Nuclear Explosions

On not learning the lessons of Fukushima and Chernobyl

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The Earthquake

On 11 March 2011 at 14-46 local time, a magnitude 9 earthquake occurred under the Pacific Ocean 110 miles east north-east of Fukushima on the east coast of Japan. Fukushima Dai-ichi, (Fukushima 1) is a nuclear power station complex of six boiling water reactors.

Reactors numbered 1, 2 and 3 were generating steam for electricity power production. Reactor No 4 was under maintenance and its nuclear fuel had been removed to storage ponds. Reactors 5 and 6 were shut down for maintenance.

HM Chief Inspector's Report

This account of the events at Fukushima 1 is based largely on the Interim and Final Reports by Dr Mike Weightman, HM Chief Inspector of Nuclear Installations in the United Kingdom. He was asked to provide the reports by the Secretary of State for Energy and Climate Change. The British government was monitoring the events for the safety of British nationals in Japan, and for the international effects of the disaster, now ranked 7 on the International Nuclear and Radiological Event Scale (INES) (the highest level).

Dr Weightman was assisted by a Technical Advisory Panel and respondents to his Interim Report of May 2011. He led a mission of experts in Japan and visited Fukushima and several other nuclear sites. His Final Report also acknowledges the assistance of the report of the Japanese Government to the International Atomic Energy Authority (IAEA) Ministerial Conference on Nuclear Safety, June 2011, and other sources, while explaining that,

because of the effects of the tsunami, not everything is known about the disaster and may never be known. Other work is under way or planned which also seeks to learn lessons from the disaster, such as the European Council 'Stress Tests' on nuclear installations (to find weaknesses in existing reactors and methods) and the work of the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD) and the IAEA on which a report, for publication in October 2012, is planned.

Electricity grid failure

The Fukushima 1 Reactors 1, 2 and 3 were protected by seismic sensors which detected shocks of 0.56g peak horizontal acceleration and triggered safe shutdowns. Similar shocks had been recorded on at least one other occasion and the reactor buildings, as before, survived without collapse, although some damage to equipment was expected. The earthquake caused electricity grid pylons to collapse, some affected by landslip, and all standby incoming power supplies to the power station failed. All but one of 13 standby diesel generators survived the shocks and were started to run pumps for water to cool the reactors and the spent fuel ponds and to provided lighting and other services.

The tsunami

In less than one hour after the earthquake, a 14m tsunami wave inundated the complex to a depth of six metres and caused extensive damaged with much debris. Fourteen other nuclear reactors on the east coast of Japan were also affected. The Fukushima 1 diesel generators and switchgear were unusable. Control and instrumentation equipment and lighting were also affected. The engineers operating the reactors lacked information about the status of the reactors and spent fuel storage ponds, and their efforts to provide and maintain emergency cooling of both required much improvisation and exposure to hazards.

Reactor explosions

Within the next two days, explosions occurred in the buildings housing reactors 1, 2, 3 and 4 and some secondary containment was destroyed. The explosions were probably of hydrogen gas produced by zirconium alloy fuel cladding reacting with steam. Fuel in the reactors is believed to have melted and in some may have breached the primary containment. There were major releases of radioactivity, initially to air but later by leakage or discharge of contaminated water to sea. In consequence of the releases to air, eighty thousand people were evacuated from their homes with little

prospect of a return other than to collect any property that they could carry in a visit of less than 2 hours.

On 29 October 2011 *The Guardian* newspaper reported on a paper published online by the journal of Atmospheric Chemistry and Physics in which European and US experts estimated that the release of Caesium 137 from Fukushima was 42% of that from Chernobyl and more than twice that from Fukushima as reported by the Japanese government.

How much of the Japanese nuclear energy industry will survive?

After the tsunami only 19 of Japan's 54 reactors continued to operate. Plans to build Fukushima I reactors numbered 7 and 8 were abandoned but plans for 11 others in Japan remain subject to satisfactory outcomes from the OECD 'stress tests'. If implemented, such plans would make nuclear electricity generation almost 50% of the Japanese total, but public opinion polls have shown that 70% of respondents favour the phasing out of the industry.

It is already apparent to those appraising the Japanese industry that, while some tolerance of seismic events may have been achieved in the construction of reactors, it was insufficient, and that the design basis for protection from tsunami was never adequate. Ten metres high tsunami waves were expected to occur every 30 years.

Prime Minister Naoto Kan must have been advised after the tsunami of some of the worst outcomes of loss of control of four reactors and spent fuel ponds. The owners of the Fukushima I site early in the crisis planned to abandon it. Kan speculated that in that event millions of people would leave greater Tokyo and that the Japanese economy would collapse. We are told, but we don't yet know by whom, that he learned that further explosive releases of radionuclides to the environment could make large tracts of land uninhabitable – a prospect that he described as intolerable. No doubt he proposed massive curtailment of the industry, and his resignation as Prime Minister may have been for lack of cabinet support. Like Mikhail Gorbachev, he was shocked to learn the hazards of the industry after a disaster. Gorbachev bitterly reproached Soviet nuclear industry leaders for their claims of a safe industry and their failure to describe even to a national leader the nature of failure.

The reactions of other communities to the disaster

In Germany, plans to phase out the nuclear industry have been revived, and in Italy 95% of those polled favoured a non-nuclear energy sector. Switzerland and other countries have, or are expected to follow suit.

In Britain, there are reports of active efforts by nuclear industry lobbyists attempting to influence the reporting of nuclear matters. ('We must work together on this and have a very strong co-ordinated message'; the e-mail author's name redacted.[1]) From the BBC's lack of scepticism in repeating incredible Japanese accounts of 'safe' discharges to the environment, they seem to have succeeded.

The British government, already committed to its justification of nuclear 'new build', must have been grateful for Interim Conclusion No 1 endorsed in Dr Weightman's Final Report that

> *In considering the direct causes of the Fukushima accident we see no reason for curtailing the operation of nuclear power plants or other nuclear facilities in the UK.*

The Secretary of State lost no time in informing Parliament that the report reassures us that

> *... new nuclear can be part of a low carbon energy mix in the UK.*

Dr Weightman, in his May 2011 Interim Report, invited comment on his interim conclusions and recommendations. It was apparent to me that many statements about 'safe' exposure to radiation were being repeated by British media without challenge, and I responded by suggesting that Dr Weightman could quote the majority view of the Committee Examining Radiation Risk of Internal Emitters (CERRIE 2004) and other authorities that there is no safe level of radiation, and that the effects of low exposure are rarely immediate. This was only part of a concern that hazards were being understated. I was relieved to find in the final report a mention of 'genetic effects to progeny', which has had little mention since the management of Sellafield advised its workers to think twice about having children.

The Final Report is detailed and reassuring in its comparison of nuclear regulation in the UK with that of Japan in the design of reactors and in site licence conditions, for example, all showing that British standards are higher. But there is some lack of congruence between the conclusion quoted above and the many detailed recommendations on British practice on such topics as flood protection, the provision of back-up water supplies for spent fuel stores, and planning for emergencies. My interest grew when I read a discussion of proposed changes in Japanese government agencies to prevent conflicts of interest by separating regulation of the industry from promotion of the industry. There was no mention of a similar need in British structures, and this is discussed below.

Towards the end of Weightman's Final Report, in 'Annex L' with the

title 'Severe Accident Progression', there are several pages of speculation about the extent of reactor core meltdown, sometimes referred to as 'core relocation'. The limitations of this section, by the sheer lack of information about the status of the three reactors, is freely admitted, but it goes some way to deal with my concern that if heads of state do not know what the worst outcomes of a nuclear disaster can be, there is a need to describe them soon, fully and to the public. Part of the explanation could be that the industry itself does not know, or lacks agreement on, the worst outcomes. Below is an extract from page 270 of the Final Report followed by an extract from recommendation 25, which deals with the same topic.

> *It should be noted that computer code models for vessel failure cannot be considered to be well validated, due to the lack of an experience base against which to benchmark the codes. It should also be noted that MAAP* [Modular Accident Analysis Program] *and MELCOR [Methods for Estimation of Leakages and Consequences of Releases] do not have models for some phenomena discussed above, such as steam explosions.*

From Interim Report 25 (confirmed in the Final Report)

> *the industry needs to … ensure it has the capability to analyse severe accidents to properly inform and support on-site severe accident management actions and off-site emergency planning. Further research and modelling development may be required;*

Steam explosions were discussed in other sections of the report, as were hydrogen explosions. A search for 'fission explosion' in the 300 page Final Report and its relevant references produced nothing.

The Final Report's end-note reference No 2 with the title 'Report of the Japanese Government to the IAEA Ministerial Conference on Nuclear Safety June 2011' is available via the URL. It is one of the sources used by Dr Weightman for his Final Report. In the Japanese government report shortcomings in design basis standards for reactors are freely acknowledged, as are the failures of the regulatory agencies in not calling for higher standards.

Chernobyl and Fukushima: explosions compared

Zhores Medvedev, in a preface to the 2011 edition of *The Legacy of Chernobyl*[2], describes the Chernobyl explosion as a nuclear explosion.

> *With this design, during the first seconds after the 'panic button' was pressed, 170 rods started to move down at once, slowed by having to displace water, not absorbing neutrons, but instead producing a reactivity in the lower part of the*

reactor core, resulting in the explosion due to the increase in criticality and reactivity. The operators did not know about this possibility and it was the first time in Toptunov's short life that he had used the emergency button. The conclusion of the paper in Atomnaja Energia *was that the dramatic increase in reactivity (nearly 100 fold) was a direct result of the design error.*

Medvedev records that the control rods were subsequently redesigned in all RBMK 1000 reactors. At page 33 there is a discussion of the possible extent of meltdown and the desperate measures taken to control it. There is also what is missing from the UK Tolerability of Risk document[3] – an account of the possible consequences of a core meltdown.

The first two explosions were great disasters, but the continuing emissions for many days of fresh radionuclides represented an even greater danger to the population and to the environment. A meltdown of the core would lead to unimaginable damage. If it could not be prevented half of the Ukraine and Byelorussia would have to be evacuated. The land would be contaminated for many years. The Dnieper and other rivers in the area would be affected for many decades. The three other reactors on the Chernobyl site (which were still working and producing electricity) would be destroyed, causing untold further damage. There were about 3000kg of accumulated plutonium and 700,000kg of uranium in the fuel elements of the four reactors in Chernobyl and vast amounts of other radionuclides. Everyone who was involved in the emergency operations around Chernobyl recognised the gravity of the situation but no one knew how to prevent the catastrophe of meltdown.

George Monbiot in a *Guardian* article[4] seemed to have taken some comfort from the possibility that three reactors at Fukushima Dai-ichi suffered some meltdown without the horrendous consequences described above. He declared 'The unpalatable truth is that the anti-nuclear lobby has misled us all'. Some are impressed, the nuclear lobby in particular, by Monbiot's speculation, but if explosive nuclear fission is possible in reactors and spent fuel stores which are out of control, there is little assurance to be gained from the experience that it occurs in one instance out of four and then with less than its full potential. Such consequences are intolerable by any measure, and low probability does not change that. The carefully worded recommendation IR25 of the Chief Inspector's Final Report supports my observation that more information is needed.

Before we leave *The Legacy of Chernobyl,* here is an extract from Dr Medvedev's conclusion of chapter 1 with relevance for the lessons of Fukushima.

It is obvious, however, from an analysis of the safety tests and other major features of the Chernobyl RBMK reactor that the main liability of the system

> *was (and still is) the absence of protection from station blackout – in other words the loss of on-site electric power.*

One does not need an earthquake or a tsunami to bring that about. Grid failure in the UK could occur by several causes including terrorism and other hostile action. It is significant that terrorism is not mentioned in the Final Report and that Dr Weightman does not discuss nuclear policy issues. He states

> *As with the Interim Report, this Final Report does not examine nuclear policy issues. These are rightly matters for others and outside my organisation's competence and role.*

This could be a consequence of misdirection of the Nuclear Installations Inspectorate by the Chair of the Health and Safety Executive (HSE), Judith Hackett, when she spoke of a duty to reassure the public[5] but has not explained where such a duty can be found in law or elsewhere.

Sections 2 and 3 of the Health and Safety at Work etc. Act require an employer to provide a safe system of work so far as is reasonably practicable and the nuclear inspectorate is appointed to enforce those requirements. An employer with a choice of methods of generating electricity and who does not wish to produce plutonium is guided by the Act towards the safer methods and, likewise, should be guided by the HSE. When presented with these arguments, Judith Hackett rejected them. By inventing a duty to reassure, and ignoring the central requirements of the Act, these rank as the worst misdirections of the inspectorate since her predecessor declared deregulation to be HSE's priority. These are instances of the independence of the regulator being compromised by government and they require the remedy (structured independence) advised and already accepted by the Japanese government.[6] The restructuring of the UK Nuclear Inspectorate, when no defect in their performance has been described, appears to be taking place ahead of legislation.[7]

In this context, it is important to note that action by terrorists is excluded from the Stress Tests proposed by the European Council and that the exclusion was at the insistence of the British Government.[8]

Other experts who postulate nuclear explosions in reactors

A Dr Webb, formerly of the United States Navy, who had worked on nuclear submarine reactors, preceded me in questioning J D Rimington on his evidence on the 'Tolerability of Risk from Nuclear Reactors' at the Hinkley Point 'C' public inquiry[9]. (Mr Rimington's document once having

been mistakenly quoted as the 'Risk of Tolerability Document'.) Dr Webb was very unpleasantly aggressive in his questioning, and I remember that I wished not to be associated with it. But the record shows that Dr Webb's assertion that nuclear explosion was possible was not disputed by Mr Rimington, nor by two senior HM Inspectors of Nuclear Installations. They treated the suggestion as incredible, but stopped short of saying that it was impossible. The NI inspectors undertook to read Dr Webb's texts, but Mr Rimington refused Dr Webb's request that he be informed of their conclusions. Dr Webb did establish that Mr Rimington was neither a scientist nor an engineer. The Tolerability of Risk document offered probabilities of a 'loss of coolant accident' but did not make clear what the consequences of such an accident could be.

The late Professor Jack Harris, FRS, FEng, was a nuclear metallurgist involved in the design of British gas cooled reactors, and a vice chairman of the British Pugwash Group dedicated to the elimination of nuclear weapons. As a supporter of Pugwash, and as a colleague in the Institute of Materials, Minerals and Mining, I was drawn to him because of his support for Ross Hesketh's position on the possibility of a nuclear explosions in nuclear reactors.[10] He and I exchanged several letters and e-mails and he confirmed that opinion, which he had already published, some years later, shortly before he died.

I worked with UK nuclear installations inspectors as HM District Inspector of Mines and Quarries when the Health and Safety Executive created a working party on management in high-risk industries, in response to the recommendation by the late Sir Frank Layfield at the Sizewell Public Inquiry. (My work included the enforcement of the Ionising Radiation Regulations.) The working party prepared a report on human error which, it became apparent, was not quite to the liking of the then Director General, Mr J D Rimington. My contribution on human error was to say that experienced managers expect it.

In retirement, I attended a seminar series at the London School of Economics and noted the response of the then NII Chief Inspector, Dr Sam Harbison, to the concern of the Association of Nuclear Free Local Authorities that a failure at a British nuclear installation could render large parts of Britain uninhabitable. He did not dispute the advice given to NFLAs. He described such failure as 'a low probability event with a high outcome'.

Until recently, I had little information about how many other Fellows of the Royal Society shared Jack Harris's view on the possibility of nuclear explosion in a reactor. Even the President of the Royal Society replied that

he had little information. Advocates of nuclear electricity generation had given me the impression that such explosion was impossible, but HSE's responses to Dr Webb's questions in the verbatim record of the proceedings of Day 59 of the Hinkley Point 'C' public inquiry at Cannington persuaded me that I was wrong about that.

Jack Harris was not the only Fellow of the Royal Society persuaded of the possibility of explosive fission in reactor fuel. It was the then secretary of the Association of Nuclear Free Local Authorities who provided me with the source of the statement by Sir John Hill when Chairman of the Atomic Energy Authority in the UK. He wrote in the house journal of the Authority in 1992

> *When the Americans chose graphite moderated water cooled piles for plutonium production they recognised that a failure of the water supply or control system could result in prompt criticality and a nuclear explosion such as happened 40 years later at Chernobyl.*[11]

Wikipedia and recent debate

Wikipedia articles, which can be edited by any person, now enjoy some protection from vandalism and are a useful source of information. Topics that are subject to peer review in science and technology journals are better sources, but often require passwords and costly subscriptions for lay readers. The Wikipedia article on Chernobyl contains the following

> *A second, more powerful explosion occurred about two or three seconds after the first; evidence indicates that the second explosion resulted from a nuclear excursion.(33)*

The expression 'nuclear excursion' appears in blue with underlining indicating that it is the subject of a separate article. The end note reference suffix (33) leads to

> Pakhomov, Sergey A; Dubasov, Yuri V; (16 December 2009). 'Estimation of Explosion Energy Yield at Chernobyl NPP Accident'. Pure and Applied Geophysics (Springerlink.com) 167 (4-5)

with a digital object identifier reference number, which leads to the complete paper with open access. The following is from the abstract

> *Comparison of estimated results with the experimental data showed the value of the instant specific energy release in the Chernobyl NPP accident to be* $2{\cdot}10^{5}$–$2{\cdot}10^{6}$ *J/Wt or* $6{\cdot}10^{14}$–$6{\cdot}10^{15}$ *J (100–1,000 kt). This result is matched up to a total reactor power of 3,200 MWt. However this estimate is not comparable with the actual explosion scale estimated as 10t TNT. This suggests*

> *a local character of the instant nuclear energy release and makes it possible to estimate the mass of fuel involved in this explosion process to be from 0.01 to 0.1% of total quantity.*

The separate article has the title 'Criticality Accident'. It states that

> *Although dangerous, typical criticality accidents cannot reproduce the design conditions of a* fission bomb*, so* nuclear explosions *do not occur.*

This represents the views of those contradicting Medvedev, Pakhomov and Dubasov, and the incompatibility of this article with the current Wikipedia article on Chernobyl is pointed out in the 'talk' page of the separate article and remains unresolved. It cannot be resolved if, by definition of 'Criticality Accident', bomb-like criticality is excluded. Resolution requires more than the begging of the question. The bomb makers could help with this, if they were not sworn to secrecy. In the meantime, laypersons like me see the debate proceeding 0.1kt of TNT equivalent at a time. We cannot be content that perhaps only 0.1% of a reactor's energy resource is acknowledged to be capable of atomic bomb-like explosion.

It is significant that the conclusion of the current Chernobyl article, that a nuclear explosion occurred approximately equivalent to 10 tonne of TNT, is not contested by any recent edit. A perusal of earlier versions shows that there has been no contest for at least the last six months. Edits of other detail have been made at the rate of up to ten per month.

What the judges said

Mr Justice Sullivan, in the High Court on 15 February 2007, ruled that the UK government's second consultation on energy policy was 'seriously flawed' and thus 'unlawful'. There had been no consultation at all, he said, because the government had provided information 'wholly insufficient for the public to make an intelligent response'.[12] In fact, the government had also blacked out the economic data in papers obtained by the provisions of the Freedom of Information Act.

The conclusion in HM Chief Inspector's Final Report on Fukushima that there is no reason to desist from building more nuclear power stations is barely supported by the findings and recommendations of the report, some of which convey well enough the need for more information on the worst outcomes of nuclear disasters.

People who remember that employees at Sellafield were once advised by their employer to think twice about having children could be a minority by now, as are those who recall that we once had public inquiries into all the

controversial and unresolved societal aspects of nuclear industry matters. Loss of habitation and infrastructure, loss of habitable land, loss of agricultural land, of clean water supplies, of animals and plants and their genetic integrity are hardly mentioned in the Tolerability Document . Similarly, more explicit and quantified accounts of harm are required of the Environment Agency when appraising new processes and the releases to the environment that will occur. Changes initiated by the Blair Government have made public inquiries unlikely as part of the 'fast track' process of 'New Build'.

Misleading information

'Safety is no longer an issue' was the statement volunteered by David Cameron as leader of the opposition to Tony Blair as Prime Minister in a 2006 debate on nuclear energy policy. No doubt Tony Blair was grateful at the time, but both can now regret that they made themselves hostages to the misfortune of Fukushima Dai-ichi. They should have known the vulnerability of reactors and spent fuel stores to loss of power supplies.

The publication of several photographs of an interim nuclear waste storage facility at shallow depth, wrongly described as an underground disposal facility, is an uncorrected example of the last government's attempt to support its assertion that 'solutions' exist for waste management problems.[13] My review of *Geological Repository Systems for the Safe Disposal of Spent Nuclear Fuel and Radioactive Waste* was published in *Materials World,* the journal of the Institute of Materials, Minerals and Mining.[14] I found that the papers by the 23 author teams and the two editors of this 750 page book did not concur that we have solutions for the management of highly active spent fuel waste. They made clear that nowhere in the world does a functioning geological depository for such waste exist, and the authors express caution rather than consensus on the likely availability of a depository for safe long-term containment.[15]

'The AP1000 is the safest and most economical nuclear power plant available in the worldwide commercial marketplace.'[16] A separate invalid claim made by the Westinghouse Company that the AP1000 reactor exists as 'a proven design already built elsewhere in the world' is dealt with in my booklet *Nuclear New Build – a Review of the Issues* at page 43.[17] A third invalid claim that the AP1000 reactor exists, this time by the Nuclear Industry Association endorsed by government, provides detail:

> *The Application sets out in detail the technical features of the AP1000 ... that the nuclear systems are located in the shield building/containment vessel and in the auxiliary building. These buildings are robust and shielded where necessary to ensure all radioactive substances are always secure.*[18]

The AP1000 reactor does not exist, and its prototype AP600 was never built. It strains belief that such false statements were sufficient to found Tony Blair's policy of building ten non-existent reactors as a 'fast track' programme to mitigate global warming. In the last five years the company has been unable to submit an acceptable design to the Nuclear Inspectorate and, since Fukushima, has retreated from the Generic Design Assessment (GDA) process for lack of funds. Mendacity as a characteristic of the nuclear industry appears to have extended itself into government. The fact that it does not insure itself for more than 1% of the potential claims carries it own message about nuclear safety.[19]

The argument that global warming and climate change require the pursuit of low carbon electricity is sound. That nuclear electricity is the only way is contradicted by the 2002 Energy Review, which found renewable energy available and sufficient for reasonable economic growth. We have lost a whole decade in developing those resources with the vigour that was needed, and capital investment now in 'new build' can only delay the benefit of benign renewable energy. Tony Blair's reasons for rejecting the 2002 Energy Review, when the industry was far from ready for expansion, remain to be explained.

Public Inquiry

The gist of this article is that the principal recommendation of the Dr Weightman's Final Report on Fukushima, that he sees no reason to curtail the operation of nuclear power plants and other nuclear facilities in the UK, is not supported by the findings and recommendations of the report, which acknowledge a failure to describe the potential worst effects of loss of control of reactors and other facilities.

The Secretary of State was quick to use the report as validation of his Statutory Justification decision of new build – that the benefits will outweigh the detriments. Parliament may not agree, and it would be prudent of the Secretary of State (who is personally opposed to new build) and the government, if they wish to enjoy the confidence of the public, to initiate a public inquiry to re-assess the detriments of nuclear power generation. In the absence of a public inquiry, Greenpeace's application for judicial review of the Justification decision will surely find many more supporters.

References

1 ‘Emails released under the Freedom of Information Act reveal the level of coordination between government departments and the nuclear industry during the Fukushima crisis’ ‘We must work together on this and have a very strong co-ordinated message’ (The e-mail author’s name redacted) Guardian 30 6 11
2 *The Legacy of Chernobyl* Zhores Medvedev Page iv Spokesman Books.com 2011 £19.95
3 *The Tolerability of Risk from Nuclear Power Stations* Proof of Evidence by J D Rimington, Director General of the Health and Safety Executive, to the Hinkley Point ‘C’ Public Inquiry. Annex 1 to Inquiry Document Reference HSE 1.
4 ‘The unpalatable truth is that the anti-nuclear lobby has misled us all’ *The Guardian 5 9 11*
5 Statement by Judith Hackett when opening the Nuclear Division conference on 17 July 2009. She said ‘It is essential that we build and maintain public confidence in a safe nuclear future – and an independent regulator is an essential element of that.’
6 *The Guardian* 16 8 11 Editorial ‘After Fukushima – Nuclear Dirty Tricks’ (in which Angela Merkel is described as one of the few political leaders who is also a scientist)
7 Gifford, C *Nuclear New Build – a Review of the Issues* p36 Spokesman Books Dec 2010 £6-00 The Bertrand Russell Peace Foundation Russell House Bulwell Lane Nottingham NG6 OBT 0115 9708318.
8 Leigh Phillips writing in *The Guardian* 26 5 11
9 Transcript of Proceedings of the Inquiry on Day 59, 31 January 1989, pp96-107 on the cross-examination of Mr J D Rimington, Director General of the Health and Safety Executive. Social Studies Library The University of Wales, Colum Road, Cardiff UK.
10 *Ross Hesketh* Jack Harris in *Materials World* a journal of the Institute of Materials, Minerals and Mining, June 2004 London
11 *Atom* No 421 March 1992, page 7
12 The High Court 15 February 2007 in Judicial Review on the application of Greenpeace and others of the government’s second consultation on energy policy.
13 In the government publication ‘Managing Radioactive Waste Safely – a Framework for Implementing Geological Disposal’ June 2008 three photographs illustrate ‘an underground disposal facility’. The photographs are of the Swedish Forsmark facility which the developers SKB describe as ‘an interim storage facility at shallow depth.’ Was this three innocent mistakes by government or another dodgy dossier?
14 February 2011
15 My paper *Geological Disposal of Nuclear Waste was* presented at a meeting of

the Wales Branch of the Institute of Materials, Minerals and Mining on 16 September 2008 at the Cardiff University Department of Earth Sciences. 28pp 58 end notes. It is posted on the website of the South Wales Institute of Engineers Educational Trust http://www.swieet2007.org.uk.

16 From the Westinghouse website.

17 Gifford, C *Nuclear New Build – a Review of the Issues* Op cit.

18 *The Justification of Practices Involving Ionising Radiations Vol 2*, p23, DECC Nov 2009. The Application mentioned is that by the Nuclear Industry Association to justify new nuclear power stations.

19 My response to the DECC Consultation on the Revision of the Paris and Brussels Conventions on Nuclear Third Party Liability 20 April 2011.