INF-2 – *The Merchant Shipping (Dangerous Goods and Maritime Pollutant) Regulations 1997*). Referring to the IAEA 1996 Regulations approvals and compliance is required for Multilateral Shipment Approval (IAEA 820) and fissile packages (IAEA 566), special use vessels (IAEA 566), details of the proposed route, controls and shipment period (IAEA 822), flooding (IAEA 671), etc. Special Provisions for vehicles carrying radioactive material are contained in Regulation 36 of the *Radioactive Material (Road Transport)(Great Britain) Regulations 1996*.

6 The UK *Competent Authority* approval for flasks (the IAEA 1999 Regulations) provides opportunity for the transport Carrier to demonstrate the adequacy of the flask design by extrapolation from other designs, calculation or by reasoned argument (IAEA 701) and where testing is undertaken much of this is on part or scale models of the flask design. Essentially, the tests impose conditions that are equivalent to an impact of about 30 mph (from 9m height or 13.2 ms^{-1} upon impact) onto an unyielding surface, followed by a drop onto a fixed penetrator (rod) from 1m, and then exposed to fire with a flame temperature of 800°C for 30 minutes.

7 Because complex subject, for brevity here I intend to bullet point the weaknesses of the nuclear industry's claims – of course, I am prepared to be cross-examined thoroughly on all aspects.

techniques being available. Even extending the flask design beyond the requirements of the IAEA tests, there remains no compulsion and little incentive to carry out testing to a severity beyond what the standards require, particularly in that such tests are expensive and difficult.

- **Concept of Over-Conservative Design:** Some of these shortfalls are acknowledged by the IAEA and the radioactive materials carriers, although these it is claimed are by far more than offset by the flask design and construction being so conservative. However, in my opinion, it is just not possible to provide an all encompassing design and, in support of this, I can give a recall many examples where real engineering systems have failed because the fault or accident conditions had not been included in the design rationale – for example: Piper Alpha, the space shuttles Challenger (1986) Columbus (2003), Chernobyl, the sunken nuclear powered submarine *Kursk* (2001) and, of course, the *Titanic*.

- **Sabotage and Terrorist Acts:** The IAEA tests and recommendations include no specific provision or requirement for testing the resistance of the flask design to intentional actions to sabotage, damage or attempts to remove the radioactive contents. The assumption here seems to be that adequate safeguards will be in place to prevent the terrorist or saboteur gaining direct and unhindered access to the flask.

5.10 EMERGENCY PLANNING

5.10.1 In the UK, nuclear facilities such as BNFL Sellafield are required to have in place both on-site and off-site emergency plans. The off-site emergency planning requirement is stipulated by the *Radiation (Emergency Preparedness & Public Information) Regulations* (REPPIR)[8] and these require specific accident scenarios to be planned for in advance. Similarly, movements of radioactive consignments by rail are also covered by REPPIR with the carrier of the consignment being required to provide and emergency plan:

- **Exemption of REPPIR:** These regulations also apply to radioactive materials in transit but, quite specifically, the by far largest of single radioactive shipments, spent fuel flasks, are exempted from the regulations on the premise of compliance with the IAEA recommendations (ie that the flask would never fail in accident conditions).
- **Sabotage and Terrorist Attack:** Even if REPPIR were to apply to spent fuel consignments, there would be no need to include for terrorist attack and sabotage because according to the regulator:[9]

  "*. . . that if a threat to the plant is judged by the operators, to fall below the limit of reasonable foreseeability then it does not need to be included in its submission to HSE. Given that there is no substantive evidence that a terrorist threat to a specific*

---

8 These regulations require the Carrier to prepare an emergency plan for Type A packaged consignments under shipment by rail, although Type B flasks are exempted from REPPIR for rail and road shipments. Separately, an emergency plan known as RADSAFE, organised by a consortium of carriers and is based on the requirements of the emergency services, drawing on the principles of the national *Chemsafe* plan, is maintained nationwide but details of the emergency response and countermeasures prepared are not publicly available.

> *plant <u>(or transport mode)</u> and in a specific manner is reasonably foreseeable, HSE considers that it is quite correct that the reports of assessment do not need to consider this. . . .'*[10]
>
> {*my <u>addition</u>*}

In the UK the situation is confused insofar that Government ministers consider the (terrorist) design basis threat (DBT) to be based on *'intelligence about the motives, intentions and capabilities of potential adversaries'*,[11] which seems to imply that there is sufficient confidence to detect the intent of terrorist act before such are carried through.

- **Vulnerabilities of the Flasks to Terrorist Attack:** That said, following events of 11 September, the potential vulnerabilities nuclear plant have attracted a great deal of attention and some evaluation has been undertaken to assess the vulnerability and release of radioactivity from irradiated fuel transportation flasks[12] subject to terrorist attack and acts of sabotage. However, nothing has been published specifically relating to the spent fuel transport by sea into Barrow and thence along the rail route to Sellafield and, moreover, physically in terms of security presence and/or modification to the flask, etc., nothing seems to have changed from the pre 11 September arrangements.

- **Probabilistic Risk Approach -v- Terrorism:** The nuclear industry's combined approach of gauging the risk of accident by probabilistic assessment and, generally, making system safety largely independent of inadvertent human action (ie neglect and/or innocent error) may have some effect in safeguarding nuclear systems against accidents and unintentional human error, but it could prove to be woefully ineffective against intentional and intelligently driven acts of terrorism. This is particularly so for when, as with the spent fuel transit consignments, the nuclear system moves out of the physically protective confines of the nuclear plant, particularly when it is journeying on roads and by rail. For this situation, it is not possible to establish an impenetrable security boundary around the fuel in transit, like the security fencing around a nuclear power station; and other and unchecked vehicles and rail trains are free to move into close proximity to the fuel flask train.

---

10 E-mail Graham Holder, HSE to Large & Associates, 26 February 2003

11 Letter, Sunil Parekh, APS to John Denham, Home Office Minister to Large & Associates, 10 May 2002, -Letter, Mike Smith, Manager Nuclear Security, Department of Trade and Industry to Large & Associates, 28 February 2003 – see also the Office of Civil Nuclear Security 1st Annual Report, October to March 2002 This contrasts to the regulatory requirement in the United States where the nuclear activity (fixed plant, transport, etc) has to be physically subject to a series of realistic DBTs.

12 *Nuclear Terrorism: How real is the Threat*, IAEA-CB-86-1 – see also, Large J H, Schneider M, *The Implications of 11 September of the Nuclear Industry*, Oxford Research Group, Rhodes House, Oxford November 2002, Large J H, *The Aftermath of the US Attacks: The End of Probabilistic Risk Analysis, Rethinking Nuclear Energy and Democracy after 09/11*, PSR/IPPNW , Switzerland, Basel April 2002, see also Luna R, *Comparison of Results from Two Spent Fuel Sabotage Source Term Experiments*, Int. J. Radioact. Mat. Transp. 11(1-2), pp 81-84 (2000)

- **Response to a Terrorist Attack:** The general assumption for nuclear accidents is that the event will occur over a time period through which the containment deteriorates, thereby several hours is assumed to pass before the radioactive release commences. Should a spent fuel transit be identified as a target by terrorists and if it is attacked, there may not be sufficient time for the response force to arrive at the scene before a significant radioactive release has occurred. There are a number of shoulder-launched rocket propelled projectiles capable of piercing the fuel flask body[13] thereby prompting an immediate release of radioactivity.
- **Emergency Plans and Countermeasures:** Another aspect of terrorism that separates accidental and malicious acts is that a well-organized terrorist attack might also intend to impede the effectiveness of any post-incident emergency response, thereby seeking to maximize the impact of the radioactive release.

5.11 RANGE OF POTENTIAL HEALTH INJURY AND CONSEQUENCE

5.11.1 Should, either in accidental circumstances or from terrorist action, the spent fuel flask fail then there is a high probability of radioactive release – it is possible to reliably model both the release and the ensuing health consequences.

5.11.2 Over the years I have undertaken a number of studies of fuel flask behaviour when subject to severe accident and incident conditions. My work, like that of others,[14] takes into account a number of variables and probabilities of conditions and process existing at the time and during the aftermath of such an incident. Here I shall set aside my own work (which is in broad agreement with others) and I shall cite the results of research and analysis undertaken by such organisations as the UK government's radiation advisory body NRPB:

- Clarke of the NRPB modelled a release from a flask in a large rail marshalling yard in an urban environment with a large population shows the probability of all (short and longer term) fatal cancers to be:

PROBABILITY	N^{O} FATAL CANCERS
0.99	0.15[15]
0.50	0.52

13 This is a sensitive topic and it would serve no point for me to identify specific models of RPG that could penetrate a fuel flask, although the availability and use of such weaponry is illustrated by the MI6 intelligence agency building attack in London on 21 September 2000 which deployed a Russian-built RPG Mk 22 anti-tank weapon which has a range of 250m for a 72.5mm diameter self-propelled round – this weapon takes about 10 seconds to prepare, aim and shoot – the round has a two stage charge, first armour piercing penetration than a delayed pop-off explosive grenade which explodes once inside the vehicle, etc., under attack.

14 For example, Clarke R H, '*Assessing the Consequences of Accidental Releases of Activity during Irradiated Fuel Transport*', Int Conf Urban Transportation of Irradiated Fuel, London April 1983 – Elder H. K, '*An Analysis of the Risk of Transporting Spent Nuclear Fuel by Train*', Batelle Pacific Northwest Laboratories, PNL-2682, 1981 - Lamb M, *Radiological Consequences of Severe Rail Accidents Involving Spent Nuclear Fuel Shipments to Yucca Mountain: Hypothetical Baltimore Rail Tunnel Fire Involving SNF* Radioactive Waste Management Associates September 2001

15 Interpretation of the probability column is direct, this being that as chance would have it less then one fatal cancer (0.15) will arise almost with certainty (99%) and that, at the other extreme, there will arise 18 fatalities at a chance of 1 in 1000.

0.10	5.8
0.01	14.0
0.001	18

- The consequences of this model are somewhat muted by the release point being in an unpopulated island (the marshalling yard) without any significant fixed (residential) population numbers within 1 to 2 kilometers of the point of release.
- Another NRPB study[16] for a situation where a spent fuel flask is ruptured by terrorist attack, gives a much larger range of probable outcomes, with late fatal cancers ranging from an expected value of ~100 to the least probable of ~1,300 fatalities (and 0 to 3 early fatalities).

5.12 **In summary:** The arrangements for transportation of spent fuel assume that it is possible to reliably predict the nature, severity and frequency of accidents. This supposes that accident scenarios that have the potential to severely damage the flask are sufficiently infrequent and that the existing regulatory framework and safeguards are sufficient to safeguard against terrorist act.

5.13 Events of 11 September 2001 introduced the reality of international terrorism and the very real risk that hazardous cargoes, such a highly radioactive nuclear reactor fuel, could well be a target of attack. Some would argue that the public perception of radiation and all things nuclear to give rise to *'fate worse than death'* could increase the choice of this being a terrorist target because a successful attack would maximise the psychological and economic impacts.

5.14 Irradiated or spent nuclear fuel is extremely hazardous, its transportation moves out of the enclosed security of a nuclear power station to travel along railway tracks that are practically impossible to fully secure, passing through centres of population where, if it were to occur, a release of radioactivity would cause the maximum health harm. Yet the towns and communities settled alongside the rail route have no specific emergency plans and practised countermeasures with which to safeguard the health and safety of relatively large numbers of public.

6 REPROCESSING SPENT NUCLEAR FUEL & RADIOACTIVE WASTE MANAGEMENT

6.1 REPROCESSING AT SELLAFIELD

6.1.1 Previously (para 3.11) I described the basics of chemical separation or reprocessing of spent nuclear fuel.

6.1.2 Reprocessing separates out three products: Depleted uranium, radioactive wastes and plutonium.[17] The depleted uranium is recovered for 'reblending' into new uranium fuel for nuclear reactors; the various radioactive waste streams are treated for interim- and long-term storage, and eventual disposal; and the plutonium (Pu-239) may be used for especially adapted reactors in the form of a mixed oxide fuel (MOX).

16 Shaw K, *The Radiological Impact of Postulated Accidental Releases during the Transportation of Irradiated PWR Fuel through Greater London*, NRPB-R147, 1983

17 For a more detailed account of reprocessing and the volumes of waste produced see Large J H *Radioactive Waste and Long Term Storage* - Evidence to House of Commons Environment Committee, August 1985

6.1.3 **Timing of Reprocessing**

6.1.4 Reprocessing is a batch process. The fuel making up each batch is chosen for its irradiation or 'burn-up' characteristics, so a single batch undergoing reprocessing may comprise fuel 'burnt' at different times in different reactors.

6.1.5 There are advantages in undertaking reprocessing relatively soon after the fuel has been withdrawn from the reactor core but these gains are by far outweighed by the disadvantages associated with the higher radioactivity (see para 5.3) and heat generation of the fuel.

6.1.6 Generally, fuel reprocessing plants such as THORP at BNFL Sellafield, are not constructed until one to two decades following the start up of the feeding nuclear power stations[18] and there may be further delays whilst the spent fuel is stored in fuel ponds at the individual nuclear power stations or at Sellafield itself.

6.1.7 Because of this enforced delay between the removal of the fuel from the reactor core at the power station, nuclear power stations have sufficient irradiated fuel storage space to hold the fuel safely (in an on-site water pond) for many years. For example, the PWR nuclear power station at Sizewell has water pond storage capacity sufficient to hold the entire spent fuel arisings for its intended 40 year operating life.

- Accordingly, delaying or stopping spent fuel movements between the power stations and BNFL Sellafield does not introduce any additional risk or safety implications that are not already prepared for at the individual nuclear power stations. Indeed, some would argue that stopping fuel movements by road, rail and sea significantly reduces the risk of accident and/or incident that could lead to a radioactive release.
- In the context of Mr Forwood's alleged action, stopping a single rail shipment for a few hours (or a day or more) would not introduce any additional safety concerns because the transport flasks are designed to maintain the fuel cool by natural dissipation of the heat generated by the fuel.

6.1.8 **Garigliano Fuel Consignment**

6.1.9 I referred to the Garigliano fuel destined for Sellafield previously (para 3.4) and that details of the reprocessing contracts held between BNFL and its customers are very confidential.

6.1.10 I understand, however, that a typical BNFL contract is versed in terms of *'equivalence'*. This means that an *equivalent* quantity of fuel (characterised by its type and burn-up) will be reprocessed, although this may not necessarily be (nor is it likely to be) the Garigliano fuel.

6.1.11 With regard to the return of radioactive wastes and fissile materials (the plutonium-239) yield from reprocessing, I understand that (generally) contracts signed prior to 1976 or thereabouts do not include for the return of radioactive wastes, whereas later contracts do require and equivalent (radio)activity of radioactive waste to be returned to the customer.

---

18 This period gives sufficient power station operational time to secure aneough spent fuel to sustain repsocessing.

6.1.12 For the later post mid-1970s contracts, instead of returning a mix batch of radioactive waste streams BNFL practises *'substitution'* whereby it returns a (radio)active *equivalent* quantity of vitrified high-level waste to the customer in account of all of the radioactive waste (low, intermediate and plutonium contaminated) separated during reprocessing. If the Garigliano 59 tonne consignment is subject to substitution then I would expect BNFL to return 7 to 8 m^3 or about 47 to 54 canisters of vitrified high level waste.

- The irony here is that it may transpire that, given the present uncertainty and doubtful economics of reprocessing, BNFL will never reprocess the actual fuel from Garigliano, with the fuel remaining at BNFL Sellafield unreprocessed.
- If so, the fuel could have safely remained unreprocessed at the Avogadro fuel store in Italy.
- Moreover, the risks of transporting the fuel from the Garigliano power station to the Italian fuel store at Avogadro, thence to the dispatching port for the sea voyage to Barrow, and then by rail to Sellafield; and similarly the risks of the return of the vitrified high level waste back to Italy, would have been additional and unnecessary risks placed upon local and regional communities.

6.1.13 **Health Impact of Reprocessing**

6.1.14 Reprocessing operations at Sellafield do not destroy or eliminate any of the radioactivity of the spent fuel, although as I have previously discussed during its pre- and post-reprocessing storage at Sellafield there occurs a small increment of natural radioactive decay.

6.1.15 However, reprocessing involves a number of streams (gaseous and liquid) which become contaminated with or carry off some of the radioactivity of the fuel. Some of these streams are diluted and discharged to the marine and atmospheric environments and, other streams such as the krypton-85 atmospheric discharges, are released without any radiological abatement whatsoever.

6.1.16 The technicality and regulatory controls applied to these processes are complex. In essence, the regulator (the Environment Agency) requires the operator not to exceed a number of specified discharge limits and to deploy best practicable means (BPM) to keep the discharges as low as reasonably practicable (ALARP).

6.1.17 The regulatory authority sets this system of discharge limitation on the basis that it is satisfied that the ensuing health harm is at an acceptable level when the economic and social benefits arising from the Sellafield operations are taken into account.

- There is considerable debate within the scientific and environmental communities about the effectiveness of the Environment Agency's regulation (via the *Radioactive Substances Act 1960*) of discharges, particularly whether the discharge limitation system should be replaced by a zero emissions approach; if it is appropriate that BNFL itself be the developer of the best practicable means (BPM) to abate its own discharges to ALARP; and if there is sufficient understanding and modelling of the complex uptake pathways leading to the human receptor, particularly in and from the marine environment.

- o There is also much debate and challenge to the basis of the regulator's tolerable detriment approach whereby the risk of health harm is equated against the claimed social and economic benefits. Neighbouring and nearby non-nuclear states such as the Republic of Ireland and Norway which are subject to measurable quantities of radioactivity discharged from Sellafield (and hence radiation exposure to their nationals - that is health detriment risk), cannot claim to receive any benefit whatsoever from the operation of BNFL Sellafield.
- o Similarly, those states that occupy areas of coast along which the sea transport passes form the Italian dispatching port, including southern Mediterranean underdeveloped countries such as Morocco, Algeria, etc., have to live with and carry the risk of radioactive release but, not only do they not receive any benefit from the transport activity, but they would not be in a position to implement any effective countermeasures to protect their nationals in the event of radioactive release occurring at sea.

6.2 MANAGING THE RADIOACTIVE WASTES

6.2.1 As previously noted, the practice of *substitution* results in volumes of low, intermediate and plutonium contaminated wastes that are (theoretically) yielded by the Garigliano spent fuel – these substituted wastes remain in the United Kingdom.

6.2.2 It is also possible that the actual fuel from Garigliano will not be reprocessed so that it too will remain in the United Kingdom.

6.2.3 Italy no longer operates any active nuclear power stations with the decision to shut down its nuclear power programme being the result of a national referendum in 1987. This means that if Italy's reprocessing contracts include for the return of an equivalent amount of fissile plutonium, Italy will have no use for this plutonium and, as a signatory of the *Non-Proliferation Treaty* (of nuclear weapons), it will have to implement and maintain rigorous arrangements to safeguard the plutonium. It is probable that Italy will require the plutonium to be kept safeguarded in the United Kingdom.

- o At this time, a strategy of the interim and long term management of radioactive wastes in the United Kingdom has yet to be determined. Government measures presently in hand include the establishment of a committee[19] which is to identify realistic strategies for future management which might or might not be in place by 2025 or thereabouts. Until that time all radioactive waste has to remain at the site of its generation.
- o Reprocessing at Sellafield produces a number of radioactive wastes streams, some of which are chemically complex and unstable. Because there is no national radioactive waste strategy in place at this time, the rendering and packaging of these wastes introduces uncertainty as to the suitability of the waste form (and packaging) for future storage and/or disposal in the longer term.
- o Continuing to produce radioactive waste streams, to which the reprocessing of the Garigliano spent fuel contributes, introduces an element of unsustainability which

---

19 The Committee for the Management of Radioactive Wastes (CORMW) is to be established in or about October 2003 with a remit to consider practicable strategies for the long term management of the present backlog and future arisings of radioactive wastes and unreprocessed spent fuel – the committee is required to report on this issue in 2006-7.

is contrary to government's acceptance and endorsement of the principle of sustainability.[20]

JOHN H LARGE

Large & Associates
Consulting Engineers,
London

[20] The principle of sustainable development was accepted by all signatory states of the Rio de Janeiro Earth Summit and has been subsequently endorsed by following summits – sustainable development is *"development that meets the needs of the present (generation) without compromising the ability of future generations to meet their own needs."*.