The Ecologist

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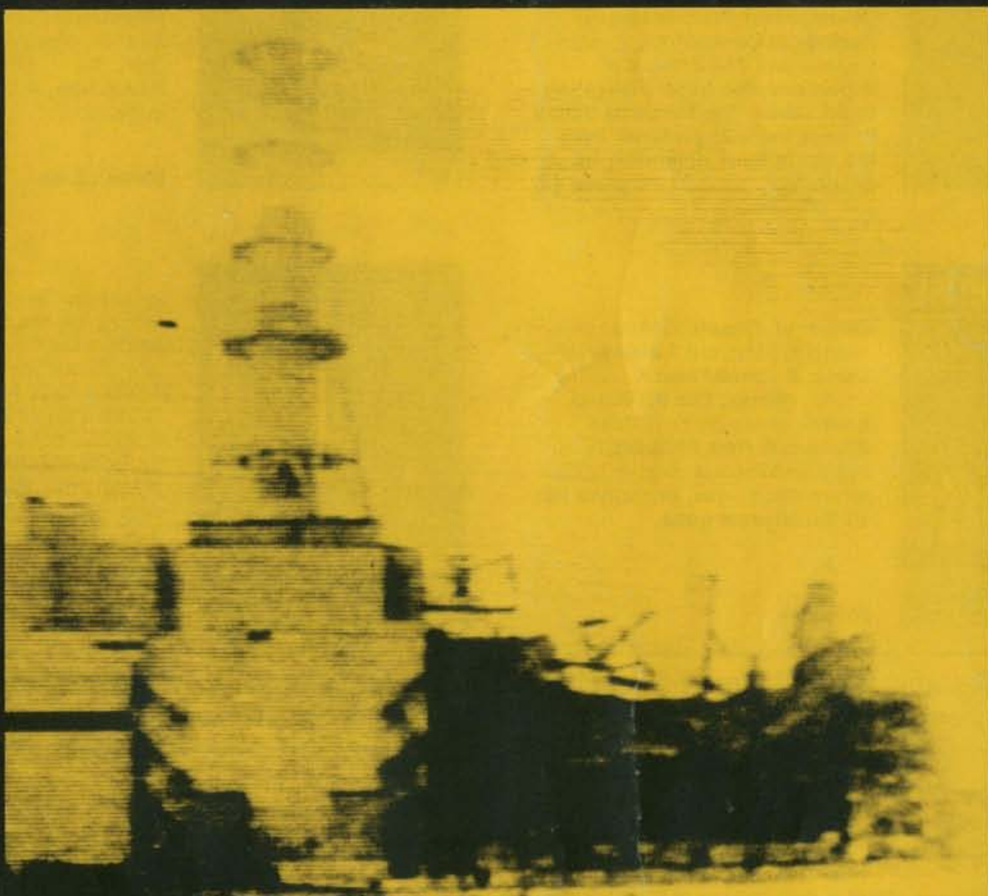
CHERNOBYL
The End of Nuclear Power?



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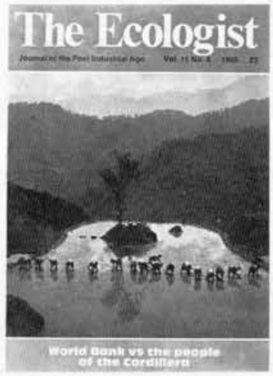

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Cover Design: Nigel Rae
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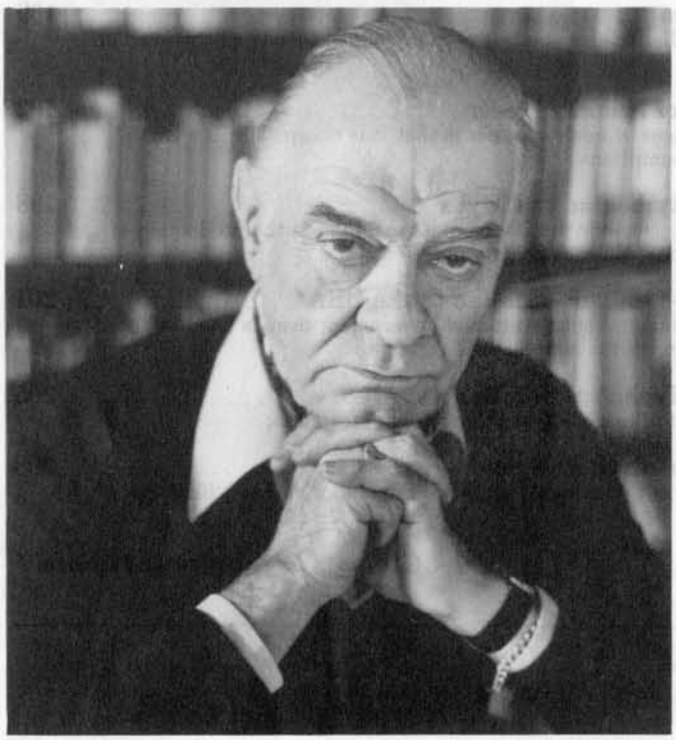
Contents page continued

OBITUARY

Denis de Rougemont, the famous Swiss thinker and writer and chairman of Ecoropa (Ecological Action for Europe), an organisation with which we are all closely associated, died on the 6th December 1985 at the age of 79. He was born on the 8th September 1906, the son of a protestant minister, at Neuchatel in Switzerland, also the birthplace of the great Swiss philosopher, biologist and psychologist, Jean Piaget.



To the French speaking public he will mainly be remembered for his famous book "Amour et Occident" (Love and the Western World) which he wrote in 1939. For environmentalists in the French speaking-world, Denis de Rougemont is mainly known for his book "L'Avenir Est Notre Affaire" (Paris, Stock, 1977) which provided a bold and comprehensive statement of what the Club of Rome calls "The Predicament of Man".

He will also be remembered as an inspiring teacher, as all those who studied with him at L'Institut d'Etudes Europeennes in Geneva, fully recognise.

Throughout his life, his main preoccupation, however, and the principal theme of most of his writings was the unacceptability of the nation state and the need to create a Europe of the regions in which local people take government into their own hands and bypass national governments whose policies are invariably destructive.

He carried on his work to the end. I visited him in hospital a month before his death. His mind was still that of a young man. His preoccupation with the terrible problems that our world faces today was undiminished, and his analysis of the causes as clear as ever. In spite of all his remarkable achievements, he felt that his work was still unfinished. There were another seventeen books he still wanted to write and only hoped that he could live long enough to finish some of them. Unfortunately, this was not to be.

A man of such wisdom, erudition, and commitment will be hard to replace.

Edward Goldsmith

Facing Facts — Now or Never

The British Government's reaction to the Chernobyl accident has been totally cynical. Opinion polls taken since the accident have been explicit in telling the nuclear industry and those in government that the public wants no more of nuclear power. Yet in Britain, Peter Walker, the Secretary of State for Energy, has made it clear that the government's commitment to nuclear power is as firm as ever.

Just two months to the day after the Chernobyl explosion Peter Walker told the Engineering Employers' Federation in London that "If we care about the standards of living of generations yet to come, we must meet the challenge of the nuclear age and not retreat into the irresponsible course of leaving our children and grandchildren a world in deep and probably irreversible decline." A few days later, on 31 July, Lord Marshall, Chairman of the CEGB, proclaimed at a press conference that without nuclear power Britain would be plunged into power cuts and shortages in the years to come.

But who is being irresponsible? The idea that the world will suffer an energy famine unless nuclear power provides at least 15 per cent of total energy in 2030, as stated by Peter Walker, is arrant nonsense. To begin with the CEGB has considerable surplus generating capacity, mainly in the form of older coal-fired stations and new oil-fired stations. Secondly, nuclear power provides us with a mere 4 per cent of our total energy requirements.

Thirdly, as we point out in this special issue of *The Ecologist*, a rational alternative exists to the use of nuclear power. Britain has massive coal reserves (p210), which with fluidised bed boilers, could be used without causing intolerable environmental damage. The technology also exists for providing our electricity from combined heat and power (CHP) generators (p213), of which many are already in operation. Also massive savings in energy can be made through energy conservation (p217).

Nor is it true, contrary to what has been claimed by Mr Walker and Lord Marshall, that nuclear electricity is cheap electricity. It is not. In 1981 we (The Wadebridge Ecological Centre) set up a committee under the chairmanship of Sir Kelvin Spencer, chief scientist at the Ministry of Power in the 1950s, to examine the economics of nuclear energy. The committee's findings, which we published in *The Ecologist*, were unequivocal: the CEGB had used a fraudulent accounting system to make nuclear power appear cheaper than coal. Although the CEGB has now adopted our figures on costs, it continues to promote the myth of cheap electricity (see p194). In reality, nuclear power is prohibitively expensive. That is why it has been virtually abandoned in the USA, where, since 1977, there have been no new orders for reactors and, indeed, where over one hundred have been cancelled. If we remain committed to nuclear power, it is not that we can build and operate reactors more cheaply than can the Americans, only that, in the US, they are built by private companies which are responsible to their shareholders, whereas, here, it is the taxpayer who must pay—although he is not told how much.

Quite apart from being expensive and uneconomic, nuclear power is an unsustainable form of energy supply. As Mr Walker himself reminds us, thermal reactors have a limited future given that a large nuclear power programme would soon consume the world's economic reserves of uranium. That leaves the fast breeder reactor, which, in theory, can multiply energy reserves some 60 times through breeding plutonium from non-fissile U-238. But this would only be true if we could master, which we have not yet done (see p198), the daunting technological problems associated with the reprocessing on a commercial scale of the highly radioactive wastes from breeder reactors. Any loss of plutonium in the fuel cycle drastically threatens the efficiency of breeding and will inevitably contaminate the environment with one of the most dangerous radiotoxins known to man.

However, it is the inherent danger of nuclear power that makes it wholly unacceptable. Given the terrifying consequences of a major nuclear accident, no one can carry out proper "destruct experiments" on nuclear reactors: instead, probabilities of accidents and of their outcome have to be assessed theoretically. This has enabled the nuclear lobby to make the wildest claims—for instance, that the chances are more than a million (or even ten million) to one against the occurrence of a serious accident. Such claims have now been totally discredited. Indeed the Nuclear Regulatory Commission (NRC) estimates that before the end of the century, there is one chance in two that a serious nuclear accident will occur in the United States.

Since the US possesses about one quarter of the world's nuclear reactors, we can, on those calculations, expect that a serious accident will occur in the world as a whole every eight years. In reality, they seem to be occuring that often. The Windscale Fire of 1957 whose real consequences have been hidden from us for so long, Three Mile Island in 1979 which was a hair's breadth away from disaster, and Chernobyl in 1986, have all occurred within the last thirty years.

Significantly, the prestigious journal *Nature*, like the NRC, no longer contests the inevitability of serious accidents. "The important question", it tells us, "is not so much how accidents like these (Chernobyl) can be prevented *but how we can live with them safely*?"

But how can we "live safely" with machines whose breakdown, as with that of the Chernobyl reactor, can lead to the contamination, with highly carcinogenic radionuclides, of an area inhabited by more than five hundred million people, a breakdown, moreover, which might have been incomparably worse?

Indeed, as Dr Richard Webb reminds us (p 167), although the accident led to the vaporisation of only 5 to 15 per cent of the reactor's core, that was enough to contaminate many parts of Europe with levels of radioactivity that were five times higher than those attained during the above-ground testing of hundreds of nuclear warheads in the 1950s and 1960s; and we must not forget that it was largely because of the contamination that such testing caused that it was eventually discontinued.

The seriousness of the Chernobyl accident and the absurdity of the idea of being able "to live safely" with future ones like it is best gauged by Richard Webb's estimate (p 169) that, on the basis of exposure to gamma radiation alone, Chernobyl could lead to the deaths by cancer of an extra 280,000 people over the next thirty or forty years.

Our Government, and the rest of the nuclear lobby, assures us, of course, that the Chernobyl accident could not conceivably happen here. It claims that our reactors are intrinsically safer than the Chernobyl reactor, described derogatively by Lord Marshall as a "chimaeric hybrid", and for which there was no containment vessel such as had prevented a major radiation release from the Three Mile Island Reactor in 1979. Richard Webb, however, who, for the last fifteen years has been studying the 'explosion potential' of reactors (p164) points out that the light water reactors we use in the West (and for which the CEGB has sought planning permission) are very much more dangerous than the type of reactor which blew up at Chernobyl. Indeed, an explosion in a BWR or PWR could easily burst open any containment now in use. Worse still, Webb calculates that fast breeder reactors have the potential for causing not only chemical explosions but *atomic* explosions too (p 166)—a terrifying thesis that the nuclear industry has yet to rebuff.

How are we supposed to live 'safely' with such machines? Why, in Heaven's name, should we be made to try? The only possible outcome of such an experiment would be the systematic contamination of our planet, rendering it ever less fit for human habitation. Indeed, if we have any sense of responsibility to our children and grandchildren, we must not rest until we have ensured the closure of our entire nuclear industry. When we consider what is at stake no other solution is conceivable.

The Editors

Political Statements on Nuclear Power

The vested interests in nuclear power have always given it a powerful pull on politics. While the present government's support for nuclear power, despite its shaky economics, have been transparent from the beginning, Labour's has wavered, and the party is now divided over whether to phase out nuclear stations as part of policy. Here are some comments. While Rob Edwards gives a rundown of party reactions post-Chernobyl, Tony Benn, Energy Minister in the last Labour government, gives some idea of the pressures on the government to succumb to the nuclear lobby. He himself has the dubious distinction of having been the last minister in power to order nuclear power plants. Meanwhile as Malcolm Bruce, Liberal spokesman for energy, points out, Liberal policy has been consistent even before Chernobyl and has demanded the phasing out of nuclear power in Britain.

Chernobyl: The Political Fall-Out

by Rob Edwards

Nuclear power has always been a uniquely awkward issue for the major political parties. It does not fit comfortably into any of the old-fashioned moulds which our politicians have traditionally used to shape their ideologies. It cannot easily be classified by capitalists, class-warriors or centralists. It splits most political parties as readily as it splits atoms.

This was always so, although only pro- and anti-nuclear devotees would have known or cared. But now, post-Chernobyl, everything has changed. Political leaders have to answer embarrassing questions on television, party spokespeople have to know what they are talking about at public meetings and party activists have to argue and agree realistic policies at conferences. All are now aware of the intense public concern about anything nuclear.

This makes it impossible—or at least very difficult—for politicians to indulge in one of their favourite pastimes: policy-fudging. The disagreements which characterise internal party discussions are almost certain to come out into the open. Cracks cannot be so easily papered over, deals cannot always be done behind closed doors, and compromises thrashed out in private may not remain so. Chernobyl has turned on the political heat.

The results, for the most part, have been rather depressing—nowhere more so than in the Conservative Party. There used to be a small but articulate anti-nuclear power lobby amongst Tory MPs. Where has it disappeared to? The only Tory cry heard since Chernobyl started spewing its lethal radioactivity all over Europe is the surreal screech of the rabidly pro-nuclear Thatcherite.

The Prime Minister Mrs Thatcher herself was quick to profess her unbounded confidence in the "absolutely superb" safety record of the nuclear industry in Britain. She refused to even consider delaying the start-up of Britain's newest nuclear power station at Torness in East Lothian, saying she had complete faith in the Government's safety watchdog, the Nuclear Installations Inspectorate.

Thatcher originally betrayed her mania for nuclear power immediately on coming to power in 1979. In September of that year she travelled to the Dounreay Nuclear Power Development Establishment near Thurso on the northernmost coast of the Scottish mainland to open a new fast reactor reprocessing plant. She made a point of standing on top of the Prototype Fast Reactor core and saying to the assembled television cameras: "You see, nuclear power is perfectly safe."

For her and her acolytes, Chernobyl has changed nothing. More than anyone it is her Energy Minister, Peter Walker, who has faithfully and forcefully banged the nuclear drum, perhaps hoping that if he makes enough noise the British people will forget about the horrible reality of what happened in the East.

Initially his favourite ploy was to attack the Russians for the appalling secrecy with which they attempted to smother the disaster. Setting aside its hypocrisy (it took 26 years for the British authorities to reveal the truth about Britain's worst nuclear accident at Windscale in 1957), this line became untenable as the Soviet Union decided to end its traditional silence on major disasters by speaking openly about Chernobyl.

With the zeal of a bible-thumping missionary, Walker then set out to bring back to the nuclear fold the fearful and timid whom Chernobyl had frightened away. For the benefit of the evening news broadcasts, he visited the Sellafield reprocessing complex in Cumbria and sang its manifold virtues. According to *The Daily Telegraph*, he bowled over the Conservative women's conference in Westminster by telling them that he was not going to abdicate his responsibility to his five children to make sure that they and their children were provided with a reasonable supply of energy during their lifetimes.

At the end of June, he delivered a well-trailered "keynote address" to the Engineering Employers' Federation in London. If we failed to meet the challenge of the nuclear age, he said, we will "retreat into the irresponsible course of leaving our children and grandchildren a world in deep and probably irreversible decline."

He argued that the world's energy demand was going to increase by two per cent per annum in line with an expanding population and spreading industrialisation. Oil reserves would run out between the years 2040 and 2065, gas between 2056 and 2066, and coal between 2066 and 2076. But, says Peter Walker, "there is no such problem about the world supply of the cheap form of uranium for years to come."

He, like every nuclear advocate since the 1950s, hangs his hopes on the fast breeder reactor. The fast reactor, he claims, "would allow the power extracted from uranium to be raised by more than sixtyfold." It would mean that Britain's existing stocks of depleted uranium could be used to create as much energy as that contained in all its technically-recoverable coal reserves.

It's a tired old story, no more convincing or credible for its constant repetition. The speech was widely interpreted as signalling ultimate Government support for the Central Electricity Generating Board's plans to build a series of American-style pressurised water reactors beginning at Sizewell in Suffolk, regardless of the verdict (expected this autumn) of Sir Frank Layfield's two and a quarter year public inquiry. It probably also confirms the Government's intention of giving the green light to the nuclear industry's madcap notion of building a large scale European plutonium fuel reprocessing plant at Dounreay, currently the subject of a local planning inquiry. The Tories, without a doubt and without any hesitation, want to launch us gleefully into the plutonium economy.

Labour's Chernobyl-induced crisis was something different. There had been growing tensions in the party ever since its annual conference last year agreed by 3.9 to 2.4 million votes to a toughly-worded anti-nuclear motion calling for "a halt to the nuclear power programme and a phasing out of all existing plants." Some of the unions with members in the industry—notably the engineers (AEU) and the electricians (EEPTU and EPEA)—were anxious about losing jobs. Some MPs—notably the front-bench environment spokesperson and Sellafield MP, Dr John Cunningham—were anxious about losing votes. There was behind-the-scenes talk of a campaign to reverse last year's decision.

The response of Labour's hierarchy was to pretend the problem did not exist. The Shadow Cabinet and the National Executive Committee never discussed it and, in contrast to most other major policy areas, no special committee was set up to deal with energy. Hence, the inevitable result of Chernobyl was chaos.

Within an hour of one another the weekend after the accident became public, the party's environment and energy spokespeople managed to come up with diametrically opposing versions of Labour's policy. Cunningham said that Britain needed to retain the nuclear option: Stan Orme MP said that it should be phased out. Worse, Labour leader Neil Kinnock put up a shambolic performance on TV in which he appeared confused about key aspects of nuclear power policy.

The public, as the *New Statesman* commented at the time, "were left with the impression of a party completely at sea". In an attempt to resolve the problem, the Shadow Cabinet set up a special committee chaired by Stan Orme. The results of its hasty deliberations, released in late May, were broadly welcomed by anti-nuclear groups including Friends of the Earth and Greenpeace.

For the first time there was an explicit promise that the next Labour Government will not build any more nuclear power stations. There was express opposition to the introduction of a commercial fast breeder reactor and a specific commitment to "immediately halt the production of weapons-grade material from whatever source". There were also a series of worthy statements about cleaner coal, the introduction of combined heat and power, improving energy efficiency and the development of renewable energy sources.

Predictably, the Shadow Cabinet document sidesteps some of the more difficult issues. There is no commitment to shut down any of the old Magnox reactors, merely a promise to publish their safety reviews and decommission those which "have reached the end of their life". It's not even certain whether a Labour Government would close down the two oldest Magnox stations at Calder Hall in Cumbria and Chapelcross in Dumfriesshire, despite the fact that they are both known to produce plutonium and tritium for nuclear weapons.

It also appears to accept that the reprocessing of Magnox spent fuel at Sellafield is necessary and only promises an "economic reappraisal" of the new generation reprocessing plant (THORP). That there are alternatives to reprocessing are not discussed. Nor is there any mention of the second generation advanced gas-cooled reactors, including that at Torness in Scotland and at Heysham near Lancaster.

The Shadow Cabinet document is far from being Labour's last word on the subject. Only a few weeks after it was published, an alarming ambiguity over the planned Dounreay reprocessing plant (it should not be built "without a full public inquiry", it said) was superceded by clear statements from Kinnock and Orme that a Labour Government would abandon the scheme.

There is still some distance between last year's conference motion and the Shadow Cabinet position, and debate at this year's conference in Blackpool is bound to be fairly heated. The Trades Union Congress, historically pro-nuclear, is also due for some fascinating discussions. With the local government union, NALGO, and possibly other unions joining the anti-nuclear camp, it is likely that the TUC itself could be won over.

All this makes it difficult to predict precisely what will end up in Labour's election manifesto and even more difficult to foresee what a Labour Government might actually do. However, hastened by Chernobyl, it

Liberal Policy on Nuclear Energy

by Malcolm Bruce

A number of recent events have brought nuclear power into question. Most spectacularly, the Chernobyl disaster has brought home to the public:

(a) that an accident at a nuclear power station is different in character and long-term effects than any other industrial accident;

(b) that the UK being crowded islands would suffer worse catastrophe than the Soviet Union and the authorities have no emergency plans that could operate fast enough.

Prior to Chernobyl there has been concern at leaks at Sellafield, criticism by the House of Commons Environment Select Committee of reprocessing and waste disposal options and widespread public opposition to the NIREX proposals for tests into sites for dumping nuclear waste.

The Liberal Party has been critical of UK Energy policy for many years. The scramble for oil from the North Sea lost a great many opportunities for UK industry. The expansion of the nuclear industry has been railroaded through by both Labour and Tory Government without alternative options being taken seriously or given fair and equal treatment. Only the Liberals have consistently opposed the expansion of the nuclear industry.

The case for nuclear power has rested on the claim that it is clean and cheap. In fact it is neither. It is difficult to get to the bottom of the economics but it is a fact that it has been expensive. Much of the Research and Development has been subvented from the defence budget and the Atomic Energy Authority. There has been expensive delays at Dungeness B and Hunterston B.

And many reactors have had to operate below their design maximum temperatures.

Nuclear power is not clean. Chernobyl proved that. There is concern at leukaemia clusters round Sellafield and Dounreay. There is a real and intractable problem of how to deal with nuclear waste.

We are not impressed with the antics of Tory MPs including the Government Chief Whip who are campaigning against NIREX plans for tests for waste disposal in their constituencies while supporting reprocessing and the expansion of nuclear power. If there is no acceptable means of disposing of waste we should stop making it.

The whole strategy of building massive power stations should now be questioned.

Strategically it leads to security problems of a major failure. It requires a long lead time. It leads to substantial over-capacity. Usually it's the wrong fuel type which is why we have surplus oil capacity and an argument between AGRs and PWRs.

We have little doubt that it is possible within known technology to produce a non-nuclear energy strategy for the UK—and even the world. Given Government backing, we believe a non-nuclear energy strategy is likely to prove cheaper and more publicly acceptable than nuclear power.

The energy establishment is now dominated by an obsessional, irrational commitment to the further expansion of nuclear power. As a result, development of conservation energy efficiency measures and alternative energy sources has been stifled. Indeed it now appears just as an alternative idea starts to look viable, the establishment pull the plug on it.

Conservation and energy efficiency measures could save 25 per cent or even 30 per cent of energy. This alone would remove the need to build *any* new major power stations of *any type*, nuclear or other.

Government grants for energy conservation and efficiency are inadequate. The threshold has been set too low and the application too restricted. As a result the take-up of allocation in recent years has only been about ⅔. Instead of increasing the grants and widening the scope to ensure take-up, the Government have just cut the allocation.

Alternative energy is not just a pipe dream. With commitment we could make rapid progress.

Solar power, heat pumps, wave power all have potential. Britain's wave power researchers are angry at the way they are treated. Each time they lowered the projected costs they were asked to aim even lower. The efficiency was applied to whole areas instead of concentrating on hot spots where tidal potential was greatest. The British research was wound up just as the Norwegians were moving to commercial prototype.

Tidal barrages on the west side of Britain could generate electricity equivalent to several power stations.

James Howden's Government-backed experimental wind turbine in Orkney has opened the door to £30 million export orders—but not the UK market e.g. Western Isles, Falklands or elsewhere in Scotland. Denmark has won £250 million of export orders from its wind technology even though Scotland has greater potential.

Geothermal energy tapping hot rocks below the earth's crust has significant potential. Interestingly one of the potential product areas is around Sellafield.

Combined Heat and Power also has substantial potential. Its expansion is being held up by the restrictive attitude of Government. The most immediate potential is in hospitals and public buildings but the electricity industry itself should be installing these instead of building massive, unnecessary new power stations. Promoters of mini-power stations claim they are cheap and efficient—effectively producing the same amount of heat as a gas boiler system but 25 per cent of its output is effectively free electricity. They could be installed in small domestic schemes as few as 50 houses. The net additional cost is slightly more than £500 per house—but the homes will save £150 a year on their electricity bills, giving a pay back over less than four years.

Biomass using vegetable matter as fuel could not only prove efficient but might usefully help solve the problems of CAP food surpluses. Farmers could benefit from fuel cash crops. Work has been done on this but it requires backing and co-ordination.

Alternative energy sources will change the character of power generation—with fewer large power generating installations and more, varied, diffuse forms of power generation.

We believe Britain's scientists and engineers can respond to the challenge of alternatives. They will not only meet Britain's energy needs, they will have substantial benefits in jobs and export opportunities. This will be more widely spread throughout Britain—but especially in the older industrial areas. We believe this strategy might create three times as many jobs as the nuclear power industry because of the export potential.

Malcolm Bruce is the liberal spokesman for Energy.

is clear that an important sea change has taken place. Labour is no longer a pro-nuclear party: the only argument is over how anti-nuclear it is.

Of all the parliamentary parties, it is probably the Liberals which emerge from Chernobyl with the most respect. They have consistently opposed nuclear power for social, economic and environmental reasons and did not need to dither around in search of suitable policies. They took advantage of the situation in June to launch a major national campaign to phase out nuclear power in Britain over a period of 10-15 years. They are committed to abandoning Torness, Sizewell and the Dounreay reprocessing plant.

However the Liberals do support the need for continued research into nuclear energy. While this is undoubtedly going to be necessary to try and cope with the enormous long-term problems involved in decommissioning reactors and disposing of readioactive waste, there could be a catch. It could be designed as the loophole which will enable them to reconcile their deep differences with their distinctly pro-nuclear Alliance partners, the Social Democratic Party.

Before the last general election in 1983, the Liberals and the SDP hammered out an energy policy based on the most cynical of compromises. It was overwhelmingly negative about nuclear power, specifically promising the cancellation of Sizewell, yet it spoke almost enthusiastically about the potential of the most dangerous type of reactor, the fast breeder. The reason for such schizophrenia was the powerful position of the SDP's leading nuclear fanatic, Robert MacLennan, the MP for the area round Dounreay where most peoples' livelihoods depend on the continuation of fast reactor research work.

The danger is that a similar kind of deal is worked this time around, effectively castrating the Liberals' principled stand. At the time of writing, the SDP had not even formulated their energy policy, though it is difficult to envisage it abandoning support for Dounreay. Thus, unless there is major fission in the Alliance, it is hard to imagine its joint manifesto for the next election containing anything that could be described as a consistent or sensible anti-nuclear policy.

That leaves the very admirable policies of the minor parties: the Scottish and Welsh nationalists and the fledgling Greens, all of which have long had the wisdom to disdain anything nuclear. Setting them aside, it is possible to draw one broadly encouraging conclusion about the outcome of the next general election.

Any result, barring an outright Tory victory, could prompt a welcome and important change of direction in Britain's nuclear power policy. If it has done anything, Chernobyl seems finally to have broken the crass cross-party consensus that has closeted nuclear power since the 1950s. We can look forward to the cancellation of Sizewell, a greatly enhanced nuclear scepticism and—who knows?—perhaps even a declining dependence on nuclear electricity. If the Tories get back in, we had better start learning how to love radiation.

Rob Edwards *is a journalist with the New Statesman.*

TOWARDS THE END OF NUCLEAR POWER

by Tony Benn

The change in public attitudes towards the use of nuclear power has been quite remarkable over recent years, and it may be a good time to step back from the controversies of the present, to review the factors that have played a part in bringing about this change.

In 1945 when the first atomic bomb was dropped on Hiroshima and Nagasaki, few people realised the true meaning of what had happened, and public comment in the west consisted mainly of expressions of relief that the war was over and that the bomb had, by shortening the war, saved lives.

It is only recently that we have learned that the Japanese Government actually offered to capitulate weeks before the bomb was dropped, and that one of the real reasons that it was used was to warn the Soviet Union of the supremacy of Western weaponry.

Then during the years of the US monopoly of the atomic weapon there was very little political interest in the subject, and very little protest, and it was only when the Russians detonated their first bomb, and after the first hydrogen bomb tests in Bikini, that anxiety in the West grew and the anti-nuclear movements began to surface.

The link between nuclear weapons and nuclear power

In 1955 President Eisenhower launched his *Atoms For Peace* initiative and it caught the public imagination as the greatest example of beating swords into ploughshares, and was widely accepted as such all over the world.

But we now know that civil nuclear power has always been a cover for nuclear weapons development, and this has been just as true for Britain and the USA as it was for the Shah or the Israelis.

For the technology to make the bomb is so closely linked to the development of power stations that it is impossible to disentangle them since it is the nuclear power programme which produces the plutonium needed for the bomb.

In the interval the evidence of this sinister connection grew as people began to piece together the information that came to light.

There was the theft of the uranium from Europe that ended up in the Israeli reactor at Demona; and the supply of uranium for the AEA from Namibia which was bought from there because no end-use safeguards were demanded by South Africa.

Then there was the West German deal with Brazil which many suspected would help that country to develop its own weapons programme.

India and Pakistan, China and France also tested atomic weapons, and it became clear that the non-proliferation treaty was unworkable, and indeed that there were no real international safeguards of any kind.

The myths of non-proliferation, safeguards and safety

These supposed IAEA safeguards being based on no more than a rough and ready monitoring system were seriously defective, and in any case, could only be enforced by political action, action that the signatories to the Non Proliferation Treaty (NPT) might not be ready to take if the offender was an ally or an important customer.

The next factor that came into play was the growing anxiety about the safety of nuclear installations as accidents began to occur, and it became clear that many of them were being hushed up.

The explosion at the Soviet reprocessing plant in Kyshtym in 1957, was very serious indeed, but though the Americans knew all about it they gave instructions, through the CIA, that this information was not to be passed to ministers in Britain, lest it lead to public opposition to the nuclear industry and arms programme.

The leaks at Windscale were also far more serious than the public was ever allowed to know and, in one case, were not fully reported to me at a time when I was the responsible Minister.

Then came Three Mile Island and other examples of defects in design and construction, factors which had also delayed the building of power stations like Dungeness B, which was years late in coming into service.

There was corrosion and spillage, and at least one example of minor sabotage at Winfrith, which led to the police being called in and the appointment of Chief Inspector Chitty to investigate reporting that the damage had been done by a disaffected employee.

Meanwhile, in the USA, public opposition to the nuclear power station programme became so strong that not one public electricity company has ordered a PWR for eight years, believing them not to have proved economic, and also concluding that the strong campaigns against from local people made them politically unacceptable.

The myth of cheap power

This, in part, opened up another area of doubt, and that was about the alleged cheapness of nuclear power, which had been introduced almost as if it would usher in an era of free electricity.

In the event the economic calculations upon which all these arguments were based turned out to be wholly suspect as we realised, when we learned that many of the research and development costs were actually borne by the Defence budget (for obvious reasons) and that no proper allowance was being made in the figuring for the full cost of decommissioning old nuclear plant, or for the long-term storage of the highly toxic wastes.

Indeed it also became clear that no one had actually found a safe way of storing that waste, and thus this deadly material is still being kept above ground in zinc-lined tanks, one of which was proved to have leaked massively at Windscale in the late 1970s.

And so the story began to unfold and the campaigners against nuclear power found the evidence to support them getting stronger and stronger all the time.

Nuclear power was expensive, it was unsafe, it was linked to the manufacture of bombs, and these were spreading all over the world. The strength of those who were against it began to grow too.

The growth of the anti-nuclear movement

The environmental arguments could no longer be dismissed as the fantasies of a tiny group of hippies who knew nothing, and represented nobody.

Green candidates began to win votes and organisations like Friends of the Earth became influential and could call on expert witnesses to support them.

There were the public enquiries at which their views could be put by their own scientists and engineers, and the Sizewell hearings have brought out a great deal that had never been established before.

The most important political point that emerged was the clear proof given that plutonium, which was produced in our stations, had been going, secretly, to the USA to make the war-heads for their missiles including those for cruise missiles, some of which are now based in Britain.

This connection between nuclear power, energy policy and peace, began to be made in earnest when the miners strike started, and the Greenham Common women linked up with the miners' wives and realised that there were direct connections between their two campaigns.

The Government was using nuclear power both to beat the miners and to re-arm, and it was clear to anyone who was ready to see for themselves, that the police were as hard on the peace women as they were on the pickets.

That is also where the South African connection fitted in, and when the Prime Minister invited President Botha to stay at Chequers she was consulting him in many capacities, one of which was in his role as "By appointment Purveyor of Uranium to Her Majesty's Government".

The power of the nuclear lobby

But perhaps the greatest factor of all in shifting opinion, was the steady realisation that began to spread, that a huge secret nuclear establishment and military-industrial lobby was developing in the heart of this country and was completely unaccountable for what it was doing.

This lobby had its own policy, whoever was in office, had its own international links, could get access to endless sums of public money, and yet never allowed the public, nor Parliament, nor even the Cabinet to know exactly what it was doing.

Indeed it was worse than that, for an even stronger suspicion grew that those who headed up the lobby, at any one time, could not be relied upon to speak the truth.

It was all these factors which played some part in moving the nation, from a genuine pride in Britain's nuclear achievements, into a people that are now increasingly sceptical and opposed to any further development of nuclear power.

My own experience

That was certainly the process through which I personally passed from the day in July 1966 when I became Minister of Technology, through to 1979 when I finished as Secretary of State for Energy, right up to today, when I would like to see a halt on all nuclear developments both civil and military.

Indeed the experience of all those years has made me personally very resentful of some of those with whom I worked closely, who never told me the whole story of what was going on, and thus allowed me, in perfect good faith, to mislead other people about what was happening.

Tribute must be paid to all those who saw what it was all about from the early days, although those who would be called Greens in Britain are, and have always been found, in all parties and none.

The Friends of the Earth have had a great influence, just as Greenpeace has now.

SERA on the Labour side, and the green Liberals have also played a part in shifting opinion, though the leadership of the SDP is very strongly pro-nuclear, just as it is pro-NATO, pro-the Atlantic Alliance, and the EEC, which has a large nuclear power station programme.

Changes in trade union attitudes

With so many people employed in the nuclear industry you would expect to find that many trade unions are pro-nuclear, and two of them the EMEA and the EEPTU have been in the lead in advocating an extended nuclear programme, with the AUEW also committed to it.

By contrast, and not unexpectedly, the miners have favoured coal and opposed nuclear, but this year the largest union of all, the TGWU, which has many members who also work in the industry, voted, at its policy making biennial conference, for a halt to all nuclear work, and that means that at the Labour Conference there is a far greater likelihood of a similar vote being carried.

Last year Labour's NEC recommended the acceptance of a similar resolution moved by the National Union of Seamen, but the Conference turned it down, with the TGWU, then, voting against it.

The end of nuclear weapons will end nuclear power

But the final end of nuclear power in Britain will come from a slightly different direction and as an unexpected by-product of the election of a Labour Government pledged to a non-nuclear defence policy, and the ending of Polaris and Trident weapons programmes.

Leaving aside the problems there may be in persuading the Americans to close their nuclear bases, the real question relates to Britain's own weapons.

For with the de-commissioning of Polaris and the cancellation of Trident, the case for Aldermaston will disappear, along with the military work at Sellafield (Windscale) and Dounreay.

Then, for the first time ever, the full costs of the nuclear power programme would fall upon the CEGB, and it would be clearly seen to be completely uneconomic, and would constitute an overwhelming case for the cancellation of any PWRs that might have been ordered before the election, and the phasing out of the existing Magnox and AGR stations, as they reach the end of their natural life.

It may seem strange that a defence decision should succeed, where energy arguments have failed, but that is yet another example of the close connection between the two.

Preparing for the counter-attack from the nuclear lobby

But, having said all that, it would be most unwise for any of us to relax our vigilance in any way, since the nuclear lobby—military and civil—will also have anticipated that same scenario, sketched out above, and will have prepared their own fall-back positions some of which can be anticipated.

Their arguments could run like this:

1. We shall need a high degree of nuclear expertise to supervise the existing nuclear stations, to perfect the toxic waste disposal techniques, and, of course, to monitor the non-nuclear policy we shall be pursuing.
2. Nuclear power is essential to prevent the miners from having so much power.
3. The oil is running out and we shall need both all the coal, and all the nuclear power, that we can get.
4. Britain's nuclear skills and establishments must be seen as a major part of our industrial base with great export potential—as in re-processing—and for that reason we must not lose them.
5. In the event of all disarmament talks breaking down there must be a nuclear option open to us—thus re-entering the weapons business by the back door.
6. The Americans may even offer to buy some of our nuclear establishments which, it could be argued, would lift the cost off the British taxpayer's back, and in return, they might offer to run them for us, here in Britain.

These are some of the arguments we may hear, and if we fall for any of them there could be a huge nucler establishment working away, in secret, under some new name like the "Disarmament and Environmental Corporation", preparing for the day when yet another government more sympathetic to them is elected and they would be back in business.

All these points will need to be borne in mind if we are to remove the threat and the cost of the present nuclear technology from our society.

A programme for action

What then should we be doing now?

Below are a few pointers, more to bring the various campaigns together, than to be suggesting anything that is absolutely new.

1. We must keep up the pressure against the nuclear weapons programme, on grounds of cost, of safety, of reliability of nuclear power and we must use every opportunity to bring them to public attention.

2. We must go on demanding the truth from those in power, and use the information that is more freely available in the USA, for example, to extract the same information from the authorities here.

3. We should demand the restoration of the Energy Commission, abolished by this government, which was a forum where all the papers and the transcripts of the discussions were published and use it to boost conservation and renewable energy sources.

4. We should insist upon an energy policy that is judged by whether it meets public need effectively, and not by the crude test of profit.

5. We should link the nuclear weapons and the nuclear power campaigns much more closely together, since they raise the same issues and, as I tried to show a victory in one would carry a victory in the other.

6. Next we should try to link up with all the international movements which are engaged in the same campaigns, and especially the trade unions which represent those workers in the uranium mines, and those whose lands are being mined for uranium, or used for nuclear establishments or tests.

7. All candidates, who are standing for election to any public office, should be asked to give an unequivocal answer to questions about their stand on these questions.

8. Campaigns should be mounted inside all the political parties, to bring about a commitment to end nuclear power, and nuclear weapons, to keep the matter high on the political agenda.

These strategies would all help to keep these issues alive, at a time when some ecologists, members of the CND and other anti-nuclear movements are unduly discouraged by the arrival of cruise missiles, and the present government's apparent determination to build PWRs, all of which are being used to demoralise us.

The danger of a major nuclear disaster

What I most fear is that we shall win the argument, on both counts, because of some hideous nuclear accident, comparable to, but incomparably more serious then, the Chernobyl accident in the Ukraine.

It must be likely that, with so many nuclear devices, of all kinds, now distributed so widely throughout the world, and not always in the best trained or safest hands, there will be some disaster that will bring us all to our senses, and create an unstoppable public demand for a halt.

Mr O'Leary, the former Chairman of the Federal Power Commission in the USA, a man who later became deputy Secretary for Energy whom I met, on my last ministerial visit to Washington, said to me: "In a hundred years there will be no nuclear power in the world".

I was very surprised at that comment, coming from someone in that position, but I believe that he will be proved to be right.

The experience of reform

Those who work to change opinion and are criticised for their stand, may easily get too absorbed in the daily struggles to see the effect of their own efforts in producing the shift in opinion that is taking place.

Having spent much of my life campaigning for reform I should tell you that all such campaigns tend to follow a standard pattern.

First reformers are ignored, then laughed at, then attacked violently for seeking to undermine all that is good and true in society.

But, if the reformers stick at it, there comes a time when there is a pause in the argument, and a period of silence, while the top people quietly change their minds, hoping that no-one will notice.

Then, quite suddenly, the policy is changed, and the reforms are made; and, in no time at all, you cannot find anyone who will admit to ever having been against them, while some will actually be claiming the credit for their own foresight in having carried the change through!

Ecologists and environmentalists are just such reformers, and this is the time to plan for that complete victory which so many have worked for for so long.

The Rt Hon Tony Benn *MP for Chesterfield was Minister of Technology and Power during the 1964-70 Labour Government, Secretary of State for Industry and Energy from 1974-79 and President of the Energy Council of Ministers of the European Communities in 1977. He has written and spoken widely on nuclear matters and his evidence given at the Sizewell enquiry in 1983 was published last year as THE SIZEWELL SYNDROME.*

The Unique Dangers of Nuclear Power: An Overview

by Jim Jeffery

Professor Jim Jeffery is the man who more than anyone exposed the fraudulent accounting methods used by the CEGB in its efforts to demonstrate that nuclear power gives Britain the cheapest electricity. He was scientific adviser to the Committee for the Study of the Economics of Nuclear Electricity, set up by the Wadebridge Ecological Centre, and gave crucial evidence on the economics of the CEGB's proposed PWR at the Sizewell Public Inquiry. Here he provides a detailed overview of the inherent problems associated with nuclear power generation.

The Chernobyl disaster in the Soviet Union has heightened and justified the fears of the general public in relation to nuclear power. In its aftermath, three quarters of the population want a stop to further nuclear development, and a sizeable proportion want existing stations closed down. Even before the disaster, nearly two thirds wanted further development stopped, as a result of their, perhaps vague, perception of the relation between nuclear power and nuclear bombs, but above all from the accident record at Sellafield and Three Mile Island (TMI). The warning signs to keep off the beaches at Windscale, the clusters of child leukaemias in Seascale and near other nuclear establishments, and the departure of the seagulls (established since the Norman Conquest) from the Ravenglass estuary, have shaken peoples' faith in the omnipotence of the 'experts'. In addition the problem of the disposal of nuclear waste has at last begun to be generally appreciated, as the people of the chosen sites battle to keep even Low Level Waste out of their districts. Intermediate and High Level Waste disposal has hardly been mooted in practical terms, but the fact that further use of nuclear power means the production of more and more of these indestructible nuclear poisons is beginning to be understood.

Nevertheless the signs are that the nuclear establishment is as determined as ever to push ahead with Sizewell B and half a dozen more PWRs, in spite of everything. This will require an intensification of the campaign, which was already underway, to try to persuade people that nuclear power in the West is really 'safe'.

The following quotations[1] are typical of recent statements by proponents of nuclear power. After Chernobyl they will apply only to the superior stations of the West! (a) "Whereas the annual death risk from road accidents is one in 8,000 per person, and from being struck by lightning one in 10,000,000, the estimated risk from a nuclear accident is much less than 1 in 100,000,000." (b) "The Three Mile Island *incident* (my emphasis) . . . did not result in a single injury, let alone death. This was not chance: the emergency protective gear worked as intended."

There are a number of points to be made in connection with such statements. The first is the qualitative difference between the figures for road and lightning deaths, which are based on actual events which have happened in the past, and the *estimate* for nuclear accidents in the future. Such estimates cannot even be based on experimental evidence, because the effects are so disastrous that even a controlled experiment is unthinkable. The nearest to such an experiment which has been carried out—LOFT[2]—did not get as near a melt down as TMI. The estimates are made by computer calculations on the basis of such contingencies as can be foreseen, and cannot take account of the unforeseen factors which only appear in actual accidents, including human error which played such a large part in the TMI 'incident', and which the Russians apparently claim was behind the Chernobyl explosion. These 'estimates' are then averaged over the whole population, thus disguising the disastrous effects of an accident on the surrounding area.

It is more reasonable to take the local estimates of those insurance companies who will not insure farmland against contamination from an accident at a nearby nuclear plant.[3]

The second point is that the full extent of the TMI accident is only now becoming apparent, as the damaged core is investigated by remote control cameras and directly from small pieces retrieved for laboratory investigation. Melted UO_2 (as distinct from a liquid mixture of UO_2 and zirconium) shows that the core was nearly 1000°C hotter than originally calculated by the official Kemeny commission.[4] Of the 100 tons of core, 30 tons had broken up and been pumped round the primary cooling system, and 70 tons was thought to remain in place. But when the camera was inserted between the outer wall and the core casing, at the

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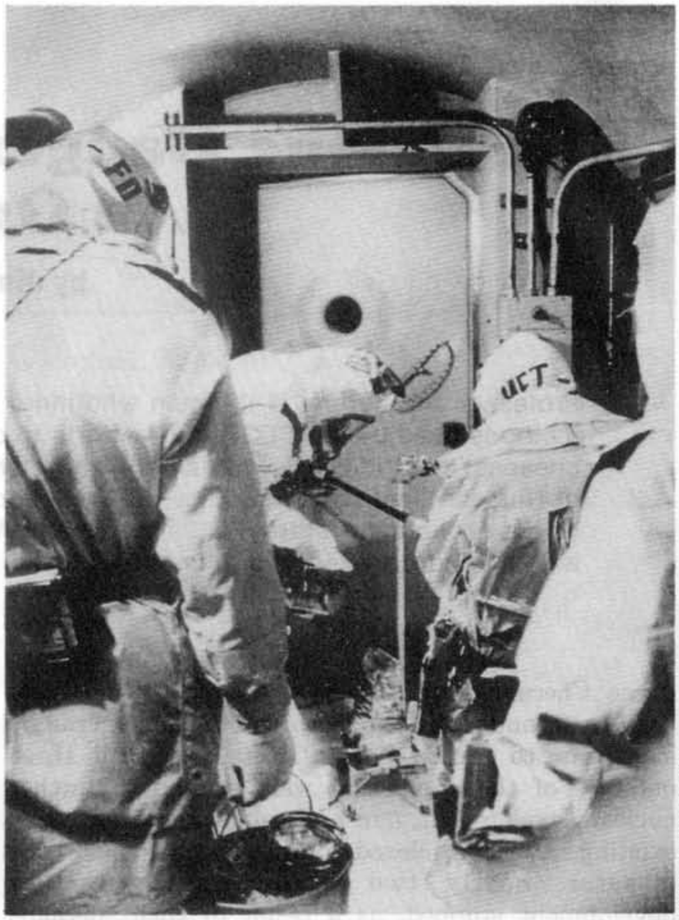
bottom, under the flow distributor plate, they found pieces of debris the size of cricket balls—some 20 tons of them—and "No one knows how they got there".[4] This is from a core which had only a partial loss of coolant. In the case of a complete loss of coolant, it seems only too likely that the 'China Syndrome' would occur and break the containment, contaminating a wide area.

The effects of such a release have been extensively investigated theoretically, and the National Radiological Protection Board has a number of computer models for predicting the results of accidents in different conditions of wind and weather. These have been used to predict the effects of accidents of different severities at the proposed Sizewell B reactor. These calculations and other relevant material have been assembled by ERR/FOE researchers, and published by the Russell Press. The booklet, 'Accidents Will Happen . . . An Inquiry into the Social and Economic Consequences of a Nuclear Accident at Sizewell B' has two maps, on pages 37 and 44, showing the effect of the downwind plume. In the worst case part of north London would have to be evacuated for at least a year, with Ipswich well inside the 20 year evacuation area; and for a wind from the east, meat from the centre belt of England, extending into Wales, would be banned from human consumption for at least a year. Crops would be banned even more widely. It is difficult to think of anything good coming out of the Chernobyl disaster, other than a stiffening and broadening of the determination to make sure no such disaster is possible elsewhere in the world, but the details of the fallout from Chernobyl will be a check on the calculations presented in this FOE document.

The third point concerns injury and death. It may be impossible to prove that TMI caused injury to people in the surrounding area, but the operating company has paid out more than £3.5 million in compensation since 1979, including around £1 million for a Down's syndrome baby. These were out of court settlements to avoid a court decision on responsibility. The insurers' denial of responsibility rings rather hollow in such circumstances.[3]

The fourth point is that all such statements ignore the deaths and injuries arising from uranium mining, on the grounds that they are the responsibility of the authorities in the countries where mining takes place. As we shall see, if mining is included it is impossible to claim that nuclear power is safe.

The other side of the propaganda for nuclear power is the attempt to drown the basic aspects of its new unique and inherent dangers in a mass of technical detail. This was particularly the case at the Sizewell Inquiry, and the evidence presented by the present author[5] was designed to bring out clearly the two major and interlinked dangers of the newly created radioactivity and the new unstoppable furnace in the core. During the cross-examination of this evidence, with the one exception of the differences between the effects of natural and man-made radiation which is dealt with later in this article, no attempt was made to dispute any of the factual material in the evidence. It is therefore possible to summarise this material here in



Three Mile Island—Harrisburg, the site of America's worst Nuclear Accident. Seven years later the clean-up still goes on.

the knowledge that the detailed references on which it is based have not been challenged by CEGB (employing four barristers, including two eminent Queen's Counsels), in what was a semi-legal procedure at the Inquiry. Any material which was not presented to the Inquiry is given its own reference in this article.

The New Dangers

Dangers from mining Uranium

The dangers fall into two categories, those arising in the actual mining of the ore, and those which occur during the milling and processing to produce the concentrated uranium oxide ('yellowcake'). The dangers from the mill 'tailings' (solid and liquid wastes, containing 99.8% of the solid matter mined, and 85% of the radioactivity contained in the original ore) are especially important.[6]

The facts and quotations given in this section are taken from the Proof of Evidence and the documents quoted therein, given by G.E. Oubridge to the Sizewell Inquiry on behalf of the Joint Ecology Parties.[6] None of this evidence was challenged during cross-examination. Most of the evidence comes from the US, because most of the research has been done there. Data on the relationship between uranium mining radiation and lung cancer started to be collected in 1954 in the US, but not until 1974 in Canada, and there are no known statistics for South Africa. Mining conditions in Canada are worse than in the US, and conditions in South Africa can be guessed from the figures given in

1980 (but omitted in subsequent years) by Rio Tinto Zinc for the cost of environmental protection. In Canada £9.8 million was spent, but in South Africa and Namibia, on larger operations, only £2.3 million.

The pressure for remedial action generated by documented health hazards has been high in the US, and conditions there, bad as they are, are likely to be less damaging than elsewhere. In spite of this, CEGB's evidence to the Inquiry on the topic of safety totally ignored the subject of uranium mining. The only statement came from a CEGB spokesman under cross-examination, 'I would assume . . . that the mining operations are undertaken under the same sort of controls that our operations are taken under.'

The main dangers from uranium mining derive from U_{238}, and for simplicity they will be described in terms of this isotope. However, it must be borne in mind that the fissionable isotope, U_{235}, although comprising less than 1% of uranium atoms, contributes significantly to the radioactive dangers, as do the atoms of thorium (Th_{232}) which are present in the ore. With some variation, the U_{238} description also applies to U_{235} and Th_{232}.

When the rock is mined, and milled to small particles, harmlessly decaying radioactive elements are thrust into the environment. Radium, the bone seeker, gets into the streams and rivers; all the radon gas gets into the atmosphere and can be inhaled, causing lung cancer; solid radioactive elements are spread as dust or washed out by rain.

Uranium is a radioactive element, and a U atom decays into a series of other radioactive atoms until it ends up as a stable atom of lead. As a consequence of these radioactive series, in a uranium ore the rock contains not only the mildly radioactive U_{238}, but other radioactive elements, all more radioactive than uranium, and some very dangerous indeed. Two of the elements in the radioactive decay series are radium and the inert gas radon (the only gaseous element in the series).

Before the uranium ore is mined it is in the form of solid rock, usually covered by a substantial layer of other rock. The uranium atoms decay into the other radioactive atoms at a steady but slow rate (it takes 4500 million years for half the original uranium to turn into lead). The radiation is absorbed harmlessly in the surrounding rock, and even an atom of the gas, radon, cannot migrate more than about 6m in rock before it decays in turn to a solid element. Unless the ore comes very near the surface, it does not contribute appreciably to the radioactivity of the environment; and even where it comes to the surface, only the top layers will contribute a small additional amount of x-rays and radon gas to increase the background radiation.

When the rock is mined, and still more when it is milled to small particles and leached with acid or alkali to extract the uranium oxide, all these erstwhile harmlessly decaying radioactive elements are thrust into the environment. Radium, the bone seeker, gets into the streams and rivers; all the radon gas gets into the atmosphere and can be inhaled, causing lung cancer; the solid radioactive elements are spread as dust or washed out by rain.

The first effect of opening up this Pandora's Box of radioactivity occurs in the mines, and the effects on uranium miners will be described first.

The Effects of Radiation on Uranium Miners

The dangers of uranium mines have been known for a very long time. As early as 1546 miners of uranium bearing ores in the Erz mountains of central Europe were reported to have an unusually high frequency of fatal lung disease. Cases of lung cancer in uranium miners were first clinically and anatomically diagnosed in Germany in 1879. In 1913 it was reported that of 665 Schneeberg uranium miners dying during 1876-1912, 40% died of lung cancer. Of 17 deaths of uranium miners in Czechoslovakia during 1926-30, 9 (53%) were due to lung cancer, and the investigators, noting the long latent period (20 years or more) and the absence of silicosis, concluded that the most probable cause of these tumours was the radiation in the air of the mine.

When large scale uranium mining started in the early 1940s for nuclear bomb production, 'the greatest mining boom since the California gold rush 100 years before' little notice was taken of the scientifically established relation between ultimate lung cancer and radiation exposure. In the early days there was no legal maximum exposure, but even the recommended maximum (equivalent to 3000-15000 chest X-rays per year—this is the sort of accuracy with which the effects are known) was exceeded, in many cases by 10 times or more. This standard was officially adopted in 1960, but two years later 68% of mines still exceeded it, and 4% exceeded 10 times the maximum. In 1967 the maximum level was reduced to one third, and pressure is growing to reduce it further by a factor of 10. Even then, the risks would still exceed those 'for a safe industry using Atomic Energy Control Board of Canada criteria'.

The result of these failures to set adequate levels or to enforce them is 'an increasing public health problem of epidemic proportions'.

Since the onset of uranium mining in the United States, the expected number of lung cancer deaths from a similar non-mining population would have been 30 up to 1974. The actual number of lung cancer deaths among the uranium miners was 144. Regarding all cases of death up to 1978, partly estimated figures give 40 expected, 205 actual deaths. But radiation can also induce death from disease other than cancer. Up to 1974, 25 deaths would have been expected from non-malignant respiratory disease. The actual number was 80. And that is only the beginning of the epidemic.

The Dangers of Milling and Mill 'Tailings'

While the dangers from uranium mining have been known for centuries, it was not until 1957 that the US Atomic Energy Commission recognised that mill tailings, if not properly controlled, were hazardous to humans and the environment.[7] The reason is obvious; 85% of the radioactivity originally decaying harmlessly in the rock is now in a pile of loose particles, open to wind and weather, from which radon gas can escape almost unhindered. Although the longest lived radioactive element, uranium, has been extracted, thorium-230, a daughter element, remains with a half life of 80,000 years, and will remain dangerous, producing radium, radon and six other radioactive elements, for nearly a million years.

Those first to suffer from this radioactive waste are the mill workers. Nearly half the radon gas in the ore is liberated during mining, and the other half during milling. The concentrations of this gas and radioactive dust mean that the mill workers get radiation doses second only to the miners. A small scale study of mill workers showed a four-fold increase in cancers which would be expected to arise from inhalation of thorium and uranium, and a larger follow-up study of mill workers' deaths has been started in the US.

Important though this aspect is, the risk to the general population is even more important. Only 5 of the 26 so-called 'active' uranium mills in the US are now operating, but each of them has a toxic tailings pile, with a grand total of 191 million tons of tailings on the ground. In Namibia tailings are being produced at the rate of 16 million tons a year, and the problem in Canada is even worse than in the US. In addition to the radioactive poisons, the tailings may contain chemically hazardous substances, including cyanide, arsenic, cadmium, lead, mercury, selenium and molybdenum, which were previously held harmlessly in the rock, but are now able to get into the environment by leaching, seepage and blown dust. Moreover these dumps are subject to massive accidental discharge into the environment; 14 spillages had been recorded up to 1979 in the US, the worst at Church Rock, where the containment was thought to be of a high standard. A dam broke, and about 100 million gallons of liquid mill waste was released into the Rio Puerco river, along with an estimated 1,100 tons of solid waste. In Australia, a similar dam failure at the Rum Jungle mine, resulted in severe contamination of the East Finniss river, so that fish and plant life in the river and on its banks were virtually wiped out. The Canadian experience is similar, but rather worse than that of the US.

But even without accidents, the radon gas will eventually escape from those few dumps at present covered by 6 feet of water, and will continue to exact its toll of lung cancer in the surrounding communities for many thousands of years. Radium, increasingly finding its way into the streams and rivers as the dumps decay, will generate bone cancers. It has been estimated that in the US, *4000 additional lung cancer deaths per year* would be caused by radon emission from mill tailing piles, mainly in the communities surrounding them. Since the production of radon will only have decreased to half its present value in 80,000 years, uranium mining has left an enormous long term problem. On the basis of this lengthy danger period, another estimate is for a total of 117 million deaths from only two piles during their hazard life.

In 1978 the US Congress undertook to shoulder the $200 million clean up of the piles resulting from defence contracts, but required uranium millers to deal with the problem from 1978 onwards. Nearly 8 years later the government programme is just beginning, with the estimated costs now $700-900 million; but nothing has happened or looks like happening to the rest of the piles. In the meantime, as the legislative director for Congress Representative Bill Richardson says, "These tailings are just blowing around New Mexico". Governor Toney Anaya of New Mexico notes that "Ground water contamination problems have been documented" in areas outlying each of the state's five milling sites. "Contamination of surface areas continues to spread through wind erosion." The same conditions are found in other states, according to Nuclear Regulatory Commission officials.[7]

One of the difficulties is to know what to do. The original idea was to cover the piles with a layer of clay, followed by a layer of topsoil, and finally plant fast growing vegetation on top. Unfortunately in one of the few cases where this has been tried so far, the radon release tripled from such a 'vegetatively stabilised' pile. Eventually the grass on top turned orange and then died. Studies on other piles also showed increased radon readings. In any case, a few feet of earth is not an 80,000 year solution in view of wind and rain erosion, and it does nothing to stop the seepage at the level of the bedrock on which most piles are built. At most it would stop the dust 'blowing around New Mexico', and reduce radon emission temporarily. Even such precautions are now estimated to cost $4000 million.

The US Environmental Protection Agency considers that remedial action is necessary for any home containing radon levels more than 0.005 units above background. The (Canadian) Ministry of Energy has promulgated regulations which allow uranium mines to give an average exposure to the public of 0.02 units, i.e. four times as much. It is no wonder that the British Columbia Medical Association concluded that 'In the light of current knowledge this might be considered tantamount to allowing an industrially induced and publicly sanctioned epidemic of cancer.' As might be

Since the onset of uranium mining in the United States, the expected number of lung cancer deaths would have been 30 up to 1974. The actual number of lung cancer deaths among the uranium miners was 144. Regarding all cases of death up to 1978, partly estimated figures give 40 expected, 205 actual deaths. And that is only the beginning of the epidemic.

expected conditions for Canadian uranium miners are even worse than in the US, and CEGB gets much of its uranium from Canada.

Newly Created Radioactivity in a Reactor

The new radioactivity arising from mining, almost pales into insignificance compared with the radioactive material newly created inside the core of a reactor from the time it is started up. Even when the mined uranium is concentrated, slightly enriched and formed into fuel rods, its radioactivity is almost non-existent (it is more dangerous as a chemical poison than for its radioactivity[8]). Yet a short time after the reactor starts operating, the radioactivity of the fission products amounts to ten thousand million Curies. The Curie (Ci) is itself such an enormously large unit that it has recently been decided to establish a new unit, the Becquerel. A radioactive source of 1 Becquerel (Bq) undergoes one atomic disintegration a second with the emission of a γ-ray or an α-or ß-particle, (or a mixture of these). γ-rays are highly penetrating and act on the body mainly from outside. α- and ß-particles are highly energetic, but lose their energy very rapidly in body tissue, with ranges usually of fractions of a mm (or a few mm for very energetic ßs). Their effects can therefore be very damaging, but only by contact with the skin or by ingestion of the radioactive material via the mouth, or inhalation into the lungs.

The biological damage caused by γ-rays is roughly proportional to their energy, whilst the relation is much more complex for α- and ß-particles, depending particularly on which organ is affected (see table p.183).

Sufficient exposure to a radioactive source will cause radiation sickness and so-called 'prompt' death. Lower exposures can give rise to fatal cancers which may not show themselves for 20 years or more—so-called 'delayed' death.

Nearly half the exposure we receive from natural radioactivity comes from radon in the air, both outdoors and inside houses (where it may be somewhat more concentrated).

To give some idea of how much new radioactivity is created by starting up a nuclear reactor, London air in 1956 contained 0.1Bq of radioactivity per litre (mainly radon). Shortly after operation a reactor creates ten thousand million Curies—one Curie being equivalent to 37 thousand million Bq.

What is the d nger from this enormous, newly created radioactivity? Danger can arise either from an accident leading to a breach of the containment, or from the high level waste which contains essentially the total radioactivity brought out of the reactor in used fuel rods. At present, after a cooling-off period, the used fuel in the UK is reprocessed, and almost all the radioactivity which was in the reactor (allowing for the decay with time) reappears in the form of liquid High Level Waste (HLW) from reprocessing. The industry assumes that after a further cooling period the liquid waste will be evaporated to dryness, and incorporated into a glassy matrix as solid waste for ultimate burial in a deep repository.

Even supposing the waste has been safely converted to glass blocks, that is only the beginning. Indeed a dose of 500 rem (which has a 50 per cent chance of being fatal) would be received in 10 minutes by a human standing 10 metres away from an unshielded new waste canister. Since radiation received varies with the square of the distance from the source, a similar lethal dose would be received in about 10 secs, at a metre away.

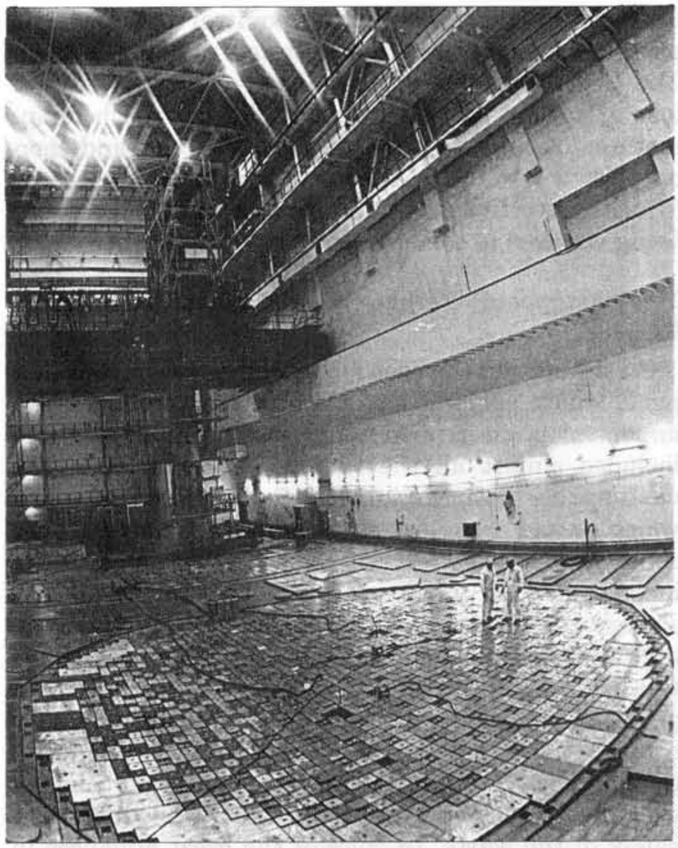


PHOTO: TASS

The main hall of a reactor room at Chernobyl

The New, Unstoppable Furnace Created in the Core

Before it is started up for the first time, a reactor is not only, for practical purposes, non-radioactive, it is not even warm. Yet soon after it is started up, it can no longer be fully shut down. The part of the heat production which cannot be 'turned off' at scram[9] is given the seemingly innocuous title of 'decay heat', and dismissed as a 'relatively small amount of heat' or 'a few per cent of that at full power'. It should be called the 'unstoppable furnace', and given the correct description as the equivalent of a large (60 ton) steel melting furnace for at least the first 24 hours, and very much higher in the early stages. This unstoppable steel melting furnace inside the reactor, derives from the newly created radioactivity in the core. It is, in fact, the combined energies of all the γ-rays, α and ß particles, produced by this enormous new radioactivity. After half an hour at full power this unstoppable steel melting furnace, newly created from the originally cold core, has reached three quarters of its maximum power, and after six hours running it has reached 90%. After this in the absence of cooling the core would melt in about an hour, and no-one can be sure what happens after that.

It is now known that TMI got much nearer this crucial melting stage than was originally thought (actually reaching the melting point of UO_2 in some places, instead of the earlier estimate of 900°C below). The LOFT experiment[2], specifically designed to test loss of coolant effects, probably did not reach temperatures as high as those of the TMI core, and then only for a few fuel elements in a very small reactor (which, nevertheless, could not be prevented from being wrecked in the process).

The Unstoppable Furnace after Removal from the Reactor

On the station the rods are stored as assemblies in a pond which requires constant active cooling. More importantly, in reprocessing, the high level waste includes almost all the radioactive material of the unstoppable furnace, and has to be stored in tanks which would boil dry in a matter of days if not constantly cooled. Even when eventually it is incorporated in glass or otherwise solidified, the surface temperature of the blocks can become very high if cooling becomes inadequate for any reason. If this heat were deliberately exploited, as suggested by a geologist in Dundee University, a radioactive sinker could be used to melt down through the earth's crust to at least half-way to the centre, and enable valuable geological information to be obtained, while disposing safely of the waste. In spite of the great advances in ceramic materials, such a project would rank in difficulty with putting a man on the moon; but the fact that the unstoppable decay heat furnace could be harnessed in this way, if the fission products were separated out early enough and concentrated into solid form, is a vivid reminder that the unstoppable furnace does not stop when the fuel is removed from the reactor. Of course, in any scheme for long term storage in a deep repository, the arrangements—concentration in the glass, distance apart of blocks, time for reduction of heat as the fission products decay—would be carefully designed to prevent such melting. Nevertheless, temperatures of several hundred degrees centigrade are likely for the first few hundred years, and it will be 1000 years or more before the temperature becomes similar to that of normal rock. Unfortunately the danger from radioactivity does not decline proportionately to the heating effect (it must be remembered that there can be highly dangerous levels of radiation associated with negligible heat production), and the specification for US repositories of High Level Waste (HLW)—none of which have yet been built—requires the prevention of any leakage to the environment for at least 10,000 years.[10]

TMI Could Have Been Much Worse

While most of the radioactivity (and the associated unstoppable furnace) is newly created in the first half hour of operation of a reactor, there are important effects which increase with the time of operation up to the production on an 'end of cycle' (or 'mature')[11] core in about 3 years. TMI had only been in operation for 3 months. If the accident had not happened until after 3 years operation, the heat from the unstoppable furnace, 5 hours after the fission shutdown, would have been 10% greater.

The Kemeny Commission Task Force concluded 'that the course of the accident would have been little altered had the fuel been end-of-cycle instead of relatively new.' However, this opinion was given before the extent of the damage to the core was known, and it seems possible that the additional decay heat might have just taken the core beyond the point at which control could be regained.

There is no dispute on the second part of their conclusion that 'there would have been a substantial increase in the long-lived activitiy to be coped with in the clean-up operation.' While the radioactivity is the major problem, the heat generated after 5 years would not have been negligible (about 100kW) for a mature core. For the actual TMI core it should now, according to the Task Force calculations, be about 14kW. At the end of 30 years, the mature core would still be producing about 40kW of decay heat as against about 4kW for TMI.

While the TMI core without active cooling would only be at most 20-30°C above the temperature of its surroundings after 5 years, a mature core would be at about 200°C under the same conditions. At 30 years the TMI rise would be a few degrees, while the mature core would still be around 100°C.

However, the cooling difficulties pale into insignificance compared with those due to radiation. After 5 years the TMI core and containment building had within them about 42 million curies of radioactive material. A mature core would have at least ten times as much. A 'jumper'[12] who could work for ten minutes on the TMI clean-up, would have to be restricted to 1 minute if the core had been mature.

The Effect of the Unstoppable Furnace on Repair, Maintenance and Decommissioning

It is not only in the fuel that new radioactivity is created by starting up the reactor. Corrosion products are carried round in the coolant, and while going through the core, the neutron bombardment creates radioactivity in them. The radioactive corrosion products lodge in various places round the heat exchanger, and create a high radiation level in the whole area. In a CEGB Report on 'Corrosion of Steam Generators Caused by Ingress of Cooling Water' it is stated that "The problem of corrosion product transport around the circuit is particularly acute in water cooled nuclear reactors, because such products are activated as they pass through the core. Activated species become deposited throughout the (primary) circuit and can present a formidable maintenance problem. For example, at Connecticut Yankee 150 men, working for a maximum of 5 minutes each, were required to remove a boiler tube." The tube needed to be removed because it had corroded owing to contamination of the cooling water. In the same paper we find, "However, with sea water cooling it takes only one leak, equivalent to 1/5th mm diametre hole, anywhere along the 200 miles of condenser tubing, to produce an unacceptable level of contamination."

The prevention of corrosion is one of the points on which the Nuclear Installation Inspectorate (NII) was not satisfied by the CEGB's original plans for Sizewell

B. Doubtless an agreed modification will eventually be produced, but whether it will work in practice remains to be seen. Corrosion is certainly plaguing the older stations in the US, (Surry 1 and 2 reactor steam generators were replaced in 1980 for a total cost of $112 million), and it is in any case not the only cause of breakdown requiring maintenance and repair. Whether there will be a supply of 'jumpers' available when the scourge of unemployment is lifted, or when the delayed cancer in such people starts showing itself, is another matter.

Difficulties of Repair at Three Mile Island

The accident at TMI started on 28th March 1979, at 4.00am. Within two hours the major damage to the core was complete, but 12 hours after the start of the accident a utility spokesman said there had been "some minor fuel failure", perhaps 1% of the 37,000 fuel rods had been damaged.

In mid-April 1979, about a week after the reactor had been brought under control, it was estimated that "Many components, including the core, will have to be replaced, possibly at a cost of $100 million."

By August 1979 Bechtel had produced a clean-up plan in which the pressure vessel would be opened up about 18 months later, and the core removed by the end of 1981. Reconstruction could then start and the reactor be 'back in business by the middle of 1983' at a cost of $400 million.

November 1979, 6 months after the accident, the containment water was 6ft. deep, and water was leaking in at 1000 gals/day. The radioactivity of the water inside was 250 Ci/cu.m. including a total of 3,000 Ci of tritium; 57,000 Ci of the radioactive inert gas, krypton (Kr_{85}) were trapped in the dome, and it proved impossible to operate the airlock entrance to the containment building. The rising water level was threatening vital electrically driven equipment.

In November 1979 the Kemeny report estimated the cost of the accident as between $1 and $2 billion, but much of this was for replacement power.

June 1980 and the Nuclear Regulatory Commission (NRC) finally agreed to allow venting of the Kr to atmosphere on the grounds that greater dangers would result from any other course.

In July 1980, the venting of 57,000 curies of radioactive krypton was seen as essential for the $400 million clean-up operation, although an independent assessor had put the cost at $1000 million as early as March 1980. Krypton was vented gradually over the month through a high stack; 2,000 people left the area. On July 23 two engineers entered the containment briefly for the first time.

By October 1980, a third or more of the 177 assemblies in the core may have suffered damage.

In December 1980 the owners of TMI, General Public Utilities (GPU), announced that the clean-up alone would cost $1,000 million, and not be finished until the summer of 1985, after which it would cost at least $260 million to reconstruct the reactor. Insurance would only cover £300 million. At the same time GPU announced that it was abandoning construction of the Forked River nuclear power plant after spending $390 million on it, and might build a coal-fired plant to obtain the required capacity.

In 1981 and 1982, the owners had to build ion exchange plants to extract the radioactive components (except tritium) from nearly a million gallons of water in the containment building and after the first look, in July 1982, at the TMI core 'reduced to rubble', GPU decided in December 1982 to sue Babcock and Wilcox, the makers of TMI, for £4,000 million.

At the beginning of September 1983, by which time the reactor should have been 'back in business' according to the original Bechtel plan, access had been obtained to the containment building, and a sonar mapping of the core showed the whole top had collapsed and very few if any assemblies were probably left intact. A small piece (1″ cube) of core material was extracted on a scoop at the end of a 45 ft rod. It is hoped that analysis of this sample will give more information on what actually happened in the core. GPU 'hopes to begin defuelling the core in March 1985 and to restore the plant to a "normal radiological condition" by 1988.'

In September 1983 GPU were accused by an NRC report of violating safety procedures and attempting to intimidate employees who objected.

After half an hour at full power this unstoppable steel melting furnace, newly created from the originally cold core, has reached three quarters of its maximum power, and after six hours running it has reached 90 per cent. After this in the absence of cooling the core would melt in about an hour, and no-one can be sure what happens after that.

In November 1983, the subsidiary company operating the plant at the time of the accident (Metropolitan Edison) was indicted by a grand jury for having 'systematically destroyed, discarded and failed to maintain records' of leaks which had taken place in the period before the accident, and had 'concealed and covered up' the data on the leaks from the NRC.

In May 1984, Metropolitan Edison admitted its guilt and was fined $45,000 and costs. In addition, the company must establish a $1 million account to help the Pennsylvania Emergency Management Agency to formulate an emergency plan for a 20 mile zone around the plant.[13]

In Feb 1985, the water had been pumped out of the containment building, but so far only wheeled, remote controlled robots have ventured down for a look. To date the job of taking out the core has not yet begun, and 'cleanup' is to continue until 1988. No decision has been made on the future of the plant. The core continues to turn up more surprises, including melted UO_2 and 20 tons of debris unaccountably underneath the flow distributor.[4]

In Oct 1985 the undamaged Unit I, shut down when the accident occurred, restarted.[14] It is almost certain that Unit II will never restart.

Clean-up at Three Mile Island

Perhaps the best indication of the problems arising from the creation of radioactive poisons by a nuclear reactor is given by the bizarre list of requirements for the clean-up of TMI. The human requirements are for 2,500 workers continuously being rotated as they reach their maximum permissible exposure to radiation. Payroll costs for the clean-up will run at $30 to $40 million a year. (The estimate of man-rems[15] required for the clean-up has since been increased by a factor of about six, so the number of workers and the payroll will presumably be increased by the same factor.)

The extraordinary quantities of materials required include: 1 million pairs of plastic overalls and a like number of plastic bootees and rubber gloves. Thousands of breathing masks, oxygen tanks and other respiratory protection devices, 10,000 sponge mops and a million square feet of plastic sheeting will be required, and, for shielding from 'hot spots', 10,000 concrete blocks and 12,000 square feet of lead sheeting, among other supplies; 350,000 gals of water-based or solvent decontamination solutions will be used for cleaning; and as these solutions render ion exchange equipment ineffective, a special $20 million evaporator has to be built to reduce these liquids to a radioactive solid which can be transported to a burial ground (if one can be found).

Most of the waste from the clean-up will be material that has been contaminated in the decontamination process itself, but no one knows where it can go, because those states with disposal facilities are restricting their use. A particularly troublesome waste is the ion exchange resin filters which take the radioactive material out of the sump water. Their radioactivity will run as high as 1,500 Ci/cu.ft., as opposed to a maximum of 10 Ci in ordinary low level waste. Moreover the fission products principally involved—caesium 137 and strontium 90—have a half life of about 30 years, which means that the main period of hazard will extend over the next three centuries. Such wastes will effectively require treatment as HLW.

There are at present no plans for disposal of perhaps 1,000 truck loads of radioactive waste of various kinds from the clean-up. TMI's state, Pennsylvania, has no waste disposal facilities for low level medical radioactive waste, and will have difficulty in persuading its citizens to allow this to be provided. There are not even tentative plans for a burial ground for waste from TMI or any other nuclear generating plant. "Very realistically", says Socolow, the state geologist "this is a very paranoic issue in Pennsylvania, where we've seen people running away, scared half out of their pants. Our state government is very much concerned that we do not add to the fears of the people." Nevertheless some disposal method has to be found; but it is an understandable reaction of ordinary people who were not consulted as to whether nuclear plants should be built, that those responsible for producing all these radioactive poisons should also be responsible for dealing with them without polluting part of Pennsylvania.

The NRC official who is overseeing the clean-up and so is particularly concerned about the high level resin filter wastes, comments, "If the DOE (Department of Energy) can't solve this little problem, should the NRC be licensing more nuclear plants?"

An interim solution to this special problem was found by sending the filter wastes (60,000 Ci per liner) as material for the DOE's research into glassification of HLW, to the Hanford laboratories, without any solution for its final disposal.[4]

It is perhaps not surprising that after this experience of the newly created radioactivity in the unstoppable furnace, the only commercial activities in the USA in relation to nuclear plants have been cancellations of previous orders, or, in the case of the Zimmer station in Ohio (97% complete), conversion to coal-firing.

Decommissioning

Until the late 1970s the preferred method proposed for dealing with a PWR at the end of its useful life was to decontaminate it, and then encase it in concrete to prevent access, and to contain the radioactivity which had been created inside the steel and concrete structures of the reactor. This was on the assumption

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that all the intense radioactivity was due to short-lived isotopes, almost entirely from cobalt 60, deriving from the cobalt in stainless steel which is used to reduce corrosion in a nuclear reactor. Cobalt 60 has a half life of 5.27 years, so that after 100 years or so it would have decayed to one millionth of its activity at shutdown, and certainly after another 100 years would be harmless. The entombed reactor would then be left as a monument to the nuclear age, or broken up and buried harmlessly elsewhere.

In 1976 calculations were published showing that radioactive nickel 59 would be formed in significant quantities over the 30 year lifetime of a reactor. Since it has a half life of 80,000 years, its activity after 100 years is hardly affected. These calculations, which "went against the whole mind-set at the time", were vigorously attacked by the nuclear industry, but a year later an even more important activation product, niobium 94, was discovered. This has a half life of 20,300 years, and its very energetic γ-rays will dominate the radiation dose from irradiated steel 70 years after shutdown. In 1981 the NRC published an environmental impact statement on decommissioning which indicates that the dose rate from niobium 94 in reactor components would be about 17,000 rems per year, if the reactor is operated for 30 to 40 years. That from nickel 59 will be about 800 rems per year. The statement adds that "These dose levels are substantially above acceptable residual radioactivity levels." The maximum dose to the public is 0.5 rem per annum.

When the US Government reactor at Shippingport, the world's first large commercial reactor, has been cut up and taken to a military burial site, we shall know rather better whether there are other unforeseen snags in the process (although since it has only been operating fully for just over 20 years there may still be others which develop later). It will be a difficult process, taking 5 years to complete, and it will generate some 11,700 cu.m. of radioactive waste —almost as much as will be produced in the clean-up of the crippled Three Mile Island reactor—although it is less than one tenth the capacity of reactors being built today. In this instance there will be no problem of the immediate disposal of waste—it will go to the military burial ground at Hanford, adding, at least as far as HLW is concerned, to the unsolved problem of what to do with the military HLW already there.

Even if experience with Shippingport does prove that the technology for dealing with a large power station is available, it is clear that some major problems would remain. Not the least of them is the immense amount of radioactive material that would have to be disposed of. According to a major study by the Battelle Pacific Northwest Laboratories, about 18,000 cu.m. of contaminated steel and concrete would be generated in the dismantling of a 1.2 GW reactor. That is about a quarter of the volume of low level wastes now generated annually in the United States. Since, as we saw in relation to TMI, the problem of waste disposal is getting more difficult, it is unlikely that any large reactor will be torn down until there is a resolution of the disposal problem.

The Waste Disposal Problem

Should the world change from nuclear weapons confrontation to nuclear waste collaboration, then the existing mess might eventually be cleared up without disaster. But the more that is produced, the more difficult the problem becomes and, those who might reluctantly agree to accept a strictly limited waste disposal facility in their county or country, will resist bitterly having ever-growing quantities of these radioactive poisons dumped in their area. Nothing short of the Swedish approach, that is a definite date for ending nuclear power, can even create the conditions for a solution.

Recent experience in the US emphasises the difficulties of waste disposal. For HLW a site has not yet been chosen, and although a repository is scheduled to be available by 1998, polls of industry waste specialists put start up at 2008 or later![16] Of the three sites under consideration, the front runner, Hanford weapons centre, has been condemned as unsuitable by a senior geologist with the US Geological Survey[17], and another would involve drilling through two aquifer layers, with the risk of water contamination.[16]

The problems of HLW disposal are highlighted by one of the (US) DOE's research projects to find 'ways the public could be warned away from such a facility centuries hence in the event that all records are destroyed, fences and signs have disintegrated, and the English language itself has mutated to strange new forms.' DOE's tentative plans are to erect massive stone monuments at repository sites, perhaps 'miniature pyramids', that would bear messages in pictographs and symbols, warning passers-by not to dig in the area. Contractors are looking around the world for written symbols which have stood the test of millenia.'[18] In the meantime storage space for spent fuel at US power stations is becoming scarce.[17]

It is noteworthy that although nuclear plant manufacturers desperate for orders are trying to increase their sales of small and medium sized reactors to the countries of the Third World, and offer a wide range of support services, none are offering to take over management and disposal of HLW.[19]

Third World countries are even less likely to want to dispose of HLW themselves, especially as recent joint research by the British Geological Survey and Delft Soil Mechanics Laboratory, together with some experimental work at the Drigg site, have shown that migration of radioactive elements can be very rapid indeed, much faster than predicted by computer models based on a homogeneous porous medium.[20] Also a recent research report[21] shows that bentonite, which has been proposed for use in HLW repositories as an impermeable barrier because of its great ability to swell in water, loses these properties when subjected to steam at 150-200°C, such as is expected in the first stages of the life of a repository.

Perhaps even more pressing is the provision for disposal of Low Level and Intermediate Level Wastes (LLW and ILW). There are three dump sites in the US, in Washington, South Carolina and Nevada. In 1979 the three states provoked a crisis by closing or restricting access to their dumps by other states. Congress passed legislation in 1980 aimed at getting new sites opened within 5 years so that the existing dumps could be restricted by 1 January 1985. Not a single new site is in operation, and none is in prospect before 1990.

Congress is staging a rescue operation, but if this fails a new crisis will arise immediately, and nuclear power stations, which produce half the total of LLW and ILW, will be in difficulties.[22]

In the UK the situation is not very different, although far less work has been done than even in the US. Public opposition stopped the programme of drilling in hard rock in 1981, and the opposition to the proposal to use an old anhydrite mine at Billingham was so great that its owners, ICI, eventually refused permission even for an investigation by NIREX (Nuclear Industry Radioactive Waste Executive) and the proposal was abandoned. The only site of those originally proposed for LLW, on a UKAEA site at Elstow in Bedfordshire, has difficulties of access 'because of local opposition to its development'.[20]

The disposal of longer lived ILW in (or under) the seabed is being considered, but the impossibility of retrieval in the event of an accident is a strong argument against this. The National Union of Seamen has prevented any continuation of the previous dumping of LLW at sea (which is at present subject to a moratorium) and refuses to cooperate with research into seabed burial. The only existing dump in the UK is for LLW, at Drigg, and this will be full sometime in the 1990s. UK waste disposal experience reinforces the conclusion that only a Swedish solution is possible for nuclear power.

The estimated cost of waste disposal is rising—HLW repository life-cycle costs have jumped from $18 billion to a staggering $27 billion—but because of the accounting procedure, virtually none of this cost appears in the cost of present electricity. US electricity users only contribute 0.1 cent out of about 6 cents per unit, to HLW disposal, or less than 2%.[16] The CEGB also covers the whole of waste disposal and decommissioning by a similar charge. The cost and the difficult and dangerous work involved are effectively being left to future generations.

The Moral Problem

In the 1982 White Paper the government accepted objectives for radioactive waste management, of which the first is given in the Department of the Environment's Policy Proof of Evidence to the Sizewell Inquiry as: "1. All practices giving rise to radioactive wastes must be justified, ie. the need for the practice must be established in terms of its overall benefit." Yet the Department has allowed the production of these new and indestructible radioactive poisons from comparatively innocuous materials in order to get the 'benefit' of heating up water to generate electricity, when there are many other ways of getting the same end result. But having got the 'benefit', we are leaving to future generations the difficult task of clearing up the mess we have made. On p.13 (6.13) of its Proof, the Department says, "In leaving the decision of disposal (of HLW) to a future generation, we in this generation have a clear moral duty to formulate the options, as we see them at present, and to develop the supporting scientific and technical knowledge so that they will be better placed than we are, to make the eventual choice." Surely we have a clear moral duty to limit in every possible way the quantities of radioactive poisons we leave to future generations, and ourselves to clear up as much as possible of the mess we have made.

The Differences between Natural and Man-made Radioactivity

The cross-examination at the Sizewell Inquiry, based on Sir Edward Pochin's evidence on behalf of the National Radiological Protection Board (NRPB), showed that the formulation on this matter in my evidence was inadequate. After lengthy correspondence with Sir Edward Pochin[23], the formulation given in the box on p.157 was arrived at.

The essential difference is due to the the concentrated form of man-made radioactivity. One would have to ingest something like 80,000 tons of rock to get a lethal dose from its radioactivity, whereas the concentrated radioactive poisons in a reactor can give lethal doses from specks of dust. The fact that there is far more total radioactivity in the world's rocks than in a reactor is irrelevant to the restricted population in the neighbourhood of such a reactor, who cannot be killed by the radioactivity of any escape of rock, but most certainly can from an escape of the contents of the reactor.

The Accident Record

Canada, the UK, the USA and Switzerland were among the pioneers of nuclear power. By the end of the 1960s there had been major reactor accidents in all four countries.

Until the Chernobyl disaster in April 1986, the nuclear industry constantly claimed that no member of the public had ever been harmed by a nuclear accident. Such claims were based on statements either that no radioactivity escaped from the plant, or that the escape was so small that it had no significant effect beyond the plant. Even if the statements about the amount escaping are accepted, the doses to the public are calculated on the basis of a rapid mixing in air or water which in reality do not occur. Air movements especially may take place with little mixing, and concentrated radioactivity be brought down by a shower far from the plant originally releasing it. Also, while there is as yet no certainty about the difficult problem of determining the effect of low doses of radiation, the evidence indicates that the present maximum dose rates are at least ten times too high (see this issue p.171). But even if the claims of the industry are accepted, how long can we go on before there are further disasters like that in the Soviet Union, if the enormous numbers of nuclear stations projected for the future are actually built. It is a sobering thought that the average number of reactor years experience per station in operation, is still only ten.

A recent U.S. Senate report gave the results of a world wide survey of nuclear reactor incidents reported to international atomic energy organisations. This showed that 151 of these 'incidents', occurring in 14 countries (none from the Eastern bloc) were such as to give rise to a significant risk of a major radiation release, although none actually involved such a release.[24] Since the Chernobyl accident this has become 152 in 15 countries, with one very major release of radioactivity.

Nuclear Accidents in the US

Since the CEGB is trying to get permission to build a US designed PWR, it is as well to remind ourselves of the more recent record there. The US is also the country where most PWRs are in use. In 1982 a US Nuclear Regulatory Commission (NRC) Report called Accident Sequence Precursor (ASP) study, gave the result of an investigation of 20,000 incidents at nuclear stations between 1969 and 1979. It identified 169 of these as possible 'precursors' to a major accident. In 52 of these cases the events were considered to hold a

Natural and man-made Radioactivity*

Radioactive materials, formed in a reactor and carried through the nuclear fuel cycle, are so highly concentrated that they are capable of being ingested and inhaled in minute quantities which would, nevertheless, give lethal cancer-inducing doses of radiation. This is completely different from naturally occurring radioactivity which nowhere exists in comparable concentrated form. To quantify this difference, the average risk to an individual in the UK of death from cancer from all causes is about 22 per cent. Most of this risk arises from chemical and biological factors not related to radiation. The average additional risk from natural radioactivity is very small—about 0.2 per cent. It is unlikely to be increased to more than 0.4 per cent by geographical variations in radioactivity. It is thus impossible for natural radioactivity, by either accident or design, to increase the risk of a normal UK individual dying of cancer by more than about 0.5 per cent (i.e. to a total risk from all causes of about 22.5 per cent). If, however, an individual is exposed, as the result of an accident, to some of the vast quantities of concentrated radioactive materials produced in nuclear reactors, then it is only too easy for his or her risk of death from cancer (or earlier radiation sickness) to become for practical purposes 100 per cent. It is this difference, together with the ever present possibility of accidents, which vitiates any attempt to present the dangers of nuclear power to individuals or restricted populations as of the same order and kind as those of naturally occurring radioactivity. Of course, if the probability of an accident releasing the enormous quantities of newly created radioactive poisons into the environment is postulated to be sufficiently small, then the average annual death rate over the whole population from nuclear accidents can be calculated to be of the same order as that from natural radiation. But this would not be true of the restricted population in the accident zone which would be wiped out. It is the intuitive understanding of this fact by ordinary people which explains the incredulity with which they react to suggestions that the dangers of nuclear power are equivalent to the additional risk of cancer from moving to Aberdeen from Surrey. This reaction is enhanced by a healthy scepticism of the odds against a nuclear accident as calculated by the industry, in the light of the actual accident record.

Jim Jeffery

*This formulation of the differences between Natural and Man-made Radioactivity was arrived at as a result of a study of Sir Edward Pochin's evidence to the Sizewell Inquiry on behalf of NRPB (Days 151-4) and correspondence with him. Although the formulation takes account of all the points raised in Sir Edward's letters, the form and contents are entirely the responsibility of the author.

significant risk of leading to severe core damage under the right conditions. The three most significant precursors were:

1. *March 1975* Browns Ferry 1.—a candle flame sets fire to and nearly destroys a 2GW nuclear station.

2. *March 1978* Rancho Seco—a dropped signal bulb sends instrumentation and automatic controls haywire. Steam generator dryout.

3. *March 1979* TMI—core destroyed.

Since 1979 there have been a number of 'incidents' which seem to show that little has changed since TMI.

4. *March 1980* Crystal River—electrical failure leads to TMI type sequence, basement flooded with highly radioactive water. No core melt down, but NRC emergency declared; 60 hours to 'cold' shutdown; two weeks before damage can be inspected.

5. *October 1980* Indian Point 2—plant flooded with 400,000 l of water, through human error and equipment failures reminiscent of TMI. Leaking slightly radioactive water into Hudson river. Out of action over 6 months.

6. *February 1982* Ginna—steam tube rupture (5th rupture in 8 years in US reactors); 41,000 l of radioactive water in sump. Site level emergency declared (potential health effects to the public); 31 hours to achieve cold shutdown.

7. *February 1983* Salem—automatic scram failure. The safety implications were 'the most significant that we have had since TMI' (NRC). The owners have been fined—and have paid—$850,000.

Doubtless the lessons learnt from these and other failures have led to improvements in design, but one thing cannot be redesigned, and that is human nature. In Salem two switches in series which should have been cleaned and oiled twice a year had not been touched between installation in the 1970s and August 1982. The operation of either would have scrammed the reactor—both failed. The operators shut the reactor down manually within 30 seconds, but if the delay had been merely 100 seconds, serious damage could have resulted.

8. *December 1984* Rancho Seco again—all power to the plant's computerised central system was lost for 26 minutes. A pump burned out, spilling 450 gallons of radioactive water on to the floor of an auxiliary building. Some of this escaped to the atmosphere as radioactive steam. In the early stages the steel reactor vessel was put through a 'pressurised thermal shock'—overheated and then rapidly cooled at high pressure. This can cause the development of cracks leading to fast fracture of the pressure vessel, destruction of the containment and release of the enormous radioactivity in the core. On this occasion only small amounts of radioactivity were released, but it took 4 hours to bring the whole plant back to 'normal'. A senior operator collapsed and had to be taken to hospital. The cause of the loss of power had not been ascertained a fortnight after the accident and no date had been set for restarting the plant. The NRC is carrying out a special inquiry.[25]

9. *June 1985* Davis-Besse plant on Lake Erie. A main feed-water pump got a message from the automatic control system to shut down, and it did. In the fast-moving events that followed, an operator punched the wrong control buttons, shutting off water to the steam generators and causing the system to lose its capacity for heat removal. The reactor coolant began to overheat. Before serious damage occurred, technicians were able to turn on an auxiliary water supply (after rushing down four flights of stairs, unlocking padlocks, putting fuses into an empty fusebox, manually switching on a pump, and struggling with a wrench to open some critical valves). The staff got things under control moments before it would have been necessary to go into an emergency cooling routine known as "feed and bleed", a step that would have worsened the crisis. The plant is still shut down for renovations, and its owner hopes to restart in April.[26]

10. *November 1985* San Onofre reactor in southern California. An electric circuit failed, cutting off power to the control room for 4 minutes. Fast work by

operators overcame a number of obstacles and brought the plant under control within hours—but not before five key safety valves failed, a "water hammer" accident cracked a main feedwater line, and a steam line ruptured. Under slightly different conditions, the water hammer damage could have been much worse. The Incident Investigation Team (IIT) did not pin down the root cause of all this, but it said the likely causes were poor maintenance, poor valve design, and poor valve testing procedures.[26]

Nuclear Accidents in the UK

1. October 1957 The worst reactor accident so far in the UK—the raging fire in the Windscale reactor which belched radioactive iodine-131 over the countryside, and led to 50 million gallons of milk being poured away—occurred in a military reactor making plutonium for bombs, and the particular cause of it could not be repeated in civil plants, although a nuclear fire, in the presence of oxygen which can be released, is always a possibility.

SELLAFIELD

"Our Record would stand up to scrutiny" *BNFL, 20th February 1986*

HERE FOLLOWS THE BNFL ACCIDENT RECORD:

21.8.50	ABNORMAL X-RAY EXPOSURE
OCT 1952	PLUTONIUM INGESTION
1952	PLUTONIUM INGESTION
4.1.53	PUTONIUM CONTAMINATION OF HANDS IN R & D FACILITY
16.6.53	ALPHA CONTAMINATION OF ROAD INSIDE SEPARATION AREA
18.6.53	BETA & GAMMA FACIAL CONTAMINATION
7.7.53	INSTRUMENT TROUGH SPILLAGE, REPROCESSING PLANT
10.7.53	PLUTONIUM CONTAMINATED WOUND
16.10.53	SPILLAGE OF URANYL NITRATE
2.11.53	CRANE FAILURE, REPROCESSING PLANT
30.11.53	SPILLAGE, R & D LABORATORY
23.5.54	FUME EMITTED IN PLUTONIUM RESIDUE RECOVERY OPERATION
15.9.54	BETA & GAMMA CONTAMINATED WOUND, R & D LABORATORY
16.11.54	LIQUOR SPILLAGE IN R & D LABORATORY
28.3.55	ABNORMAL PLUTONIUM DISCHARGE TO EFFLUENT TREATMENT
16.8.55	PERSONAL ALPHA CONTAMINATION, PLUTONIUM RECOVERY
15.11.55	ALPHA CONTAMINATED WOUND
2.11.56	PERSONAL BETA CONTAMINATION, STORAGE FACILITY
14.1.57	FIRE IN METAL RECOVERY LAB.
MAR 1957	CONTAMINATED SEPARATION AREA ROADS
13.6.58	ABNORMAL FILM EXPOSURE, R & D LABORATORY
21.6.58	INCIDENT IN PLUTONIUM FINISHING PLANT
20.7.58	ABNORMAL EXPOSURE INSTRUMENT MECHANIC
23.10.58	PERSONAL ALPHA CONTAMINATION IN PLUTONIUM FINISHING PLANT
OCT 1958	APPARENT CRITICALITY CLEARANCE CONTRAVENTION
27.1.59	LIQUOR SPILLAGE IN STORAGE FACILITY
6.2.59	PERSONAL CONTAMINATION
27.8.59	ACCIDENTAL WITHDRAWAL OF FUEL ELEMENT INTO OPERATING AREA OF WINDSCALE POND
27.1.60	FIRE AT EFFLUENT TREATMENT PLANT
30.3.60	PLUTONIUM SPILLAGE, R & D LABORATORY
25.5.60	PERSONAL CONTAMINATION, R & D LABORATORY
JUNE 1960	ABNORMAL FILM DOSES, PLUTONIUM FINISHING PLANT
24.6.60	PLUTONIUM CONTAMINATION, R & D LABORATORY
DEC 1960	ABNORMAL WAIST EXPOSURE, R & D LABORATORY
1961/62	FAILURE OF PLUTONIUM EVAPORATORS, REPROCESSING PLANT
16.10.61	FIRE DRIGG TRENCH
1.4.61	WHOLE BODY EXPOSURE GREATER THAN 3 REMS
31.8.61	EXPLOSION IN FUME HOOD (PERCHLORIC ACID) IN R & D LAB.
JAN 1962	ABNORMAL EXPOSURE
23.5.62	FLOOR CONTAMINATION IN R & D LABORATORY
NOV 1962	ABNORMAL EXPOSURE
24.9.63	PLUTONIUM CONTAMINATION, R & D LABORATORY
28.7.64	GLOVE BOX PRESSURISATION, R & D LABORATORY
2.12.64	FIRE IN DRIGG TRENCH
3.12.64	GLOVE BOX EXPLOSION IN R & D LABORATORY
5.3.65	OVER EXPOSURE IN MAGNOX PONDS
17.5.65	PERSONAL ALPHA CONTAMINATION, R & D LABORATORY
25.1.66	PERSONAL ALPHA CONTAMINATION IN R & D LABORATORY
JAN 1966	OVER EXPOSURE, CHARGEHAND FITTER
JAN/FEB 66	OVER EXPOSURE, SHIFT FOREMAN
12.2.66	OVER EXPOSURE, FITTER
1.4.66	OVER EXPOSURE, RIGGER
OCT 1967	APPARENT LOSS SMALL QUANTITY PLUTONIUM
7.11.67	PLUTONIUM WOUND, PLUTONIUM RECOVERY PLANT
29.11.67	FIRE IN DRIGG TRENCH
DEC 1967	OVER EXPOSURE F/M, IN MAGNOX POND
18.3.68	PLUTONIUM WOUND IN R & D LABORATORY
23.7.68	PERSONAL CONTAMINATION, MAGNOX PONDS
29.8.68	PLUTONIUM WOUND IN R & D LABORATORY
30.8.68	PLUTONIUM WOUND IN R & D LABORATORY
13.10.68	SPILLAGE IN REPROCESSING PLANT
SEP 68	LEAKAGE OF ACTIVITY TO SEABURN SEWER IN EXCESS OF AUTHORISATION
23.10.68	SPILLAGE, REPROCESSING PLANT
28.10.68	SPILLAGE, REPROCESSING PLANT
4.1.69	APPARENT REINFRINGEMENT OF CRITICALITY CLEARANCE, PLUTONIUM RECOVERY
17.2.69	ALPHA CONTAMINATED WOUND, R & D LABORATORY
18.2.69	LIQUOR SPILLAGE IN R & D LABORATORY
17.2.69	FIRE IN R & D LABORATORY
MAR 1969	SPILLAGE IN STORAGE FACILITY
13.3.69	PLUTONIUM LIQUOR SPILL, IN R & D LABORATORY
25.3.69	HIGH FILM DOSE, REPROCESSING PLANT
9.5.69	HIGH BETA & GAMMA HAND DOSE, REPROCESSING PLANT
19.6.69	PLUTONIUM RELEASE, REPROCESSING PLANT
9.7.69	FP LIQUOR SPILLAGE, HEAD END PLANT
10.10.69	ABNORMAL EXPOSURE, URANIUM PURIFICATION
7.11.69	SPILLAGE, PLUTONIUM FINISHING
8.2.70	PLUTONIUM CONTAMINATED WOUND, PLUTONIUM FINISHING
28.5.70	PERSONAL ALPHA CONTAMINATION, DECONTAM PLANT
JUNE 1970	APPARENT OVER EXPOSURE OF 4 PERSONS, STORAGE FACILITY
JULY 1970	OVER EXPOSURE OF TRANSPORT DRIVER
24.8.70	CRITICALITY ACCIDENT IN PLUTONIUM RECOVERY
22.9.70	RELEASE OF PLUTONIUM IN R & D LABORATORY
7.12.70	RADIATION OVER EXPOSURE, HA LIQUOR STORAGE
17.12.70	RELEASE OF PLUTONIUM IN R & D LABORATORY
DEC 1970	RADIATION OVER EXPOSURE OF HP MONITOR
6.3.71	PERSONAL CONTAMINATION, R & D LABORATORY
19.3.71	FIRE IN PLUTONIUM FINISHING PLANT
30.6.71	PLUTONIUM CONTAMINATION WOUND, PLUTONIUM FINISHING PLANT
16.7.71	FISSION PRODUCT CONTAMINATION OF FITTER, STORAGE FACILITY
18.8.71	APPARENT CONTRAVENTION OF CRITICALITY CERTIFICATE, REPROCESSING PLANT
28.8.71	FUME OFF (BUTEX/NITRIC ACID REACTION), STORAGE FACILITY
OCT 1971	RADIATION OVER EXPOSURE OF F/M, HEAD END PLANT
5.9.71	ELECTRICAL SUPPLY FAILURE, PLUTONIUM FINISHING PLANT
18.10.71	PERSONAL BETA & GAMMA CONTAMINATION, HA LIQUOR STORAGE
25.10.71	PLUTONIUM EXPOSURE, PLUTONIUM FINISHING PLANT
3.11.71	RADIATION OVER EXPOSURE OF HANDS, MAGNOX PONDS
29.3.72	PLUTONIUM EXPOSURE, WOUND, PLUTONIUM RECOVERY PLANT
15.5.72	ABNORMAL SHOE CONTAMINATION
MAY 1972	ABNORMAL EXTREMITY DOSE, MAGNOX PONDS
DEC 1972	IODINE-131 DISCHARGE, REPROCESSING PLANT
11.1.73	ELECTRICAL FIRE IN CORRIDOR, R & D LABORATORY
11.4.73	CRITICALITY CLEARANCE INFRINGEMENT, PLUTONIUM FINISHING PLANT
MAY 1973	HIGH FILM DOSE, REPROCESSING PLANT
2.7.73	HIGH BETA & GAMMA HEAD DOSE, REPROCESSING PLANT
12.7.73	PERSONAL BETA & GAMMA CONTAMINATION IN MAGNOX PONDS
SEPT 1973	HIGH FILM DOSE PROCESS WORKER IN REPROCESSING PLANT
26.9.73	BLOW BACK INCIDENT IN HEAD END PLANT. 35 WORKERS CONTAMINATED
7.12.73	LOSS OF ELECTRICAL POWER IN R & D LABORATORY
4.1.74	PERSONAL BETA CONTAMINATION IN REPROCESSING PLANT
30.1.74	PERSONAL CONTAMINATION IN R & D LABORATORY
JAN 1974	HIGH FILM DOSE, PROCESS WORKER IN OXIDE PONDS
9.4.74	LOSS OF WINDSCALE SUIT EXHAUST FILTERS
10.4.74	LOSS OF WINDSCALE SUIT EXHAUST FILTERS
22.5.74	APPARENT INFRINGEMENT OF CRITICALITY CLEARANCE, PLUTONIUM FINISHING PLANT
29.5.74	PERSONAL PLUTONIUM CONTAMINATION IN PLUTONIUM FINISHING PLANT
27.6.74	GLOVE BOX INCIDENT IN R & D LABORATORIES
3.7.74	BETA & GAMMA CONTAMINATED OVERALL
2.9.74	PERSONAL ALPHA CONTAMINATION IN R & D LABS
26.9.74	BETA & GAMMA CONTAMINATED SOCK IN CHANGE ROOM
27.9.74	ARRIVAL AT WINDSCALE OF A CONTAMINATED CEGB FLASK AT BERKELEY
DEC 1974	HIGH FILM DOSE, MAGNOX PONDS
1.2.75	PERSONAL PLUTONIUM CONTAMINATION, R & D LABS.
7.2.75	PERSONAL CONTAMINATION PLUTONIUM FINISHING PLANT
17.2.75	IRRADIATED METAL ON INACTIVE WASTE TIP
15.4.75	SPILLAGE OF PLUTONIUM LIQUOR IN R & D LABS
14.5.75	LEAKAGE OF ACTIVITY TO RIVER CALDER
14.5.75	ABNORMAL OVERALL CONTAMINATION, MAGNOX PONDS
MAY 1975	RADIATION OVER EXPOSURE OF C/H PROCESS WORKER
4.6.75	SPILLAGE OF HA LIQUOR IN SHIELDED CELL, R & D LABS.
10.6.75	SPILLAGE FROM FLASK ON LEVEN FISHER, BARROW
JULY 1975	HIGH FILM DOSE PROCESS WORKER PLUTONIUM FINISHING PLANT
JULY 1975	HIGH FILM DOSE C/H PLUTONIUM FINISHING PLANT
JULY 1975	HIGH FILM DOSE C/H PLUTONIUM FINISHING PLANT
23.9.75	PERSONAL ALPHA CONTAMINATION, ACTIVE LAUNDRY
SEPT 1975	ABNORMAL FILM EXPOSURE
SEPT 1975	ABNORMAL FILM EXPOSURE, MAGNOX PONDS
SEPT 1975	QUARTERLY WHOLE BODY DOSE, GREATER THAN 3 REMS, MAGNOX PONDS
6.10.75	CONTAMINATION PLIERS ON INACTIVE WASTE INCINERATOR TIP
10.10.75	CONTAMINATED CLOTHING FITTER IN OXIDE PONDS
14.10.75	CONTAMINATED CLOTHING PROCESS WORKER IN MAGNOX PONDS
7.12.75	SPILLAGE OF MAGNOX POND WATER
14.12.75	CRANE LEFT CONTROLLED AREA UNMONITORED
11.1.76	PRIMARY SEPARATION PLANT DISSOLVER PRESSURISATION
21.1.76	COOLING COIL LEAKAGE, HIGH ACTIVE STORAGE TANK
13.2.76	ABNORMAL COVERALL CONTAMINATION
26.2.76	ABNORMAL TROUSER CONTAMINATION
1.3.76	ABNORMAL COVERALL CONTAMINATION
3.3.76	ABNORMAL FILM DOSE
13.3.76	ABNORMAL LAB COAT CONTAMINATION
26.3.76	ABNORMAL COVERALL CONTAMINATION
MAR 1976	ABNORMAL FILM DOSE
7.4.76	ABNORMAL COVERALL CONTAMINATION
7.5.76	ABNORMAL COVERALL CONTAMINATION
14.5.76	ABNORMAL COVERALL CONTAMINATION
22.5.76	SPILLAGE 1ST FLOOR CORRIDOR IN URANIUM PURIFICATION PLANT
4.6.76	SPILLAGE GROUND FLOOR CORRIDOR IN URANIUM PURIFICATION PLANT
14.6.76	ABNORMAL LAB COAT CONTAMINATION
20.7.76	PERSONAL CONTAMINATION OF LAUNDRY WORKER
JULY 76	SPILLAGE, SAMPLE BULGE PRIMARY SEPARATION PLANT
10.8.76	SPILLAGE SCRUBBER CIRCUIT, PRIMARY SEPARATION PLANT
17.8.76	PERSONAL ALPHA CONTAMINATION, R & D LABORATORY
2.9.76	ABNORMAL FILM DOSE
2.9.76	PERSONAL CONTAMINATION, PLUTONIUM RECOVERY PLANT
14.9. 76	RADIATION OVER EXPOSURE, URANIUM PURIFICATION PLANT
10.10.76	SEEPAGE FROM SILO CONTAINING HIGH-ACTIVITY WASTE
14.10.76	CONTAMINATION OF BASIC TROUSERS WORN BY PROCESS CHARGEHAND

2. *September 1973* A blowback occurred in the Head End Plant at Windscale (now Sellafield) reprocessing complex which was put on an amber alert; 35 employees were contaminated, and the plant was closed down and eventually abandoned.

3. *June 1977* Over a year before final commissioning of the AGR, Hinkley Pt. B (which was 78 months late—11 years from start to finish) a major cooling water pipe broke, and a fire hose had to be rigged up to cool the concrete shielding to keep it below safe temperature levels.

4. *September 1977* An operator error at Hunterston B let several thousand gallons of corrosive sea water into the stainless steel core of the reactor. This led to a shut down for many months, and the total cost was well over £50 million.

5. *October 1981* After several days BNFL admitted that iodine-131 has been emitted from Sellafield reprocessing plant. The plant was shut down, and urgent investigations eventually established an

operator error at Hinkley Pt. A led to six fuel rods, freshly discharged, being shipped to Sellafield instead of being stored on site. Normally the rods are held for at least 80 days, by which time the iodine-131, with a half-life of 8 days, has decayed to 0.1% of its original amount. Early reprocessing releases the iodine present as a gas.

6. November 1983 Accidental discharge of radioactive solvent into Irish sea at Sellafield; 25 mile stretch of beach contaminated. BNFL prosecuted and fined.

7. June 1984 Heysham I provided an accident with many similarities to some aspects of TMI.[27] A report from the Nuclear Installations Inspectorate concludes that the event 'revealed weaknesses in procedure, ergonomics and human performance' in the control room, showing that CEGB is far from having learnt the lessons of TMI. During testing, two of the blanking units used to simulate the effect of fuel rods fell to the bottom of the fuel channels and were not noticed. When fuel was later loaded, the channels registered 'anomalous readings', but no action was taken. When the reactor went critical, alarms showed that the two channels were registering higher than average temperatures at the gas outlets. Again these warnings were missed by the operators. Half an hour later, when a computer assisted scan highlighted the abnormal temperatures, checks were finally made and the reactor shut down manually.

The original alarms appeared both on a screen on the reactor engineer's desk, and as part of a Major Cause Alarm display. CEGB set up a working party to review 'urgently' the implications of the accident. In this case, the worst that might have happened would probably have been damage to a few fuel rods, with any release of radioactivity kept within the primary coolant; but in more difficult circumstances, similar operator errors led to TMI.

It is of vital importance that we should prevent the results of such operator errors from occurring here by stopping Sizewell B from being constructed, and running down nuclear power production.

A few days after this accident at Heysham, water was accidentally pumped into a storage tank containing radioactive tritiated water. The radioactive water overflowed, and some escaped from the control area.

8. October—November 1985 Three leaks at Hinkley Point. B AGR.[28] (a) A burst boiler pipe flooded the reactor. The contaminated water was pumped into tanks, diluted and released into the Bristol Channel. Details were kept secret, and news of the accident only leaked out after four days. (b) Less than a month later, 24 tons of CO_2 coolant were lost. This gas had not been inside the reactor, but the incident does not say much for handling procedures. (c) The major accident occurred a week later when a one inch hole appeared in the gas circulation system; 8 tons of hot pressurised CO_2 gas containing suspended radioactive 'crud' and possibly iodine-131 from small fuel rod leaks, escaped into the containment building and then into the atmosphere. The leak took four hours to plug, and another 15 tonnes of CO_2 had to be deliberately vented (in this case, filtered) to reduce pressure. Personnel in the reactor hall were evacuated, and all 500 staff were given potassium iodide pills as a precaution against the effect of radioactive iodine-131.

9. January 1986 Sellafield. Nearly half a ton of uranium accumulated in a discharge tank, because of a faulty evaporator handling uranyl nitrate. This could have been drained back into the plant, but was discharged into the sea to add to the 2-3 tonnes normal annual discharge. As usual, this high local concentration was compared by BNFL's spokesman to the large amounts of widely dispersed uranium occurring naturally in the Irish sea and sediments.[29]

10. February 1986 Accidental release of plutonium mist in the decanning plant caused amber alert at Sellafield; 30 workers evacuated. The mist was not completely contained within the plant.[30]

11. February 1986 At Transfynydd power station during start up, a pressure relief valve opened incorrectly, and 13 tons of slightly radioactive carbon dioxide escaped into the atmosphere for 14 minutes before the valve could be closed manually. The filter, which should have prevented solid particles from emerging also failed, and radioactive rust particles escaped with the gas.[31]

A PWR is even more dangerous than an AGR

The three most dangerous accident possibilities from the operation of a PWR do not apply to an AGR. These are as follows: (a) Fast fracture of the pressure vessel, with massive flying fragments breaching the containment, and melt down of the core releasing large amounts of radioactivity into the environment. (b) Fracture of the primary coolant system leading to unforeseen effects from the consequent two phase (water and steam) system. No adequate theoretical understanding of two phase flow exists, so that only semi-empirical approximations, partially checked by experiments, are available for specific types of failure. If such approximations are inadequate or the failure does not conform to the types considered, unanticipated disastrous results may follow. (c) The high power density in a PWR—over 20 times greater than in an AGR—means that much less time is available to deal with emergencies, perhaps 5 minutes compared with half an hour or more in an AGR.

It is difficult to understand why CEGB should wish to build an unnecessary nuclear station of any kind, but to change to a type with additional dangers is on the face of it such an indefensible decision that it must lead to suspicions that undisclosed factors are at work.

The fact that the PWR has additional dangerous features does not mean that the AGR is safe. The same unstoppable furnace and radioactive poisons are created as for any nuclear reactor. In addition, the graphite moderator means that in a LOCA the carbon dioxide coolant might get contaminated by air, adding a graphite fire to the unstoppable decay heat. Even if air were initially prevented from entering, a failure of the circulation pumps combined with loss of pressure would lead to overheating of the core with disastrous consequences, including almost inevitably an eventual graphite fire, as in the disasters at Windscale in 1957 and Chernobyl in 1986.

Nuclear Power proclaims its dangerous Character in its Organisation and Research

Nuclear power is so uniquely dangerous that it is forced to declare the fact in its own safety organisation. No other human activity (outside warfare) has such elaborate warning and evacuation plans in the event of an accident. The mere list of emergency arrangements tells its own story. Regional and National Nuclear Emergency Information Rooms to coordinate help to the stricken station; special weather forecasts for the area; stocks of iodide tablets in readiness for issue to those members of the public at risk from ingesting or inhaling radioactive iodine (this is likely to be too late, certainly for the most effective use—in the US and Sweden small packages of potassium iodide tablets have been issued to residences surrounding nuclear plants); specialist facilities for radiochemical analyses at the Central Radiochemical Laboratory at Gravesend and the CEGB's Berkeley Nuclear Laboratory; stocks of emergency equipment; emergency evacuation; prevention of access to affected areas; prevention of the consumption of contaminated food; collaboration with Government Departments and keeping ministers advised. Some of the provisions would apply to a disastrous chemical accident, as at Seveso, but taken as a whole they demonstrate the unique danger which has called them into existence.

In addition, nuclear stations are the only constructions in the UK which are formally required to have safety related plant capable of withstanding an earthquake and the only plant whose third party liability is limited (to £20 million per incident). Claims above £20m must be made to the government, and there is provision for the other countries which are party to the Brussels Convention to contribute to the costs. In other words, the industry is so uniquely dangerous that its insurance has to be subsidised by government.

The safety related research also tells its own story. About a third of the £40 million a year spent at the UKAEA research centre at Winfrith Heath, Dorset, is used to study the safety of nuclear plant. The laboratories and underground test beds are spread well apart on a site of more than eight square miles. One of the main programmes is concerned with the effect of low velocity heavy objects—from crashing aircraft to the blade sheared from a turbine—on the safety of buildings. A most important investigation, which is not however mentioned in the report, must be on the effect of a fragment of an exploding PWR pressure vessel on the containment building. From the results so far, such low velocity objects turn out to be more hazardous than high velocity military missiles. Nuclear power is so uniquely dangerous that even its 'safety' research proclaims the fact.

> I fear that Chernobyl will not be the last accident. I listened to the debate held 13 May 1986 and wondered how different it would have been if that accident had occurred at Bradwell, Hunterston, Oldbury or Torness. I share the view expressed today. This is a technology that humanity cannot handle, and, not for the first time, the public are ahead of Parliament in perceiving that.
>
> **Tony Benn**

Why make Nuclear Accidents possible?

Faced with the difficulties and dangers of nuclear power outlined above, most people's reaction is 'Why on earth do they want it?' The answer at the present day is probably given by a term which the Kemeny Commission commented on in relation to TMI: 'mind-set'. It is an Americanism which needs no translation. But what set so many minds in the direction of nuclear power development was a belief, supported by experience for a few years in the 1950s and 1960s, that electricity consumption would increase exponentially for the foreseeable future. The existence and persistence of this 'mind-set' was demonstrated in the evidence on economics given to the Sizewell Inquiry and in a paper in Energy Policy.[32] Figs 4 and 5 in that paper show comparisons of CEGB's forecasts of future demand and the actual outturns. In 1966 the forecast demand for 1982/3 was 100 GW. By 1974/5 the 1982/3 forecast had reduced to 55 GW. The forecast then reduced year by year (an average of 2.3 GW pa), until in 1981/2, because the fluctuating actual demand started to go up again, CEGB got the forecast one year ahead exactly right at 41.2 GW. In spite of the downward plunge of the line of forecasts for 1982/3, CEGB's medium term forecasts (7 years ahead) continue to climb, and their long term forecast for 2023 at 57 GW, is 2 GW more than the forecast for 1982/3 made in 1974/5. CEGB admitted at the Inquiry that, in the latest ten years for which forecasts for the seventh winter ahead and actual outturn could be compared, they had been consistently wrong, with a maximum error of 29%, and a ten year average overestimate of 26%. This 'mind-set' which can only see a mirage of future increase in supply of electricity, is the fundamental factor (behind the crumbling facade of alleged economic benefit) generating the continued pressure for nuclear power. The extent of that pressure can be judged by the expenditure (or commitment to expenditure) of £200 million on Sizewell B before the Inquiry had heard the evidence, and before the NII had agreed the safety of the design. This should be compared with the tremendous *resistance* put up by CEGB to starting the coal-fired station, Drax B (demanding, and getting, £50 million 'compensation' from the government for ordering 'ahead of need').[33]

Nuclear Power Not Necessary

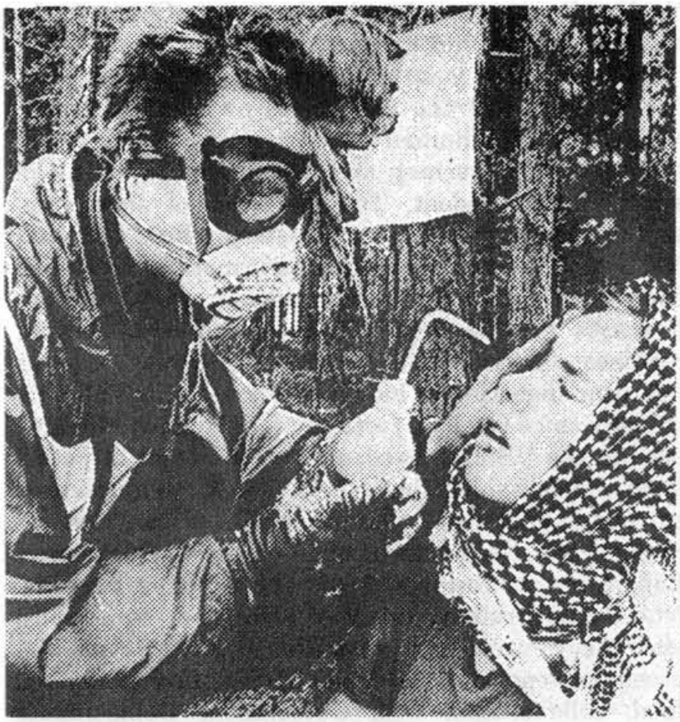
This 'mind-set' has no longer any theoretical basis. For any conceivable future expansion (say a tripling of GDP by 2030 as envisaged by the Dept. of Energy in

Energy Paper 39) improvement in energy efficiency can increase faster than energy end use. We ought to be preparing, not for varying degrees of energy growth to the year 2000 and beyond, but for substantial energy shrinkage (at least in the industrial countries) despite assumed increasing affluence. This possibility has now been documented for all major industrial countries, and in the UK the pioneering work of Gerald Leach and his colleagues[34] has been buttressed and extended by the monumental study 'Energy Efficient Futures'[35]. Such a programme is actually being carried out in practice in the US through the legally binding Northwest Conservation and Electric Power Plan enacted in 1983.[36]

Only the refusal to recognise the extent of conservation that is possible, and the inevitability of its substitution for new energy production over the next fifty years, enables proposals such as Sizewell B even to be considered. This substitution is already starting, and once the investment in energy saving is determined according to similar criteria to those applied to energy supply, as recommended by the Select Committee on Energy, the case even for replacement of existing power stations cannot be made until well into the next century, as Energy Efficient Futures has shown. It is time that the proponents of nuclear power realised that their product is not only unwanted, but not needed, even on the DEN's extravagant view that by 2025 we shall be trying to cope with three times as much of everything.

It is often asked how, in the face of all this evidence, nuclear experts can continue unanimously to assert the need for nuclear power. The answer has recently been given in the columns of ATOM, the glossy propaganda magazine for nuclear power produced by the UK Atomic Energy Authority. In issue No. 350, December, 1985, a review is given of the discussions of a panel of experts, convened during the General Conference of the International Atomic Energy Agency in September 1985, to discuss small and medium sized power reactors. The review is by James Daglish, until recently the editor of ATOM, and contains one very significant sentence, as follows: 'Throughout the discussions, the need for an expansion of nuclear power capacity to meet ever-increasing energy demand was taken as self-evident'. Only by refusing to look at the evidence for alternative possibilities, so painstakingly documented in the publications given above, can the 'experts' maintain the facade of unanimity.

But there is also another 'mind-set' which derives from the idea of 'Atoms for Peace' as a partial atonement for the nuclear bomb. This is by no means confined to those who were involved in the wartime work on the bomb or the plutonium factories to supply the UK weapons. All scientists and technologists must surely feel to some extent that the nuclear bomb is the ultimate perversion of science, and there were very few at the time who did not welcome 'Atoms for Peace' as some expiation. This desire to compensate can produce the defence of nuclear power as 'clean' and 'safe', because the technical solutions are alleged to have been found to the dangers and problems, at least to the



A victim of Chernobyl.

point where they are said to be essentially no different from other industrial activities. Sympathy for the motives of such protagonists must not, however, be allowed to extend to uncritical treatment of their arguments, which are essentially the same as those of the other 'mind-set'.

Summary of the New Unique and Inherent Characteristics of the Dangers from Nuclear Power

1. An unavoidable product of the operation of nuclear power stations, plutonium, can be used as weapon material capable of destroying the human race and probably most life on earth.

2. Nuclear power produces a furnace which, while cold to start with, can never be completely shut down once it is started. This unstoppable part of the furnace is equivalent, in the crucial early stages of partial shutdown in the event of an accident, to a large steel melting furnace inside the core. It must be a unique human activity, to start a dangerous undertaking in the certain knowledge that, once started it cannot be stopped.

3. Nuclear power necessarily produces a completely new, large scale poisonous material (HLW), theoretically capable of killing off the human population of the earth many times over, and, in the unstoppable furnace which is another aspect of its radioactivity, provides the energy for widespread dispersal of the poison in the event of an accident.

In addition, very large quantities of less concentrated poisonous material (ILW and LLW) are produced. These also have to be kept isolated from the environment for long periods.

4. This poisonous material can act at a distance to produce radiation sickness, cancer and genetic effects. It is completely undetectable except by the use of sophisticated instruments.

5. If ingested or inhaled, this poison, never before

seen on earth and created from material which is almost innocuous by comparison, gives rise to radiation sickness, cancers and genetic effects. Other (chemical) poisons can give rise to comparable effects, but these can all, in principle, be destroyed or prevented from being formed. The unique character of radioactive poisons from nuclear power is their indestructibility. For practical purposes nothing but time can change their toxic characteristics, and in many cases the time required is on a geological scale. For historical purposes such material can be said to be unchangeable and indestructible.

6. Nuclear power is so uniquely dangerous that it is forced to declare the fact in its own safety organisation and research.

7. Nuclear power is unique (apart from the construction of bombs from the plutonium it produces) in being relentlessly promoted in spite of its dangers, although humanity has no need for it.

References:

1. *Nuclear Power—The Reason Why*, by Arthur Palmer, Labour MP for Bristol North East 1974-83, former front bench Opposition spokesman on energy and Chairman of the Select Committee on Science and Technology, 1974-79. Published by the Electrical Power Engineers Association, with a Foreword by the General Secretary, John Lyons. 1983, p.8 and footnote.
2. Loss of Fluid Test facility. *Science*, Vol. 229, 9.8.85, p.538.
3. *N. Scientist*, 28.2.85, p.5.
4. *N. Scientist*, 28.3.85, p.16.
5. The Inquiry reference to the original Proof of Evidence, 'The Unique Dangers of Nuclear Power', is SSBA/P/4, presented on behalf of the Stop Sizewell B Association and Ecoropa on 12/13 July 1984. 83 references substantiated all the unreferenced statements in this article.
6. The Inquiry reference to this Proof of Evidence on the hazards associated with uranium mining is JEP/P/1.
7. *Science*, Vol. 229, 9.8.85, p.537.
8. *Atom*, 347, Sept. 1985, p.39.
9. Emergency shutdown. The story goes that when the first Fermi pile was built in the squash court of Chicago University at the end of 1942, the large cadmium safety control rod was suspended above a channel in the pile by a rope. As the control strips were pulled out by hand until the pile went 'critical', a man with a sharp axe was stationed ready to cut the rope if there was an unforeseen excursion of power. He was the Safety Control Rod Axe Man, and an emergency shutdown has been a 'SCRAM' ever since.
10. *Nature*, Vol. 316, 29.8.85, p.757.
11. A third of the starting core is replaced at the end of the first year and another after the second. At the end of the third year the core is 'end-of-cycle' or 'mature', with one third having been operating for 3 years, the second for 2 years and the third for 1 year. The 3 year section is then replaced and after another year the core is again 'end-of-cycle'. 'Mature' is less precise and may mean merely over 3 years operation.
12. A new US 'profession' of people who do repairs in areas with high radiation levels by jumping in and out quickly.
13. *Nature*, Vol. 308, 22.3.84, p.308.
14. *Elec. Rev.*, Vol. 217, 18.10.85, p.9.
15. The total work force multiplied by the average exposure in rems. Maximum individual exposure allowed is 5 rems per year. The original estimate was 2,000—8,000 man rems, the revised estimate, 13,000—46,000.
16. *Science*, Vol.230, 11.10.85, p.150.
17. *The Times*, 7.3.85, 'Worries over long term safety grow in America'.
18. *Science*, Vol. 225, 3.8.84, p.489.
19. *N. Scientist*, 3.10.85, p.25.
20. *N. Scientist*, 31.10.85, p.30.
21. *Nature*, Vol. 318, 7.11.85, p.50.
22. *Science*, Vol. 229, 2.8.85, p.448.
23. The Inquiry reference to this correspondence is SSBA/S/255.
24. *Guardian*, 2 May 1986.
25. *Science*, Vol. 231, 24 Jan. 1986, p.334.
26. *Science*, Vol. 231, 28.2.86, p.913.
27. *N. Scientist*, 22.11.84, p.4.
28. *The Times*, 3 Dec. 1985; *N. Statesman*, 8 Nov 1985, p.6; *Guardian*, 30 Nov. 1985.
29. *Guardian*, 24 Jan. 1986.
30. *Guardian*, 6 Feb. 1986.
31. *Guardian*, 7.3.86 and letters 13.3.86.
32. The Sizewell evidence was referenced as SSBA/P/1 with (ADDS1-7), 'An economic critique of the CEGB's case for a PWR at Sizewell' by J.W. Jeffery on behalf of SSBA and Ecoropa. Part of this evidence has been summarised on the basis of an agreed document showing the relations between the very different economic results obtained by CEGB and SSBA. This summary 'A Critique of the CEGB's economic case for a PWR at Sizewell', by J.W. Jeffery is published by *Energy Policy*, Vol. 14, No. 1, February 1986, p.65-78.
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34. 'A Low Energy Strategy for the UK', IIED, 1979.
35. 'Energy Efficient Futures—Opening up the Solar Option', Earth Resources Research, 258, Pentonville Road, London, N1 9JY.
36. Inquiry Reference SSBA/S/38—See SSBA/P/1, p.67 (Ref. 67) for details.

WESTERN REACTORS: HOW THEY COMPARE WITH CHERNOBYL

by Richard E. Webb

Intent on defending its interests, the nuclear industry in the West responded to the Chernobyl accident by saying "it couldn't happen here!—our reactors are completely different and intrinsically safer. Moreover, our engineering standards, quality control and operator training are vastly superior compared with those of the USSR." Lord Marshall, chairman of the CEGB called the Chernobyl RBMK reactor a 'chimaeric hybrid' and as late as July 31st, assured the public that it could not be licensed or built in the UK. In fact, Dr Richard Webb, a foremost authority on the hazards of nuclear reactor operation, explains why western light water reactors, the most common type used in the world, are intrinsically more dangerous. The CEGB is now seeking to build Britain's first commercial light water reactor (PWR) at Sizewell, no more than 100 miles from London, followed by a series elsewhere in Britain, including at Hinkley Point in Somerset and Druridge Bay in Northumbria. Dr Webb also shows how the fast breeder reactor, like our prototype at Dounreay in Scotland, and the French 1300 MW (e) Superphenix at Creys-Malville, is incomparably more dangerous and is actually capable of exploding like an atomic bomb.

Governments of Western Europe have assured the public that despite the Chernobyl reactor eruption, there is no cause for closing down the nuclear power plants in Western Europe; for the Western reactors are designed differently than the Chernobyl reactor, with better safety provisions to prevent reactor eruptions and releases of radioactivity.

Contrary to such official assurances, Western reactors are much more hazardous than the Chernobyl RBMK-type reactor plant. Thus:

1. The use of a large pressure vessel in the PWRs and BWRs with its potential of a catastrophic explosive rupture, which is a single failure event for which there is no protection. The PWR and BWR containments are not designed to withstand a reactor vessel rupture. The 100-ton vessel closure dome could be blown 500 metres upwards by a vessel rupture, easily destroying the containment. Furthermore, such a dome blow-off could conceivably carry away the reactor nuclear control rods, causing a severe runaway of the atomic reaction in the reactor core (due to the control rods being rapidly pulled out of the core), in addition to the tendency of the exploding reactor coolant to blow the core through the containment—all of which are possibilities which have not yet even been investigated. The Chernobyl RBMK-type reactor uses no reactor pressure vessel, and thereby avoids such catastrophic potentialities.

Dr Richard Webb, *a nuclear engineer, trained by Westinghouse and the US Navy, with a doctorate from Ohio State University on the explosion potential of fast reactors, was the author of* **The Accident Hazards of Nuclear Power Plants** *(University of Massachusetts Press) and of the report* **Catastrophic Nuclear Accident Hazards—A Warning for Europe.** *He also contributed to a West German Government study of the explosion hazards associated with its SNR-300 fast reactor at Kalkar.*

2. The fuel rods in PWRs and BWRs are all bound together in a compact, large bundled mass of fuel rods (40,000 rods) inside a single vessel; whereas in the RBMK the fuel rods are separated in groups of 18 rods that are dispersed in a large block of graphite, which has very good heat conduction and dissipation properties. The bunching of fuel rods in the PWRs and BWRs thus concentrates the fuel to maximise the heatup temperatures of a fuel meltdown, and consequently to maximise the potential for fuel boiling and vaporising and releasing the fission products and plutonium. The fuel bunching also maximises the potentials for a coherent interaction and mixing of a large mass of molten fuel and water, to produce the maximum potential steam explosion, which is about 200,000 pounds TNT equivalent for the PWR and BWR. Also, the single large vessel provides a source of ready water for such a steam explosion, which cannot be drained out in an emergency, as was the steam quench pond beneath the Chernobyl reactor.

3. As is also the case for the Chernobyl RBMK reactor containment structure, the PWR and BWR containments are *not* designed to withstand any reactor accident possibility involving fuel melting, hydrogen explosions or burning, steam explosions, or steam over-pressure. In PWRs and BWRs the containments can also burst by carbon dioxide gas pressure buildup and also by sudden air heating and pressure surges from molten fuel spray discharges from the reactor vessel. All of these mechanisms can potentially rupture or burst the containment easily. Moreover, the containment vessel building in PWRs and BWRs is much larger and voluminous than the Chernobyl RBMK vault type containment chamber, which means that a containment burst in Western reactor plants would be much more powerful. For example, a PWR containment burst would yield an

explosion the equivalent of about 10,000 pounds of TNT or more. Such a containment explosion would surely destroy one or more adjacent reactors at a plant with more than one reactor, and thereby cause a chain reaction of reactor eruptions—a most cataclysmic accident. This is especially a possibility in France which has typically four to five PWR large containment reactors at one station.

4. The containment building of the Three Mile Island (TMI) reactor—the US reactor which suffered the well-known accident in 1979—has frequently been cited as proof that a Western-style reactor containment building would have prevented a serious release of fission products at Chernobyl, since, when the Three Mile Island accident occurred, US containment building had effectively contained the fission products that escaped from the destroyed reactor fuel rods. This claim, however, is unfounded. The TMI reactor safety systems and containment building were not designed to contain the reactor accident that had occurred, which involved fuel rod disintegrations and hydrogen production. A hydrogen explosion occurred in the containment building, yet the containment was not designed for hydrogen explosions. Luckily, the peak pressure of the hydrogen burn did not exceed the containment's design pressure level. (The containment was designed for the limited steam pressure of a simple coolant pipe rupture.) In the TMI accident, more hydrogen could just as well have been generated before the hydrogen ignited, and consequently a much more powerful explosion could then have occurred to burst the containment. Also, the heat up of the reactor core during the TMI accident could have been more serious. It was just luck that the haphazard sequence of events that happened at TMI had resulted in a limited core heatup. It could just as well have been worse. For instance, a fuel meltdown and a catastrophic steam explosion could have occurred, as could a pressurised discharge of the molten fuel from the weakened reactor vessel and a consequent bursting of the containment by the combination of a hydrogen explosion and air that could have been rapidly heated by the molten fuel spray inside the containment chamber.

Neither can one say that the eruption potentials by runaway atomic reactions are worse for the Chernobyl RBMK-type reactor than for the Western reactors. For the atomic runaway accident potentials have still not been fully evaluated for PWRs and BWRs.

The Bavarian Environment Minister, Mr Dick, has pointed out the positive 'reactivity' feedback potential of the Chernobyl RBMK reactor; namely, the possibility of a self-induced *increase* in the atomic reaction due to a loss of reactor coolant, such as a coolant pipe rupture in the system. Of course, an increase in reactor power worsens the loss of cooling condition.* Mr Dick asserted that in German reactors, which could be taken as referring to PWRs and BWRs in general, a loss of coolant results in an inherently automatic 'interruption' of the atomic reaction. However, this claim, which is widely accepted, has not been proven. In the official reactor safety analyses in the United States, the assumption is made for one class of loss-of-coolant accidents in PWRs, namely a small reactor coolant pipe rupture, and for any size pipe rupture in BWRs, that the atomic reaction is stopped by *external means*, namely, by a rapid insertion of the reactor control rods into the reactor core, and *not* by an inherent self-induced response of the reactor to the loss of coolant from the system, as Mr Dick and others assume.

In 1983 failure to insert the control rods in a US PWR led to a minor emergency, fortunately in that instance there was no loss of coolant. The physical designs of the PWR and BWR reactor systems, including the reactor itself, suggest possibilities of *increases* of the atomic reaction, even atomic runaways, during loss-of-coolant accidents with failure of control rod insertion, due to complex coolant behaviour during the time when the reactor coolant first begins to discharge from the reactor. Also, even if the control rod insertion system were operable, there is still a question of an atomic runaway being triggered before the control rods move into the core to stop the atomic reaction; At least for BWRs the theoretical computer simulation models of the reactor for calculating the coolant behaviour of the reactor following a pipe rupture are too simplified to predict reliably the possibility of runaway atomic reactions occurring during pipe rupture accidents. Moreover, to establish experimentally reactor behaviour, full-scale reactor loss-of-coolant testing would be required. However, such tests are not practicable. Not even small scale experiments have been made for reactor loss-of-coolant accidents, except for one test of a very small special test reactor, but this test was not designed to test for atomic runaway possibilities.

Also, PWRs and BWRs have their own peculiar definite potentials for dangerous positive feedback behaviour, as does the RBMK. For example, in a BWR (boiling water reactor) the sudden closure of the reactor steam outlet valve, followed by a failure of the external safety actions to control the atomic reaction or shut it off, would lead to an atomic reaction runaway. This type of accident is the opposite of a loss of coolant. In this case the reactor pressure rises, which by a nuclear effect, causes the atomic reaction to increase, which in turn adds more heat energy to the reactor, which in turn causes a more rapid increase in the reactor pressure, which then causes a more rapid increase in the atomic reaction rate (reactor power), and so on, a positive feedback process which produces a runaway atomic reaction.

According to quite elaborate computer calculations which I have made, in this accident the reactor fuel would melt in six seconds. The melting could then conceivably cause an extremely rapid pressure surge and a consequent final powerful atomic runaway that would produce a most catastrophic reactor explosion.

The conclusion which I have reached based on my analyses is that the prevention of catastrophic accidents at nuclear power plants depends essentially on the careful, correct fabrication, construction, operation, and maintenance of the reactors, and not on any inherent limitations of reactor eruptions or inherent containment capacities of the reactor containment structures to absorb eruptions and contain the radioactivity, should a mishap occur.

This last point is crucial. For the Western nuclear reactor developers have convinced themselves, on the basis of speculative theoretical analyses, that should a

*This positive feedback potential could have caused the Chernobyl accident or contributed to it.

reactor accident occur which results in "severe core damage", which they concede is possible (indeed such has happened at Three Mile Island), the *likely* course of the reactor accident would still not be catastrophic. Thus they assume that no strong steam explosion would occur to rupture the containment building (an assumption of 'inefficient' mixing of molten fuel and water to produce only a weak explosion); that a reactor vessel rupture would probably only be a splitting open of the vessel without breaking the containment (no damaging high velocity projectiles); that the containment building would not burst but would merely leak to vent excessive pressure, resulting in a serious but not catastrophic fission product release; that a hydrogen explosion in the containment would likely not be the full potential; that a chain of malfunctions occurring to trigger a severe runaway of the atomic reaction is not likely and that atomic runaways triggered by loss of coolant accidents are not credible. But these judgements and beliefs are not founded on full theoretical analyses and experimental verifications, which would require full-scale tests.

Better Engineering in the West

Some might argue that Western reactors are more carefully constructed and operated so as to make the likelihood of serious mishaps acceptably small (for example, the standardised reactor designs in France). However, there was the Three Mile Island accident, and several other near catastrophic reactor mishaps in the United States. For instance, in an emergency incident in 1983 in a Westinghouse pressurised water reactor in Salem, New Jersey, the safety systems failed to stop the atomic reaction rapidly enough. Fortunately, the emergency was a minor one, for which there was time to shut down the reaction by slower means, and was not a serious event requiring a rapid control rods insertion. Also, there was the Gundremmingen BWR over-pressure accident in 1977 in West Germany, which damaged pressure-relief safety valves and contaminated the reactor building or the containment chamber, and caused the plant to be closed down.

The Soviet officials explained that the cause of the Chernobyl accident was "the coincidence of several highly improbable and therefore unforeseen failures", meaning, *multiple failures* of reactor system components causing the accident. However, multiple failures also caused the Three Mile Island accident. The safety systems of Western reactors are designed basically to control only those accidents that are caused by a single failure in the system, not multiple failures. Yet, multiple failures can be expected to occur. Again, there is no protection for a reactor vessel rupture, which is a single failure event; and so even the single failure principle is not fully complied with.

In 1984 one of the PWR reactors at the Bugey nuclear power plant in France (4 PWRs and a gas-cooled reactor) suffered a chain of failures which resulted in a complete loss of the two independent grid sources (external sources) of electric power feeding the station or the reactor. Electric power is needed to maintain control and cooling of the reactors. Then one of the two diesel-electric generators (back-up power) failed to start, leaving only one diesel-generator, which fortunately operated. So in this incident a catastrophe was evidently narrowly averted.

Fast Breeder Reactors

The fast neutron, liquid metal (sodium) cooled, plutonium breeder reactor, or fast breeder reactor for short, is being strongly developed in Europe, USSR, United States and Japan; for example, the Super-Phenix in France, the Prototype Fast Reactor in Great Britain, and the SNR-300 reactor in West Germany (SNR-300 has not yet been started up). The function of the fast breeder reactor is to convert the abundant but not fissionable uranium-238 isotope (99.3 per cent of the natural uranium is U-238) into fissionable *plutonium,* while also fissioning plutonium fuel to produce power. The plutonium breeding would thus exploit the full nuclear energy potential of the uranium resources, and thereby make nuclear energy a permanent energy source. Otherwise, the rare uranium-235 isotope of high-grade uranium ores would be exhausted in the short term (say 30 to 50 years), according to official analyses. Eventually, 90 per cent of nuclear power reactors will be fast breeder reactors, if nuclear energy continues to be developed and exploited.

Unfortunately, fast breeder reactors also have catastrophic nuclear accident hazards, especially *nuclear explosion* potentialities, due to the high concentration of fissionable material in the reactor core, unlike the low concentration (3 per cent or less) in conventional reactors, like PWRs, BWRs, RBMKs, Britain's gas-cooled reactors, and CANDU.

Until recently, upper-bounding type calculations which I have made for SNR-300 reveal core explosion potentials ranging from 2000 to 20,000 megajoules* of explosion energy for a variety of different possible mechanisms, with no upper limit yet established for these mechanisms. A typical mechanism consists of a small sodium coolant vapour explosion occurring on the periphery of a partly molten, disintegrated reactor core in a loss of reactor cooling accident with a failure to stop the atomic reaction. The small explosion could blast a portion of the fuel further into the core and thereby trigger off a severe atomic reaction runaway—*a nuclear explosion.* (A rapid compaction of fissionable material produces nuclear explosions, like in an atomic bomb in the extreme case.) The calculated explosion energies greatly exceed the SNR-300 containment design value of 370 megajoules. Such explosions would destroy the containment and involve the near complete vaporisation of the plutonium fuel material and the fission products, and blow this radioactive material into the atmosphere, with catastrophic consequences of course. Besides the fission product fallout consequences, which are comparable to those of conventional reactor eruptions, the much greater plutonium inventory in the fast breeder reactor, and the definite release of virtually all of the plutonium, would have much more extensive catastrophic plutonium fallout

*500-5000 Kg TNT.

consequences: possible abandonment of a land area size 500,000 to one million square kilometres, due to plutonium fallout dust contamination alone.

The SNR-300 reactor (and presumably other fast breeders too) is designed for a limited degree of absorption and containment of a reactor core explosion (370 megajoules for SNR-300); but the official calculations of explosion potentials are made with computer theoretical 'models' of the violent behaviour of a "core disruptive" accident which are unrealistically simplistic. They are founded on arbitrary assumptions. A great many full-scale reactor destructive tests would be required to develop and verify such theoretical methods of calculating core accident behaviour and explosions, but these are clearly impractical.*

In the core of a fast breeder reactor there exists a great quantity of plutonium (fissionable material). Upon a core disruption accident, this plutonium fuel material could divide itself into a number of small, separated compacted masses of plutonium fuel (actually a mixture of plutonium and uranium-dioxide), each mass being nearly 'critical'. In such a situation it is possible that one small compacted mass of fuel could explode, as a result of some collapse of more fuel on it which triggers a strong atomic reaction runaway. This explosion in turn could drive a second, separated small compacted mass of fuel towards a third separated mass at a *high velocity,* like in the Hiroshima bomb mechanism. *The result is a secondary atomic reaction with a calculated 1 to 3 kilotons TNT equivalent explosion. Hiroshima was 12.5 kilotons.*

* My detailed analyses and calculations are set down in a series of treatise which are part of the report of the official West German Government study of the SNR-300 explosion hazards (1981-1982) plus a final January 1984 treatise which I have also issued. I would like to commend the West German government for sponsoring the study, as it has greatly advanced our knowledge of the fast breeder reactor accident hazards.

Furthermore, the atomic reaction would not necessarily be limited to the 1 to 3 kiloton TNT energy release value. For the extreme high pressures of the secondary reaction could conceivably drive or compress other, still-unreacted fissionable material remaining in the reactor core, before the whole core mass is blown apart, to induce still more atomic reaction excursions, *which might end in an explosion considerably greater than that which occurred at Hiroshima.*

I note here that Dr David R. Inglis of the United States, who was one of the original forty physicists who developed the atomic bomb at Los Alamos in 1943-45, and whose scientific work in the bomb project was precisely the kind of analysis and calculations of rapid fuel assembly and explosion energy yields which I have made for my fast breeder reactor accident analysis, agrees that the atomic-bomb-like explosion mechanism for fast breeder accidents, which I have conceived of, is credible and needs to be examined. Indeed, the official history report of the Los Alamos atomic bomb project reveals that an 'autocatalytic' reaction, like that of the conceived mechanism, is one of three possibilities for producing atomic bomb explosions. The other two were the ones adopted for making atomic bombs: the so-called 'gun-type' mechanism used in the Hiroshima bomb, and the plutonium implosion type. Autocatalytic type mechanisms were not developed in the Los Alamos project, because they were regarded as not 'efficient', rather than that they could not produce atomic bomb size explosions (1 kiloton or more).

As we can see, the fast breeder reactor is potentially extremely dangerous. Indeed, one may ask, how can one possibly justify the construction and operation of conventional nuclear reactors, and making the population dependent on nuclear energy, when the reactor type needed to make nuclear energy a lasting power source has such catastrophic explosion accident hazards?

Chernobyl: What could have happened

by
Richard E. Webb

Only a small percentage of the Chernobyl core appears to have been released. As Richard Webb tells us, we were fortunate that the accident was limited to just one reactor, and undoubtedly we owe a great debt to those who fought the blaze at Chernobyl with extraordinary courage and sacrifice. Practically all those involved in the first hours after the explosion were exposed to lethal doses of radiation. In the next emergency can we expect people to sacrifice their lives in the same manner?

The accident could just as well have been much worse. The potentialities were as follows:

1. The initial plume that went to Scandinavia encountered no rain until it reached Sweden. Had it been raining in Poland and in the Soviet Union, the fallout would have been much more concentrated, at least by three times. Instead, as much as one half of the plume of radioactivity dispersed over the Arctic and oceans.

2. The wind direction of the plumes, especially the initial one, could have been more in the direction of Western Europe, and would have resulted in very high fallout levels in West Germany, France, and other Western European countries.

3. Much more fission product radioactivity could have been released from the reactor. My estimates suggest that a mere 5 per cent to 15 per cent release of

the volatile fission products in the reactor can explain the radioactivity levels measured in Western Europe (particularly Sweden and Bavaria). So there could have been 6 to 20 times more release of the caesiums and iodines, for instance. We in the West do not know the atomic chain reaction runaway potentials of the RBMK-type (Chernobyl) reactor; nor the circumstances of the atomic runaway that occurred at Chernobyl, and what controls or protective or mitigating actions might have luckily averted a worse runaway.

4. There are also the less volatile fission products, mainly cerium-144 and zirconium-95 and others, which comprise over half of the radiation emission potential of the fission products in the reactor. Also, these fission products have shorter half-lives than the caesium-137; so that they emit their radiation in a much more concentrated period of time after an accident, namely during the first two years. Therefore, had the Chernobyl eruption been more severe—hotter and more violent—and released most of the cerium-group of fission products as well as the volatiles, then the total accumulated dose burdens at a given distance from the reactor would not only have been much greater than the actual accident, but the first and second year doses would be very high in relation to the 30-years caesium dose. That is, the short term consequences of the accident would have been much more harmful to the population. Such a near full release of the reactor fission products, say 70 per cent, would have had the following potential consequences for Europe (partial list):

- Abandonment of 160,000 square kilometres of land at least.
- Evacuation of pregnant women and infants for 600,000 to 4 million sq. km.
- General evacuation for a year or two of 230,000 sq. km.
- Ruin of agriculture for about one million sq. km. due to strontium-90 alone for many decades.
- Permanent abandonment of 150,000 sq. km. due to plutonium fallout.*

5. The preceding potentialities assume a fission product release from the core of a single reactor at the Chernobyl station. There was also the potential for the eruption of the spent fuel stored next to the reactor, caused by a more destructive reactor eruption. Depending on the amount of spent fuel in storage, the release of caesium, strontium-90, and plutonium could have been twice or more the inventory of these fission products in the reactor.

6. The other three reactors at Chernobyl also could have erupted, including their spent fuel storages. Again, the eruption of unit 4 could have been worse. A worse reactor explosion conceivably could have destroyed the adjacent reactor system, causing it to explode, and so on to the other reactors. Or, a full eruption of the Chernobyl Unit 4 reactor would have caused such extreme radiation levels in the plant area that the plant workers would have had to evacuate the plant, leaving the other reactors and their cooling systems unattended, allowing them to break down and thereby causing them also to erupt. In fact there is evidence, I recall, that the Chernobyl plant was evacuated for a time. Also, had the fire fighters known that they would receive a lethal dose of radiation, perhaps they would not have stayed to try to control the reactor fire, and it might then have erupted more severely.

There was also a danger of an extremely powerful, volcano-like steam explosion. This could have occurred if molten fuel of Unit 4 had collected at the bottom of the reactor, melted its way through structures, and then fallen into the pool of water that lay beneath the reactor as part of the containment system (the steam quench pool for loss of coolant accidents). The potential steam explosion could have exploded and expelled the whole reactor block, maximised the fission product release, and forced the evacuation of the other reactors, if not destroying the other reactor systems directly by mechanical blast and fire.

Incidentally, during the first week of the accident I had contacted the Science Department of the Soviet Embassy with advice on principles to minimise the chance of further eruption and explosion. Two copies of my August 1984 *Warning* report were immediately hand-delivered to the Embassy. The report warns, among other things, of steam explosion potentials due to fuel melting and mixing with water, and refutes official claims to the contrary. Some time later, after the Soviet Embassy received my report, the Soviet engineers at the Chernobyl plant sent men with water-diving suits into the radioactive water basin beneath the reactor to open up by hand the valves to drain the basin, and thereby eliminate this steam explosion danger. This action constitutes an official recognition of the seriousness of the steam explosion danger of reactor accidents.

All things taken together, the Chernobyl accident could have been much worse with 200 to 400 times the radiation consequences, not counting the strontium-90 and plutonium potentialities, and also with much more intensive short term doses. The accident could have been cataclysmic for Europe, not only because of the radiation potential but also because of the social disruption it could have given rise to.

*Figures taken from *Catastrophic Nuclear Accident Hazards—A Warning for Europe,* August 1984, by R. E. Webb.

The Health Consequenes of Chernobyl

by
Richard E. Webb

In all Western countries affected by the Chernobyl fall-out most governments and their scientific advisers, have assured their citizens that the risks from the increased radiation exposure to themselves and their children are negligible. Dr Webb, on the basis of the best available information, claims that exposure to external gamma radiation alone could result in as many as one quarter of a million extra cancer deaths over the next few decades.

The concentration of the radioactive fallout from the Chernobyl accident varies, depending on the location in Europe. The first-week peak radiation levels in Sweden following the accident varied from 2 to 50 times the natural level, depending on the location in Sweden, or 0.02 to 0.5 mr/hr. In Bavaria the peak ranged from 3 to 17 times the natural level, or 0.03 to 0.17 mr/hr. The peak radiation level is a measure of the radioactivity contamination of an area, by which one can estimate the accumulated exposure or dose over a period of time since the fallout occurred, accounting for the decay of the radioactivity with the passage of time. To simplify the analysis we may assume that the *median* peak radiation level in typical areas of Sweden and Bavaria was about 10 times the natural level. I assume that the fallout is less elsewhere in Western Europe the further we get from Chernobyl. The radiation has already decayed substantially with time to the level of the longer lived radioactivity.

Particularly relevant is the projected accumulated radiation dose due to the external *gamma rays* from the ground fallout over a period of time, say the first year and the first thirty years, respectively, since the accident occurred. This radiation dose 'burden' depends on the composition of the radioactivity in the fallout. From the Swedish and Bavarian data it appears that the fallout consists mostly of the volatile fission products, mainly iodine-131, caesium-134, and caesium-137, which vaporise at relatively low temperatures and consequently are most readily released in a reactor accident, and little of the other, harder-to-vaporise reactor fission products, mainly cerium-144 and zirconium-95 and others. For the 'median' fallout level the projected doses are calculated as follows, assuming a person stays outdoors on the ground (an upper limit); that is, no shielding of housewalls:

- 150 mr for the first year; (no shielding)
- 500 mr for the first 30 years

More practically, a person stays inside buildings most of the time, where the walls provide substantial shielding, assuming the building (home) interior is cleaned of fallout dust. If we assume a two thirds reduction of the radiation due to the shielding of the walls (a reasonable value) and an average time of four hours* spent outside per day, the doses would be approximately:

- 60 mr for the first year; (Bldg. shielding;
- 200 mr for the next 30 years. 4 hrs/day outside)

*Spending only two hours outside each day reduces the values by only 15 per cent.

For the peak fallout areas the values are:

Time Period	*Sweden*	*Bavaria*
First year	300 mr	100 mr
30 years	1000 mr	340 mr

(Bldg. shielding; 4 hrs/day outside)

The West German Government declared an estimate of the maximum projected whole-body dose in West Germany from external radiation of only 5 mr for the time period from the beginning of May to the end of the year 1986, less than a one year period. However, the government report giving this estimate does not supply the radioactivity data on which the estimate was made nor the methods of calculation and assumptions, except for a "dose conversion factor", which relates the dose rate with 1.0 Bq/m² of caesium-137 on the ground. I found that the West German official dose conversion factor value to be one half of the value given in a classic US Government report of nuclear accident hazards potentials, and that even the US Government value is in error (low), as it neglects a certain radiation amplification effect, namely reflected gamma rays, called 'skyshine'.

It is noted here that my estimates are solely based on idealised flat surface conditions. The real terrain and local radioactivity concentrations could cause higher doses. In the final analysis only actual, precise measurements can determine the dose rate at a given location/area from the fallout. Also, buildings might offer more shielding than I assume, and perhaps the radiation is less intense for persons living in apartment buildings.

As we see from the above figures, the estimated projected doses for Bavaria and parts of Sweden, are close to the level at which it is suggested that pregnant women and infants be evacuated. These are serious doses.

Radioactivity contamination will be much worse closer to the reactor, though perhaps over a narrower region. In Poland the maximum measured radiation level was a peak of about 2.5 to 5 mr/hr, or 250 to 500 times the natural level. The corresponding projected dose burdens are, taking the 2.5 mr/hr value:

- 1500 mr for the first year; (2/3 bldg. shielding
- 5000 mr for the first 30 years. and 4 hours/hr outside

This is almost at the level which would justify abandoning the area. It means also that part of the Soviet Union—a segment from Chernobyl to Poland—should have greater fallout levels and thus may have to be abandoned. Calculations, using classical atmospheric smoke plume dispersion theory, and assuming a release fraction of 5 per cent of the volatile fission products from the reactor, match the peak first-week radiation levels in Sweden and Poland fairly well. These calculations show that at least 8000 square kilometres in the Soviet Union and Poland are severely contaminated.* Also, the same calculations predict that 115,000 sq. kilometres are now contaminated to a degree equal to or greater than the above-assumed 'median' fallout level (an initial peak of 10 times the natural level) (though this area would include part of the Baltic Sea) and that in this 115,000 sq. kilometre zone (the Chernobyl to Sweden sweep) the fallout amounts to only one half of the assumed 5 per cent fission product release of volatile fission products. The rest of the fission products, according to that estimate, fell out over a wider area, including the Arctic, though at lesser density.

In the area in the immediate vicinity of Chernobyl, for instance the town of Pripyat and other towns close to the reactor, the radiation levels could have been very high; yet there was a delay of 36 hours before the town of Pripyat was evacuated. My calculations show that the radiation level there could have been anywhere from 30 mr/hr to 1000 mr/hr or more, for a 5 per cent release of volatile fission products depending on the meteorological and plume factors and conditions. One official Soviet statement gives the maximum radiation level in the so-called 30 kilometre "exclusion zone" as only 15 mr/hr. Still, this 15 mr/hr value would justify evacuation; but it is very possible that the population in Pripyat and other nearby towns (a population of 95,000) received a very large dose of radiation, conceivably a maximum of the order of 36 rems, causing acute radiation sickness and exposing them to a very grave cancer risk.

The Death Toll

Smoke from the burning reactor lasted for several days with shifting winds. Also the initial radioactive cloud release had meandered around Europe. Consequently, most of Europe was contaminated, not just a path from Chernobyl to Sweden. The limited information on the fallout distribution in Europe prevents an accurate analysis. However, on the basis of sophisticated computer calculations (Lawrence Livermore Laboratory, USA) of the Chernobyl radiation cloud, (assuming hypothesised fission product release values but otherwise accurate weather data for tracking the air/cloud movements in Europe) and on examination of the radiation measurement reports of various locations or countries of Europe, I estimate that the caesium was released into three separate plumes by the accident, which has seriously contaminated about 600,000 square kilometres of land. Assuming the 15 per cent total release of the volatiles from the reactor, I calculated an average projected 30-years dose burden for individuals in this 600,000 sq. kilometre zone of 2000 mr. (Again, this assumes 2/3 shielding and 4 hours outside per day.**) By this figure one can estimate the possible health injury consequences of the fallout, particularly the cancer risk.

It would take a controlled experiment of a very large population over a very long period to establish the health injury rate of radiation exposure. This being so, one can only estimate it on the basis of statistical assumptions. The International Radiological Protection Commission (ICRP), for instance, gives a probability of 0.01 per cent extra cancer deaths per rem of whole body dose. But a higher rate cannot be excluded. We point out in this issue that a 10 to 20 fold higher cancer mortality rate for low doses of radiation is one which more closely fits the facts. With this figure one can make an estimate of the projected number of cancer deaths caused by the Chernobyl accident fallout over the above-stated estimated 600,00C sq. kilometres zone. The result of *280,000 cancer deaths cannot be excluded!* This assumes a population density of 120 persons per sq. kilometre: 600,000 x 120 x 2 rems x 0.002 = 288,000. This is from gamma radiation alone. The cancer increase from all external and internal sources of radioactivity will be higher still.

Also, we can only worry about the extent of the genetic injury to offspring, as there is no way to quantify the risk-probability factor. Viewed another way, the total population dose could be around 144 million person-rems over 30 years—an equivalent of one rem exposure to 144 million persons.

Conclusion

A nuclear shutdown is truly urgent. We should not risk any longer a possible cataclysm. Presently, the attitude of governments is to take the risks and learn the hazards as we operate the nuclear plants. However, I think that this policy is extremely unwise (even reckless); for it is imperative that we evaluate and establish the full accident hazard potentials before we suffer (any more) accidents, which could be much more catastrophic than Chernobyl. The risks are much greater than the authorities assume, both to those alive today and to future generations.

Admittedly, it is a difficult decision to shut down our nuclear power stations, because special interests would be drastically affected, and also because of the loss of the electricity provided by the plants. The difficulty is especially acute in France, where about 70 per cent of the electricity is now generated by nuclear power, according to official figures. However, the supposed economic benefits of nuclear power do not eliminiate the accident hazards. Our present difficulties and predicaments were caused by not fully evaluating the nuclear accident hazards before the construction of the reactors, even though some of us nuclear reactor scientists were warning about the catastrophic accident hazards and recommending more research of the hazards.

The way out of our predicament, therefore, is to undertake a full review and investigation of the nuclear accident hazards, develop the facts, disseminate the scientific knowledge to the public, and make a judgement on the basis of sound knowledge. Above all, the public should be safe and not endangered. I believe that this means shutting down the reactors immediately. The reactor eruption potentials are too great. The possibilities are real and many; and many accident possibilities remain to be evaluated. I think that, were the nuclear hazards fully investigated, the public and the scientific and engineering community would come to the same conclusion.

*On July 17 the Soviets announced that 1000 sq. km are 'contaminated'.

**1750 mr. assuming 2 hours outside per day.

THE EFFECTS OF LOW-DOSE RADIATION

by Peter Bunyard and Graham Searle

In the areas around many nuclear installations in Britain childhood and adult cancers have demonstrably increased. As a result of Yorkshire Television's film, *The Nuclear Laundry* in which the incidence of childhood cancers close to Sellafield were shown to be at least 10 times the national average, the government called on Sir Douglas Black, ex-President of the British Medical Association, to chair an inquiry. In effect, the Black Committee concluded that the levels of radiation in the area were far too low to be associated with such an increase. The Committee's conclusions were based on official understanding of the health effects of low level radiation. This view is increasingly difficult to reconcile with the findings of scientists such as Dr Alice Stewart of the Oxford Survey of Childhood Cancers.

The low-dose radiation controversy, which the authorities and especially the National Radiological Protection Board (NRPB) hoped had been laid to rest at the Windscale Public Inquiry of 1977, resurfaced with a vengeance at the Sizewell Public Inquiry. No longer was the controversy a mere academic struggle for the establishment of the most likely hypothesis to explain the mechanism of cancer induction by radiation. Underlying the debate at Sizewell was the discovery (in both instances by the Press, and not by supervisory authorities such as the NRPB) of cancer clusters in the workforce at particular nuclear installations and among the general public in their vicinity.

James Cutler's Yorkshire Television Programme—Windscale, the Nuclear Laundry, shown in November 1983—produced evidence, later confirmed by the Black Report,[1] that the cancer rate among children in the vicinity of BNFL's Sellafield reprocessing plant was unusually high. While Cutler's programme implicated the radioactive waste discharges from the Sellafield plant, Sir Douglas Black, in his report for the government, played down any such connection on the basis that the cancer cluster was not a unique occurrence in the British Isles and, equally important, that the levels of radiation in the environment as measured by various government bodies were insufficient by a factor of at least 40 to have induced the high cancer rate.

Meanwhile the local press in East Anglia had discovered a high leukaemia rate among the population in the vicinity of the Sizewell A magnox station which had been in operation since 1966. The cancer rate was particularly high among CEGB workers at the plant, but again the authorities denied that radiation exposure either within the plant or outside could have been responsible for the disease.

Peter Bunyard, *fellow of the Wadebridge Ecological Centre and author of Nuclear Britain;* **Graham Searle**, *founder of FOE, UK and advocate for the Stop Sizewell B Association during the two year public inquiry.*

Evidence at the Sizewell Inquiry, presented by witnesses for the Stop Sizewell B Association (SSBA), confirmed that which both the CEGB and BNFL originally denied; namely that the incidence of certain kinds of cancer known to be radiation-sensitive among the respective workforces at Sizewell A and at Sellafield was indeed statistically significant. Another line of evidence, also presented by SSBA witnesses and in particular by Dr Alice Stewart of the Oxford Childhood Cancer Survey, indicated that advisory and regulatory bodies such as the International Commission on Radiological Protection (ICRP) and the National Radiological Protection Board (NRPB) had misinterpreted the accumulated evidence on the effects of radiation on human populations, with the result that their models for estimating the effects of low dose radiation were out by a factor of between 10 and 20. The considerably higher risk factor that emerged from both Dr Rosalie Bertell's and Dr Stewart's evidence not only provided a mechanism by which the significantly higher cancer rate among radiation-exposed workers and among members of the public might be explained: it meant that public perception of the nuclear industry as a 'safe' industry, was no longer acceptable; instead the industry was accompanied by an undesirable level of risk.

Lies—damned Lies

Early on in the Sizewell Public Inquiry, Graham Searle of the SSBA asked Mr Pepper of the CEGB whether any CEGB station had an incidence of leukaemias significantly in excess of anticipated levels. He was told "I am advised by Dr Bonnell—medical adviser to the CEGB—that there is no CEGB station where the incidence of leukaemia or any other radiation induced diseases are statistically significant in excess of the anticipated incidence".[2]

That view, steadfastly maintained by Dr Bonnell, conflicted absolutely with that of Professor Harrington, chairman of the CEGB Epidemiological Advisory Committee, who was reported as saying: "The expected incidence of leukaemia among the Sizewell A workforce would be rather less than one, whereas it is established that the actual incidence has been significantly in excess of this".[3]

Professor Harrington put the *expected* incidence at 0.30 cases which accorded well with the calculations of two SSBA witnesses, Professor Blackith of the Department of Zoology and Dr Michael Stuart, senior lecturer in the Department of Statistics at Trinity College, Dublin, who obtained 0.36 and 0.344 respectively. As cross-examination of Professor Blackith revealed, four cases of leukaemia among Sizewell staff had been diagnosed, three of which had resulted in deaths. Three of the four diagnoses were of myeloid leukaemia.

The CEGB then claimed that the third death not only occurred outside the study period—by one month as it happened—but that, being an ex-employee of the CEGB, this victim could no longer be categorised as a CEGB worker. The SSBA pointed out that extending the study period would hardly change the expected incidence of death, whereas it would have a considerable effect on the *observed* incidence of death. Moreover the 'ex-employee' had only become 'ex' because at 56 years old he had taken premature retirement five months prior to his death on account of his disease.

Reluctantly, and after months of diligent cross-examination of Board witnesses, the CEGB admitted that leukaemia incidences among the Sizewell workers had been statistically significant. But what about the general public in the Leiston area? Of 12 cases in the Leiston area, only 9 actually fell within the parish of Leiston-cum-Sizewell, to which should be added two post-1981 cases, giving a total of 11.[4] Compared with the total of 11, the anticipated age and sex corrected incidence was 7.9. Therefore Leiston had an excess of leukaemias but not one which was statistically significant. Nevertheless certain anomalies existed in the figures. The ratio of males to females was 9:2 whereas the ratio based on general mortality statistics for the UK indicated an expectation of 3.9 males to 4 females. Furthermore, of the 9 male cases, four of whom worked at Sizewell A, the ratio of myeloid leukaemia to lymphatic leukaemias was 6:3, whereas in the anticipated total of 3.9 males, the anticipated ratio for the two kinds of leukaemia would be 1.9:2.

As Searle pointed out in his summing up for the SSBA, the preponderance of males and the preponderance of myeloid leukaemias amongst the Leiston cases suggested the presence of a myeloid leukaemia-causing agent. Ionising radiation was the obvious contender.[5]

Under cross-examination Sir Edward Pochin formerly the head of the NRPB and a member of ICRP, agreed with the evidence presented by Searle that ionising radiation could cause chromosomal damage in human white blood cells at doses well below the maximum permitted for radiation workers. He also agreed that a likely causal relationship existed between chromosome rearrangements and cancers, including leukaemias.[6]

Dr Bonnell, meanwhile, flatly rejected the conclusion that the doses received by the Sizewell A workers could have in any way resulted in their disease.[7] The CEGB nevertheless admitted that three of the stricken workers were recorded as having received external radiation at approaching twice the normal background during the years they worked at the reactor, although the fourth was recorded as having received only an additional 7 mrem per year.[8]

Bonnell's contention that a connection between the diseases of the four men and radiation was "not tenable"[9] was based on the ICRP risk estimates. Yet as Professor Blackith observed at the Sizewell Inquiry, Dr Bonnell turned the proper method of investigation and analysis on its head. He looked first at the radiation doses received by the Sizewell workers and concluded that they were miniscule, and "took that into account before . . . looking at statistical incidences."[10]

When Dr Bush, the District Medical Health officer for East Suffolk, undertook his study of leukaemia incidences amongst the Sizewell A workforce and throughout the East Suffolk Health Authority area, it was not because he had been alerted by the CEGB or any responsible authority to the excess of leukaemias at Sizewell A.[11] As he replied to Searle, his attention was not drawn to the leukaemia incidence by the Health and Safety Executive, by the NPRB or by the CEGB Epidemiological Advisory Committee, but by the press.

That a virus was involved was, as Dr Bush suggested,[12] consistent with the geographical distribution of the homes of the affected individuals. But, as Professor Blackith observed,[13,14] many viral infections were known to be immuno-suppressive, and that would be consistent with his causal hypothesis that radiation exposure coincident with suppression of the immune system (which would otherwise mop up aberrant cells) could be the mechanism for leukaemia-production. As we shall see, it is the survival of aberrant cells, rather than cell destruction which is the problem.

The Healthy Worker Effect

In general people either die from cardiovascular disease, from accidents, from cancer or from infectious disease; the latter often being associated with cancer. Circulatory disorders, including strokes, are a major cause of death, followed by accidents and cancers. Indeed in the UK one out of four women will die of cancer and approximately one out of five men. Should small doses of radiation cause a commensurately small rise in the incidence of fatal cancers the difficulty then may be to pick out that increase from all causes of death. Furthermore the average life expectancies of the exposed population may hardly appear to have been affected. For epidemiologists the problem is to determine beyond reasonable doubt that a particular environmental insult has actually led to premature death among what may be a small proportion of the population. How many, for instance, will have had their lives shortened because of the Chernobyl fall-out? Dr B. Lambert, a radiobiologist at St Bartholomew's Hospital in London, believes that the toll in the UK will be at least 500. Yet over that same period 7 million of the UK population will have died of cancer anyway.

How then can one pick up an added mortality risk that is causing less than one hundredth of a per cent increase in cancer, and one quarter of that when it comes to all causes of death? The situation may be confused further by an overall increase in cancer on account of other environmental poisons. And what level, if any, of additional disease is acceptable to society?

The problem of determining the number of cancers caused by radiation is further compounded by what is known as the 'healthy worker effect'. Health statistics for the general population show that on average those who have graduated from university or technical college have a much better life expectancy than those of the same age who go straight from school to work, and age for age, they have much lower rates of cancer mortality compared with manual workers. If those who in general are most exposed to radiation during their work at a nuclear establishment such as Hanford come from the professional classes, then one might expect less of an effect on health than if the population at random were exposed to similar radiation.

In fact, by comparison with the general population, workers in the nuclear industry may have a 25 per cent lower mortality rate from all causes of death, cancers included. When those statistics were first discovered after an investigation into the mortality rate of those working at the Hanford nuclear establishment in the United States, some researchers naively tried to claim that low doses of radiation must be positively beneficial to health. Today, noone either in the nuclear industry nor outside it believes that radiation is good for health: instead the concept of the 'healthy worker effect' is generally accepted, it being recognised that health screening before acceptance for employment in demanding work, combined with the requirement for those with professional qualifications leads to a better than average life expectancy. In effect, the industry's reputation is enhanced if the health of the workers is shown to be good: it is also good for morale and the industry would hardly want to employ people who are basically unfit. Any statistics, therefore, on the mortality of employees in the nuclear industry, both those still working in the industry and those who have left it, retired or otherwise, must be viewed with caution, and should only be interpreted after taking the healthy worker effect into account. This means with regard to Sizewell A there is an even greater disparity between observed and expected leukaemias than the figures suggest.

The question then arises whether the healthy worker effect is one which wears off as the workforce ages. By the time the workers in the nuclear industry are 60 years old has their life expectancy deteriorated to the point statistically when there is no longer any difference between them and the general population? And what about cancer? Surely it is nigh impossible to screen for that when employing people whereas there is less of a problem when checking for cardiovascular disease? In the Sizewell Public Inquiry the question as to what precisely the healthy worker effect meant in terms of cancer and longevity was raised during the cross examination of two witnesses for the SSBA, Dr Rosalie Bertell and Dr Alice Stewart.

Mr Bartlett, Counsel to the CEGB, suggested to Dr Bertell that the healthy worker effect is one which dwindles away with time, so that as a worker approaches retirement, his risk of mortality from whatever cause approaches that of the general population. He said:

> "What I am suggesting to you is that the healthy worker effect is less pronounced, that is to say the difference between the worker and the person who is not employed within the industry you are considering is less pronounced the further you move away from the time when the employee was first employed."[15]

Dr Bertell replied: "I know of no research that confirms that". Mr Bartlett then suggested that while the screening process may be effective in weeding out those with potential debilitating diseases other than cancers, it would be far more difficult "if not impossible to screen out potential cancer cases from cases of other diseases. You get a healthy worker effect which is more pronounced for non-cancer deaths than it is for cancer deaths!" In her answer Dr Bertell said "Your question was that it is harder to screen out someone who would later get cancer than it is to screen out someone who later would get diabetes or a coronary. I think that is an invalid statement."[16]

Mr Bartlett pursued a similar line of questioning with Dr Alice Stewart over the cancer incidence in the survivor population of Hiroshima and Nagasaki compared with what it might have been in those who died after the blast and prior to the collection of data in 1950. Mr Bartlett suggested that in order for the cancer deaths in the survivor population to be lower than might be expected from its exposure to radiation, the survivors would have to be specially resistant to cancer.[17] Yet as Dr Stewart stressed, "cancer goes with general mortality. It must not be separated." Mr Bartlett then asked:

> "What evidence do you have to suggest that those healthy persons, as you put it, are more resistant to cancer than others?"

To which she replied:

> "Well you can take it—and I give an example in the letter[18]—if you take various levels of social class in any population you get the probability of a premature death. The risk of a premature death in the poor people is, say, three times as high as in the upper social classes. This applies to all causes of death." She then went on to say, "All you have got to do is to take your official statistics of mortality and divide them into cancer and non-cancer deaths. You will observe this effect is a non-cancer and cancer effect according to wealth. These two things go together. There is nothing magic about cancer as a probability of dying. It just happens to have a longer latency than the others. Therefore it is more easily obscured by other causes of death."

Both Dr Bertell, and Dr Stewart, particularly from her association with the Hanford data on the mortality of nuclear industry employees (the MSK studies), were adamant that a healthy worker effect for both cancers and non-cancers existed with regard to workers in the nuclear industry, and that it was not an effect which wore off significantly as the workforce aged. Thus a young man selected for his good health and presumably for his abilities to work in the industry should still on average retain his advantage of greater life expectancy compared with that of a standardised person of the same age and sex of the general population.

The question of the healthy worker effect arose specifically in Dr Bertell's proof with regard both to the study[19] of the US reprocessing plant at Hanford in Washington State, and to a recent study carried out on the male workforce for Sellafield.[20] Dr Bertell cited a letter from D.K.R. Phillips of British Nuclear Fuels Ltd (BNFL) to *World Medicine*[21], in which he laid out certain facts on mortality pertaining to 11,500 BNFL male workers and ex-workers whose overall period of employment encompassed the 32 years between 1948 and 1980. Over that period 1,600 deaths have been identified, more than two-thirds among ex-workers. Dr Phillips wrote:

> "The latest results, taking account of statistical uncertainties, show that (i) the total number of deaths from cancer (400) is slightly lower than that which might be expected (454) among such a group on the basis of national figures, and the same is true of deaths from all causes; (ii) the small number of deaths from leukaemia, bone and thyroid cancer and multiple myeloma which are regarded as particularly susceptible to radiation, is consistent with expectation (16.8); and (iii) there is no significant difference in such comparisons between those classified as radiation workers and the rest of the workforce, apart from the suggestion that the latter may have a slightly higher mortality rate than radiation workers."

As Dr Bertell pointed out in her proof and reiterated during her cross-examination by Mr Bartlett, all the data given in that letter supported the notion of a significant healthy worker effect. Thus, even though only a small proportion of the total study population had died, some 14 per cent, the cancer mortality rate was 88.1 per cent of the general UK rate—a 12 per cent healthy worker effect. Exactly the same lower rate was found for non-cancer deaths among the study population.[22]

In his letter to *World Medicine* Mr Phillips stated that since the late 1940s at all BNFL sites some 21,000 radiation workers of a total working population of 40,000 had received 160,000 rems over the 32 year study period. As Dr Bertell pointed out[23] some of that exposure may have been very recent and hence not a contributor to the cancer risk of the study population. Using the ICRP mortality risk factor of 10^{-4} per rem, 16 excess cancer deaths would be expected over the worker lifetime, but since only 13.9 per cent of the total workforce had died, the expectation to date would be for 2.2 excess cancer deaths.

According to Dr Avery of British Nuclear Fuels,[26] the correct total radiation exposure figure for the Sellafield workforce of 11,500 was 1,174 Sieverts or 117,400 rems. On the basis of ICRP cancer fatality risk estimates, the excess lifetime deaths among the Sellafield group would be 11.7. With 13.9 per cent dead of the 11,500 by 1980 the expectation to date would be for 1.6 excess deaths due to radiation. On Dr Bertell's risk estimate between 3 and 14 times higher than that of the ICRP there would be between 4.7 and 22.7 excess cancer fatalities (0.29 to 1.4 per cent of the deaths, and 1.2 to 5.7 per cent of the cancers): again somewhat lower figures than given in her proof. Those estimates would accord well with the observed estimates of Stewart, Mancuso and Kneale from the Hanford worker data, and Dr Bertell claimed, the numbers of excess cancers could be contained within the 400 observed cancer deaths.

As a result of Dr Bertell's claim that she knew of no study of radiation workers that suggested a falling off of the healthy worker effect as the workforce aged, Dr Avery[18] referred to the BNFL Mortality Studies. He pointed out that in addition to the limitations of any mortality analysis where only a small proportion of the workforce population had died,

> "Analysis is also limited by the lack of reliable qualification of the 'Healthy Worker Effect' . . . The following points, however, have a measure of general acceptance.
> (i) The initial healthy worker effect, i.e. the factor by which the national age standardised mortality rate should be reduced to represent the mortality rate for a just employed workforce is about three.
> (ii) The healthy worker effect decreases with time and after about 15 years, reaches a constant value close to unity. In other words, when a just employed workforce has been followed up for more than 15 years, the mortality rate applying subsequently is similar to that of the age standardised national population. (For the proportion of the workforce which remains employed, the healthy worker effect reaches a constant value somewhat in excess of unity.)"

Dr Avery then gave the latest results from the BNFL studies reproduced in Table 1.[27]

Table 1

Sellafield Mortality 1948-1980

Summary table, including statistical uncertainty (two standard deviations)

	SERVING EMPLOYEES		RETIRALS		OTHER EX-EMPLOYEES		TOTAL	
	Observed deaths	O/E	Observed deaths	O/E	Observed deaths	O/E	Observed deaths	O/E
Cancer	122	0.71±0.15 (0.69)	119	1.20±0.20 (1.15)	159	0.87±0.15 (0.87)	400	0.88±0.09 (0.85)
Non-Cancer	329	0.67±0.09 (0.68)	392	1.19±0.11 (1.21)	482	0.88±0.09 (0.97)	1203	0.88±0.05 (0.90)

O/E is the ratio of observed to expected deaths. *Figures in brackets are O/E values published earlier by BNFL and now updated.*

The Emergence of Cancer

When the workers are subdivided into radiation and non-radiation categories, the cancer rate among all employees, serving or otherwise, is seen to have increased in terms of the observed to expected ratio among the radiation workers from 0.81 up until 1975 to 0.87 up until 1980, while it has actually fallen among the non-radiation staff from 0.95 to 0.91. Meanwhile, the non-radiation staff show overall a mortality that is more consistent with the age standardised mortality for the general population than with the more selectively screened radiation workers.

Meanwhile the total multiple myeloma deaths among the workforce between 1948-1980 were no more than four, a number that had not changed from the 1975 data. That observed number of multiple myelomas (given that in Dr Avery's estimation the healthy worker effect is transient) accords with an expected equivalent number of 4.3.[28] However, when these figures were put before the Inquiry, Professor Blackith for the SSBA rejoined that those four cases of multiple myeloma deaths up to the end of 1980 did not properly reflect the current situation, inasmuch as there had been an *additional five deaths* from the disease between 1980 and 1983. That information, after some delay, was elicited from P.W. Mummery of BNFL, who in a letter to Professor Blackith gave some details of the multiple myeloma deaths among the Sellafield workforce.[29]

In fact in addition to the four deaths which had occurred up until the end of 1980, there was one death in 1978 but only traced later, and two deaths post-1980 (one in 1982 and one in 1983). In addition Mr Mummery mentioned two deaths from the disease in 1983, for which the Office of Population, Census and Statistics (OPCS) coded death certificates were not then available. The ratio appears destined to become 9 deaths from myeloma to approximately 4 expected, and already we are moving into the range calculated by Dr Rosalie Bertell using a higher risk factor—again without accounting for the healthy worker effect. As Professor Blackith observed,[30] all four cases of myeloma known in 1980 were among serving employees. Details of the remainder became available to the Inquiry later,[31] and as of 12th December 1984, indicated that three of the extra deaths occurred among retired employees and two among other ex-employees. A tenth case (then still living) was shown to have worked only a few weeks at Sellafield before being moved elsewhere in the company, though why he should have moved is not stated. Of all the 9 multiple myeloma deaths of Sellafield workers, 7 were of radiation workers. As Professor Blackith concluded:

> "When allowance is made for the bias in the calculations attributable to the 'Healthy Worker Effect' there is clear evidence of a statistically significant excess of multiple myelomas in the Sellafield workforce in recent years."[32]

Over the period 1976-1983, for instance, Professor Blackith puts the odds against finding the five myeloma cases observed at roughly one in 50. The chances of finding the four cases observed in the period 1981-1983 are as low as between 1 in 100 and 1 in


PHOTO: BAKER

A Sellafield reprocessing worker, ready for action.

1,000. The BNFL response was that "the probability for the period 1981-83, if taken in isolation does fall within the significance band. Plainly observations of such small samples determined by selections of particular calendar years must be viewed with great caution and against the varying trend over the different periods described above."[33]

Before we can come to ultimate judgements about the excess cancer mortality among Sellafield workers and in particular of multiple myeloma, information giving individual worker doses on a year by year basis, date of employment, type of work, age and mortality must be made fully available. Only then can the kind of cohort analysis carried out in the Mancuso, Stewart and Kneale Hanford III Study be performed.[34]

Specifically it would be interesting to know whether significance should be attached to there being 7 multiple myeloma deaths among radiation workers out of the total of 9 for the whole workforce. Clearly the numbers of non-radiation workers and radiation workers and factors such as age should be taken into account.

Given the present state of the BNFL data, it would certainly be premature for BNFL and the NRPB to congratulate themselves that the Sellafield workers have a clean bill of health regarding radiation. As Dr Stewart pointed out when cross-examined at the Sizewell Inquiry, such nuclear establishments would be ill-advised to consider themselves to be "health farms".

Indeed, Dr Avery's admission[35] that the healthy worker effect appears to vanish completely after the just-employed workforce has been followed up for 15 years is itself cause for concern. Both Dr Stewart and Dr Bertell are adamant that the healthy worker effect should persist throughout employment and even beyond the age of retirement, those employed having a significantly better chance of surviving beyond the average life-expectancy of the general population. Certainly there is no evidence in the Hanford data of a fading out of the effect, and in her proof of evidence[36] Dr Bertell made reference to a study of Chalk River employees where over a 30 year period the observed to expected ratio for deaths from all causes averages out at 0.73, clearly reflecting the persistence of the healthy worker effect.

A Model Establishment

Hanford has been described as a model establishment: certainly we know that the collective dose to the workers there has been considerably lower than that at Sellafield. Figures cited by BNFL record a cumulative exposure of 53,000 man rem to 12,700 white male workers who already had two or more years experience at the Hanford plant by March 1974 compared with a Sellafield total of 120,000 man rem to 9,400 male radiation workers over a similar period from 1975 to 1982.[37] As Dr Bertell pointed out:

> "Hanford is a military nuclear installation with very rigid selection procedures for health, excellent medical care, and also very low exposure rates relative to at least other nuclear facilities in the United States. Hanford is a showplace."[38]

It may be therefore that the 'reversal' of the healthy workers effect—which does not appear to occur at Hanford but does at Sellafield—is not a natural process, to be accepted as such, but is rather an alarming phenomenon. As Dr Bertell put it: "The reversal of the healthy worker effect for BNFL employees is itself a problem . . ."[39]

The Dose-Response Relationship

The nuclear industry has long prided itself on being a 'safe' one in which to work and alongside which to live. Exposures to admittedly-dangerous radiation are so tiny, it argues, that the risks to health from radiation-induced cancers are so small as to be dismissible. Of this the industry is sure, for it has absolute confidence (as evidenced at the Sizewell Inquiry) in its own understanding of the dose-response relationship between radiation exposure and cancer formulation.

In the early years of nuclear power, the latency period for cancer ensured that there would be no excess cancers diagnosed amongst those exposed to low radiation doses. But, as we have seen, more and more cancers have begun to show up: more cancers, that is, than would occur if the industry's understanding of dose-response were correct. If the nuclear industry (and the National Radiological Protection Board) are wrong, no longer can it be claimed that nuclear power is 'safe'; and for a more reliable explanation of the forces at work we must turn from the claims made by those with a vested interest in nuclear power and examine the findings of truly independent researchers.

By her dogged persistence, intuitive grasp of the material in front of her and quick intelligence, Dr Alice Stewart has undoubtedly been one of the biggest thorns in the side of the official radiation dose standard setters. Ideas dimly grasped a decade ago have now crystallised. They have been tested against the data and shown to stand up. That Stewart's findings have not gained acceptance within the nuclear industry is not because they are flawed, but because their acceptance would threaten the whole future of nuclear power.

Dr Stewart first came into the limelight in respect of the low-dose radiation controversy with her epidemiological study of the incidence of cancers among children whose mothers had received pelvic X-rays during pregnancy: a study which came to be called the Oxford Survey of Childhood Cancers (see *The Ecologist* Vol 8 No 5). When she first started that study in the 1950s she was reacting to the observation that childhood leukaemias appeared to be on the increase, her hypothesis—and one she still adheres to—being that the post-war use of antibiotics had enabled children to survive, who prior to the antibiotic era would have died from an infection to which their resistance in the "pre-leukaemia state" would have been significantly reduced. In a paper published on the Immune System and Cancers of Foetal Origin, she and her co-author G.W. Kneale claim to have found evidence of early loss of immunological competence in cases of neoplasms occurring in juveniles.[40] The effects observed included heightened sensitivity to infection from birth onwards for all types of childhood cancer, higher levels of sensitivity for leukaemia than for lymphomas and higher levels for lymphomas than for other solid tumours.

Meanwhile, as a result of the information gathered during the Oxford Survey of Childhood Cancers, and the careful matching of controls, Dr Stewart discovered that children whose mothers had received pelvic X-rays during pregnancy had a significantly higher incidence of childhood cancers than those whose mothers had not been X-rayed.

When, at the Sizewell Inquiry, Dr Stewart was asked by Henry Brooke, Counsel to the Inquiry, whether her interest in low dose radiation effects had begun around the time of the Hanford Study in 1977, she answered:

> "It started earlier than that. It started way back in the 1960s when, almost by accident, we discovered the fact that a single X-ray given to a pregnant mother could produce a cancer in the child. It was a very unlikely event. At that time, when X-rays were more dangerous than they are today, we reckoned it was a one in 1,000 chance that this could ever happen, but then it was at a time when low level radiation was put well above 100 rads, and it was a very shocking finding. We naturally enough were thought to be very wrong and so we hammered away at it and finally came out in 1970 and had the temerity to put a risk estimate. We had not, of

The Chernobyl accident has provided a sharp reminder that a single momentary exposure to a minute dose of ionizing radiations—no more than the tiny amount of radiation needed to produce an x-ray photograph—may be sufficient to initiate a disease process which leads to a cancer death any time during the next ten, twenty or thirty years.

Although the risk of this eventuality is extremely difficult to detect, nevertheless proof that it repeatedly happens can be found in the Oxford Survey of Childhood Cancers and other studies of delayed effects of pregnancy x-rays.

From these studies we have learnt, first, that all childhood cancers have foetal origins and, secondly, that sensitivity to the cancer induction effects of radiation is much higher towards the beginning than the end of the prenatal period. From a recent Japanese survey we have also learnt that the effects of pregnancy x-rays on childhood cancers are exactly matched by effects of background radiation. Therefore although late effects of the Chernobyl accident will not be distinguishable from other (universal) effects of natural radiation and nuclear weapons tests they will certainly include extra cancer deaths and even more insidious damage to the pool of human genes.

Dr A.M. Stewart, Director of the Oxford Survey of Childhood Cancers

course, individual risk doses, because they had not been measured, but we had got from experts who were serving on the Adrian Report estimates of what the foetal dose was at different years. We built this into our data, which were going over the corresponding years and surfaced with a figure which said: "If you give 1 million children 1 rad of ionising radiation shortly before birth, you can expect in the next 10 years to get 572 extra cancer deaths." Well, at the time, 600 cancer deaths per million children under the age of 10 was a normal incidence. So it was very close to saying that 1 rad of ionising radiation was equivalent to doubling the risk for a child if given shortly before birth.[41]

As Dr Stewart stated, that finding soon proved to be at variance with data emerging from the A-bomb survivor study, which, on the basis of her risk estimate of rad doubling dose, for the last trimester, should have found 26 extra cancer deaths amongst 1,297 children exposed *in utero* to a wide range of estimated doses. In fact only one cancer was found after the study started in 1950, in a girl aged 8 who died of a liver tumour. Since the national rate was 0.75 the conclusion was that radiation had had no effect on the foetus.[42]

Today the exceptional sensitivity of the foetus to radiation is generally accepted, and the reason why the anticipated cancers were not seen after 1950 can be explained.

Masking Effects

Stewart's particular forte has been to look for masking effects, never first to accept data at face value when intuition would suggest that other factors must be in play. Thus the falling immunological competence of children in the pre-leukaemic state disposes them to die of infectious disease prior to their exhibiting cancer. Only by taking away that mask through the use of antibiotics, will the real rate of cancer be revealed. However, with the mask in place, as Sir Edward Pochin speaking for the NRPB, pointed out,[43] the A-bomb survivors, studied since 1950, have shown at most a few additional cancers aside from which there is no evidence of life-shortening.

The dogma has, thus, developed amongst radiation standard-setters that, deaths from massive acute doses aside, radiation at low and intermediate doses does not have significant health effects.

As Dr Stewart herself has observed[44] for many years the risk of all 5-year bomb survivors dying was some 30 per cent below the national rate in Japan. But as she made clear when she appeared at the Inquiry, such apparent normalcy, or indeed better than normalcy, hides the truth. What she and her colleagues have attempted to do is to scrutinise the data, whether the A-bomb data, the Oxford Survey of Childhood Cancer data or the Hanford data, to unmask the various factors at work.

From the A-bomb data, non-cancer deaths appear to occur at a normal or even below normal rate, the implication being, as Dr Stewart stated in her proof to the Inquiry[45] that "all high dose survivors had fully recovered from all tissue-destructive effects of the A-bomb radiation by October 1950".

The other unexpected finding, she continued, "was also the discovery that, at dose levels below 50 rads, the cancer risk was too small for direct observation even in a study population which included almost 70,000 of these persons. However, when risk estimates for these low dose survivors were based on linear extrapolation of the cancer deaths recorded by high dose survivors, there was found to be close agreement with other high dose studies."

There in a nutshell was a situation which lulled everyone concerned with radiation protection recommendations and standards into a false sense of security. Yet how on earth could the survivors of a population that had been subjected to the inestimable trauma of the A-bomb and the terrible conditions that prevailed during the winter that followed, in the ruins of the two Japanese cities, even come back to being normal, any more than could the concentration camp survivors? From the beginning Dr Stewart believed that the data on A-bomb survivors should incorporate some 'disaster effect':

"I was very vague in my ideas," she said referring to a BEIR (Committee on the Biological Effects of Ionizing Radiations) meeting in 1972, "but I had an idea that it might be quite difficult for the mother and child to survive in these appalling circumstances and that people we had lost might not be all representatives of the people who survived."[46]

Her notion was brushed aside by Dr Jablon, one of the principle collators of the Atom-bomb data, but gradually Dr Stewart has refined her ideas on what she has described as her "silent forces" hypothesis.[47] By that hypothesis the A-bomb survivors studied from the fifth year after the explosion would have naturally been among the healthiest of the population, the bomb and the ensuing trauma having selected out the 'fittest' of the population. Moreover, those 5-year survivors closest to the hypocentre would tend to have come from fitter and more resilient members of the population than those living further away.[48]

That "healthy survivor effect" would be opposed by another delayed force—residual bone-marrow damage—which would result at some later date in a deficiency in the blood forming tissue, leading to a loss of immunological competence and to death from such diseases as aplastic anaemia. When asked at the Sizewell Inquiry what the threshold for bone-marrow damage might be Dr Stewart said "I would say it lies near 50 rads, but it could be anywhere above 20."[49]

Stewart and Kneale have found further evidence for the two silent forces, (the "healthy survivor effect" and residual bone-marrow damage) in the published data to be found in the *Ninth Life Span Study* of the A-bomb survivors.[50] By excluding both deaths from cancer and deaths from cardiovascular disease from the mortality data of the A-bomb survivors, they were left with a large residual group that included all the infection deaths. As can be seen in Figure 1[51] the dose-

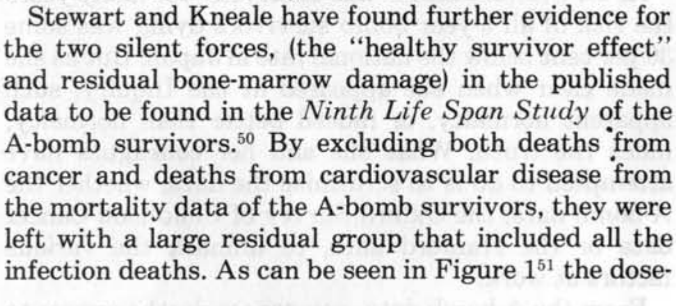

Fig 1 Non-cancer deaths of A-bomb survivors exluding cardiovascular deaths and trauma.

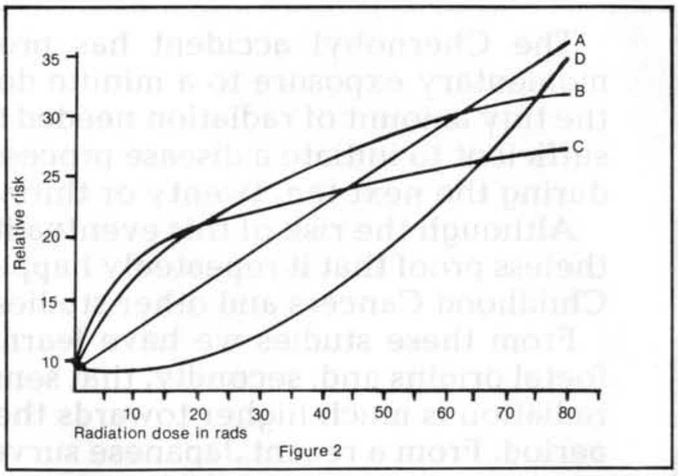

Figure 2

The different curves shown basically summarise the relative cancer risk caused by ionising radiation according to various theories. In Curve A—the straight line hypothesis—the relative risk rises proportionately with radiation dose. The straight line hypothesis is the one used by the ICRP and other standard setting bodies such as the NRPB on the assumption that it is "conservative" and will, if anything, overestimate the relative risk at low doses. Curve D assumes that very low radiation doses are less consequential per unit dose in causing cancer than are higher doses. Many health physicists believe curve D to be more representative of the facts. However, according to Dr Alice Stewart the evidence increasingly points to curves B or C being the true state of affairs. In both B and C very low doses of radiation are seen to be more effective in inducing cancer compared with higher doses. Indeed the point at which the cancer rate doubles in B and C is around 15 rads, whereas in A it is closer to 30 rads and in D to 50 rads.

response curve was found to be U-shaped, and Stewart and Kneale explain these findings as strongly indicative of a healthy survivor effect acting more vigorously as the estimated dose approached 250 rads and from then on being counteracted even more vigorously by an accelerating ratio of observed to expected deaths. Stewart and Kneale point out that

"the steep downward slope of this biphasic curve shows that below 50 rads, selection effects of early deaths were much stronger than other effects of the bombing; and the steep upward slope at high dose levels shows that above 50 rads other mortality effects of the bombing were at least twice as strong as the selection effects."[52]

"Official estimates of the cancer risks of A-bomb survivors could be an order of magnitude lower than the actual risk. This would not only account for the present (order of magnitude) difference between ICRP and MSK (Mancuso, Stewart and Kneale) estimates of the cancer effects of low level radiation but would also make it unnecessary to assume that there is no return to foetal levels of cancer sensitivity in old age."[53]

Stewart and Kneale obtained the relationship shown here in Figure 1 by plotting ratios of observed to expected deaths against radiation dose for non-cancer deaths of A-bomb survivors excluding cardiovascular deaths and trauma. In that exercise Stewart and Kneale abstracted data on cardiovascular as well as other non-malignant diseases from the Life Span Study Ninth Report.[54] That the "other non-malignant diseases" showed in the early years a downward trend with dose at least down to 250 rads exposure which did not appear with cardiovascular disease, proved their point, they claimed, that a healthy survivor effect had not only been in force, but could actually be revealed.

Only persistence and a dogged, highly intelligent pursuit of the truth vindicated Dr Stewart's discovery of a significant cancer effect from X-rays given to pregnant women. At the Windscale Inquiry much of what she said was dismissed in the Inspector's Report. At

Table 2 Hanford occupations: classifications by socioeconomic status, type of work, and danger levels

Socioeconomic level	*Description*		*Danger levels*	*Man-years No*	*%*
1	Professional and technical		1	26 861	2.83
			2	27 208	2.86
			3	25 584	2.69
			4	23 754	2.50
2	Clerical		1	47 598	5.01
	Operatives and other manual			34 529	3.63
			2	27 001	2.84
			3	23 167	2.44
				33 828	3.56
	Totals	Hanford work years		269 530	28.36
		Post Hanford		680 990	71.64
		Follow up period		950 520	100.00

the Sizewell Inquiry Sir Edward Pochin for the NRPB, who was one of the Assessors at the Windscale Inquiry, said with reference to Dr Stewart's Oxford Study:

> "I believe that the evidence she produced is sound, and is valuable as an aspect of radiation protection, and I believe that if her data had not been closely scrutinised they might have been dismissed."[55]

Two recent papers in the *British Journal of Industrial Medicine* by Kneale, Mancuso and Stewart, give the results of refining the Hanford data.[56,57] In the second of these[58] Dr Stewart and her two colleagues point out that when the cancers of the Hanford population of workers are classified according to the criteria of ICRP 14[59] into all cancers of radiosensitive tissues as distinct from all other cancers, the correlation between dose level and cancer mortality becomes significant. Thus whereas the observed to expected ratio is 0.79 at the lowest dose level of 0.01 to 0.25 rads, at 4 rads and over, the ratio climbs to well above unity—for instance for doses greater than 10.05 rads the ratio goes to 1.32.

The division of the Hanford workforce into nine different groups relating to the type and nature of the job in the plant, and its ranking with regard to four levels of radiation exposure as indicated in Tables 2 and 3, gave highly significant results. The professional and technical staff were in general found to exhibit a vigorous healthy worker effect—as evidenced by a negative score—except those exposed at the highest danger level, number 4 in the ranking, where the healthy worker effect compared with the average for all the workforce almost vanished. On the other hand clerical staff as well as operatives and other manuals not exposed to radiation—hence at the lower danger levels—showed positive scores with regard to differential mortality. Altogether by cross classification of four obvious factors, namely sex (2 levels), hire age (5 levels), hire dates (4 levels), duration of employment (2 levels), the data could be separated into 80 cohorts. Five levels of differential mortality for each job title were defined, so that altogether 400 cohorts were produced.

In fact nearly half the dangerous work at Hanford, measured in terms of radiation exposure, was carried out by personnel with professional and technical qualifications. Indeed the levels of mortality were found to be considerably higher for the lower than the higher grades of work. The mortality risks only became similar for these specialists and non-specialists doing the most dangerous jobs.

In their *Hanford Radiation Study III,*[60] Kneale, Mancuso and Stewart use the data derived from Hanford to give a likelihood of the shape of the dose-response curve. In this analysis the various shapes of the curves, whether linear, quadratic, square root law or cube root law, that have been proposed by different authors were identified, and they are reproduced here in Fig. 2.[61] The curve which best fits the data is the square root or half-power law. That curve shows a non-linearity of dose response. Moreover the doubling dose (by which the incidence of radio-sensitive cancers is doubled) appears to be of the order of 15 rads as distinct from 30 rads for the linear model. For the quadratic model, which assumes that radiation-induced cancers show an acceleration in incidence at high doses compared with low doses, the doubling dose is 60 rads.

In their conclusion Dr Stewart and her colleagues

Table 3 Hanford occupations: relations between socioeconomic levels, radiation doses, and differential mortality. (Figures in parentheses are ranking positions within each socioeconomic level)

Socioeconomic levels	*Occupations*	*Danger levels*	*Monitoring scores (means)*	*External radiation mean annual dose in millirems*	*Differential mortality scores§*
1	Professional and technical	1	1.92(1)	87(1)	−228(1)
		2	2.74(2)	168(2)	−210(3)
		3	3.08(3)	260(3)	−222(2)
		4	3.69(4)	639(4)	− 29(4)
2	Clerical	1	2.03(1)	37(1)	+ 92(5)
	Operatives and other manual	1	2.28(2)	61(2)	+ 65(3)
		2	2.76(3)	126(3)	+ 82(4)
		3	3.20(4)	166(4)	− 43(1)
		4	3.60(5)	831(5)	− 35(2)

§These indices of general mortality measure the change in logit probability (x 10^4) of the death rates being higher (+) or lower (−) than the average for all workers with control for age, sex and calendar year.

agree with other studies on the effect of high dose radiation, that, above 100 rem, the doubling dose for radiosensitive cancers is in the region of 200 rem. The importance of their work is to bring to our attention the likelihood that low dose radiation, particularly in the young, carries with it a significant danger—one which is 15 to 20 times greater than earlier estimates by other authors.

Some critics of the MSK studies of the Hanford population have come to the conclusion that the notion of a 15 rems doubling dose is absurd given that a lifetime's exposure to natural radiation would generate several times more cancers than are actually observed.

However Dr Stewart and her co-authors state that the apparent *reductio ad absurdum* of natural background radiation causing more cancers than actually exist, can be accounted for by three factors:

1. Progressive increase in sensitivity to cancer induction by radiation with advancing age means that most of any one person's lifetime exposure (i.e. after the person is born) to background radiation is occurring at relatively insensitive ages.
2. Long intervals between cancer induction and death mean that any effects of background radiation will only find expression among individuals who live to an advanced age.
3. The assumption that each death from cancer has only one cause is certainly an over-simplication.[62]

At the Inquiry, Dr Stewart reiterated that the mistake has been to extrapolate linearly down from the results of high dose radiation studies to low doses, and to claim then to have been conservative.

Talking of standard-setting bodies such as ICRP, she said:

"I have suspected that all of them had this basic fault, that they thought it safe to go from high dose to low dose, assuming there was only one radiation effect, namely mutations."[54]

The Underestimation of Risk

We appreciate that the effects of low dose radiation on human health remain controversial. We also appreciate that people living in the vicinity of any industrial plant, of whatever nature, will tend to look to it as a scapegoat for any unusual disease that crops up in their midst. Childhood leukaemia around Sellafield is one such example, as are the reported incidences of children born with eye defects to families living close the Re-chem's chemical incineration plants in Scotland and South Wales. The problem is to discern whether such clusters of diseases have arisen through chance, or through some identifiable carcinogen or teratogen arising from the factory, or through a so-far unidentified agent present, naturally or otherwise, in the local environment.

We have continually been told both at the Sizewell Inquiry and outside, that the radiation exposure of workers at Sizewell A, or of the general population around Sellafield is far too low—in the case of Sellafield some 40 times too low—to account for the unusually high incidence of disease. Thus the Black Report while "it does not exclude the possibility of a localised excess of cancer in young people living near

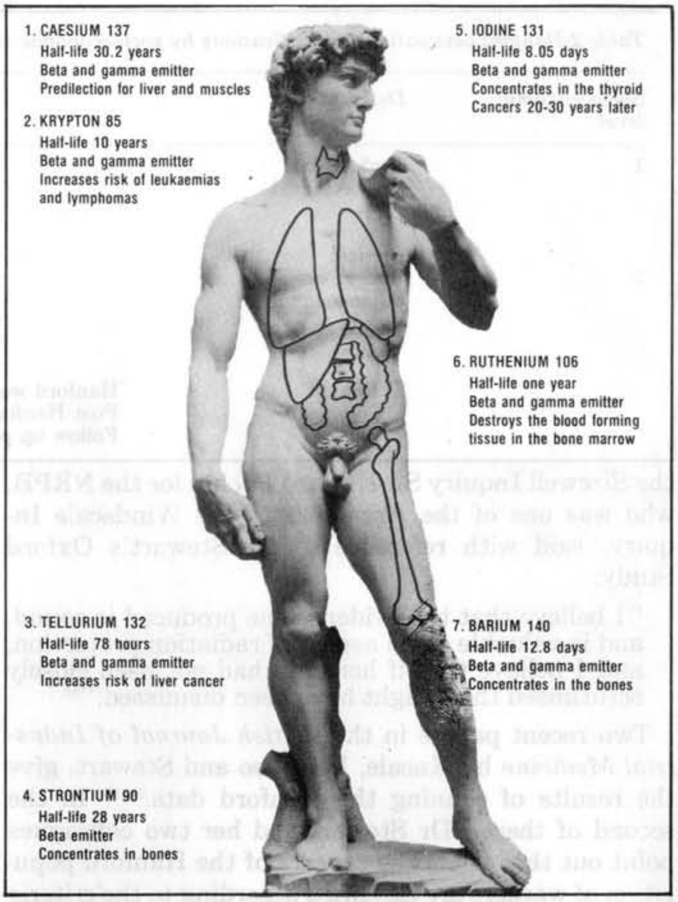

PHOTO: SCIENCE ET VIE

The medical risks from exposure to radiation.

Sellafield" comes to the conclusion that:

"In summary, background radiation would be expected to cause 0.5 deaths from leukaemia; additional radiation exposure from the discharges would be expected to cause less than 0.1 deaths from leukaemia; in fact 4 deaths from leukaemia in under 20 year-olds were observed in Seascale during the period under consideration."[62]

Sir Douglas Black and his advisers made it abundantly clear in compiling their report on the investigation of the possible increased incidence of cancer in West Cumbria that they were using generally accepted NRPB criteria for evaluating cancer risk from radiation. For instance, in paragraph 4.47 page 70, they say:

"It is generally assumed that the relationship between dose received and number of leukaemias or cancers induced is linear. However, there is considerable evidence both from radiotherapy experience with patients and from animal and *in vitro* work that this assumption probably produces an overestimate of the number of cases induced by radiation at low dose rates when low LET (low energy transfer) radiation is being considered, because repair of damaged DNA can occur to a greater extent at low dose rates. Nevertheless, if we assume a linear relationship, thus making a further 'worst-case' assumption then the dose received by the 1950 cohort from the Sellafield discharges can be calculated to be expected to give rise to a maximum of 13 per cent of 0.1 additional cases of leukaemia or 0.013 cases. If one considers the entire Seascale population under 20 up to 1980 then the expected number of additional cases can be similarly calculated to be about 0.013 x 7 = 0.091 cases."

We believe that the Black Report is wrong and cannot accept that the linear model at low doses rates provides us with an overestimate, 'worst-case', situation. The linear model does not fit the facts. It is merely an extrapolation down from high dose studies. Instead we would argue that the square root law curve fits the facts accumulated to date from low dose studies on human populations. The cancer risk at low dose rates must be increased by a factor of 15 to 20.

With that increased risk one is, we would venture, approaching the factor difference between the observed and expected incidence of childhood leukaemia in Seascale. Furthermore the notion that low dose rates are potentially less harmful because of DNA repair mechanisms exhibits a misunderstanding of the likely mechanism of cancer induction, in which faulty repair is the problem, rather than cell death as caused by more extensive damage to the cell.

As Dr Stewart told the Sizewell Inquiry:

> "The other thing that had to be accounted for was that at very low doses it is known there is a thing called 'chromosomal repair'. As we know that the radiation mutational damage is something to do with damaged genes, damaged chromosomes, there had to be a logical reason why if you were right down in the low dose level where we were, that you might expect it to be quadratic, there would be a healing effect, but all we can say is that expectation is not fulfilled, and therefore you would argue that the so-called healing is not necessarily a good thing. It is a good thing from the point of view of the cell because it allows the cell to survive, but unless it is 100 per cent efficient—and it could easily just be 99 per cent efficient—it might mean that you enable a cell to survive that is carrying a bad gene . . ."[54]

We think, given the evidence emerging from all quarters, that the present standards under which the nuclear industry operates will have to be revamped to take account of the insidious, yet greatly underestimated, risks of damage to the human population brought about through anthropogenic sources of low dose radiation. Undoubtedly once the new estimates of risk from low dose radiation are taken on board, the concept of the degree to which the nuclear industry can be considered a 'safe' one will have to change. The fact is that the safety margin and permissible exposure rates under which the nuclear industry now operates are neither adequate nor safe. The danger is that the present-day emergence of an excess of radio-sensitive cancers among the population at risk, whether workers in the industry or general public, may represent no more than the tip of the iceberg, the remainder being submerged—for the present—by the latency of radiogenic cancers.

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The Sellafield Discharges

by Peter Bunyard

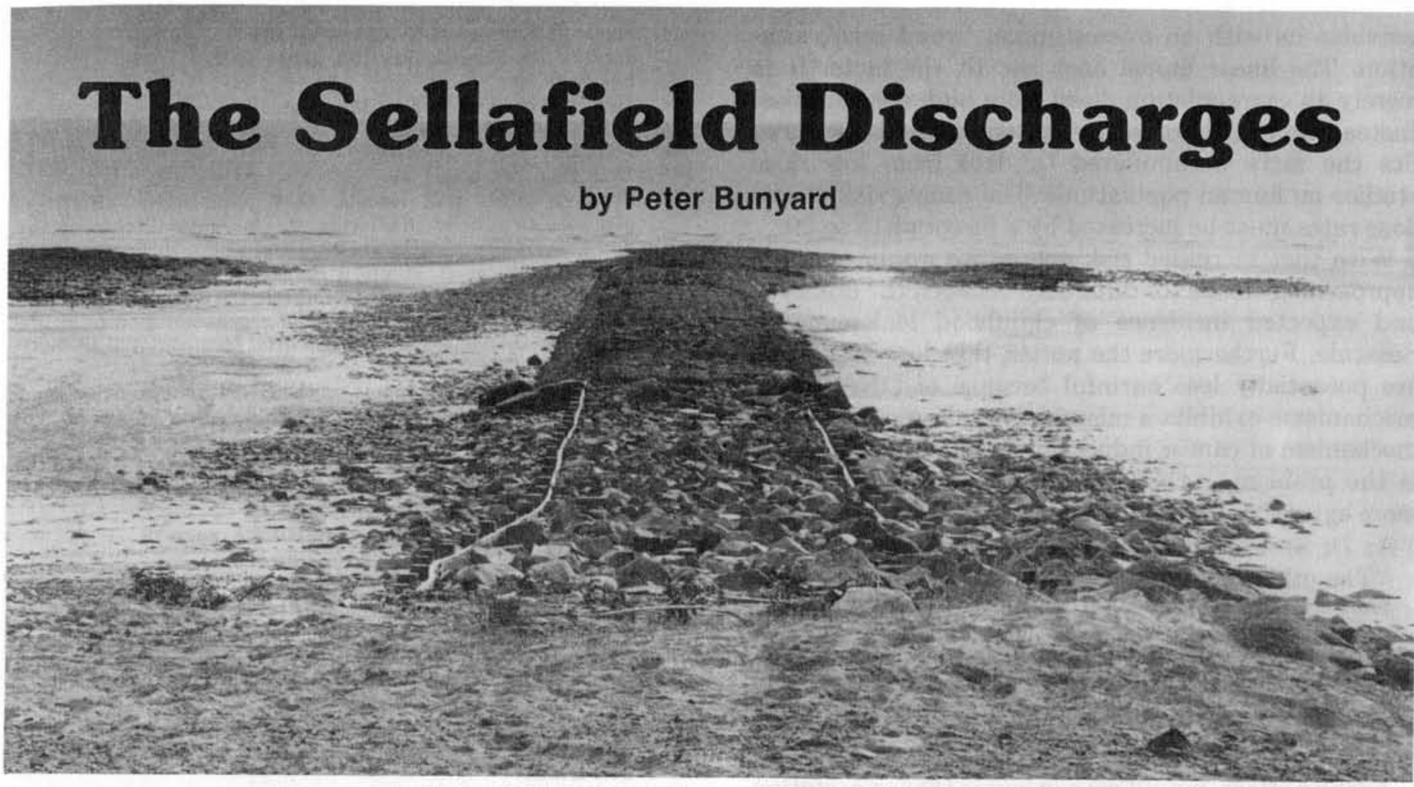

PHOTO: MARTIN BOND

Rocks covering the Sellafield pipeline which discharges radioactive waste into the Irish Sea

Sellafield is the most polluting nuclear installation in the world, and one with the worst accident record, barring Chernobyl. The contamination of the Irish Sea and the Cumbrian coastline has now reached dangerously high levels as a result of a combination of routine discharges and accidental releases from the plant whose true extent and implications have been constantly hidden from the British public.

Windscale, now known as Sellafield, is a complex of nuclear installations sited on the western reaches of Cumbria between the Irish Sea and the Lake District. Sellafield's prime purpose is to extract out plutonium and uranium from spent reactor fuel rods and to make it available for civil or military nuclear programmes. Indeed, plutonium from Windscale's plutonium piles was used to make the bombs exploded over the Montebello Islands off the Australian coast in 1952, an act which heralded Britain's entry into the arms race, next in line after the United States and the USSR*.

The Sellafield site therefore contains cooling ponds for storing spent fuel awaiting reprocessing, silos and special tanks for holding nuclear waste, fuel fabrication plants for manufacturing plutonium oxide fuel for the prototype fast reactor at Dounreay in Scotland, and, in addition to the B 205 magnox reprocessing plant and its B 204 predecessor, various derelict reactors including the twin plutonium piles and the steel-domed prototype advanced gas reactor, as well as an experimental vitrification plant for encapsulating high activity waste and the excavated site for THORP, the next in line reprocessing plant. The four 50 megawatt Calder Hall reactors form part of the complex, and like the rest of the installations were taken over by BNFL in 1971 when the company was formed as an offshoot of the UK Atomic Energy Authority (UKAEA).

An "Organised and Deliberate Scientific Experiment"

The military origins of Sellafield have left a double legacy. Not only are operations there shrouded in secrecy, particularly with regard to reprocessing and the quantities as well as quality of plutonium in storage, but little attempt is made by BNFL or its predecessor, the UKAEA, to put its house in order with regard to radioactive discharges into the environment. On the contrary, as has now come to light some 30 years later, discharges of radioactive effluent were *purposely* increased during the 1950s as part of an "organised and deliberate scientific experiment" in order to follow the pathway of various radionuclides through the environment. The man behind the experiments, Dr John Dunster, was at the time health physicist with the UKAEA, then in charge of the plant. Today Dunster is director of the National Radiological Protection Board (NRPB), the body responsible for recommending the maximum permissible radiation exposure standards for members of the public and for

* Officially only that plutonium extracted from the Calder Hall and Chapelcross reactors should be used for defence purposes, and only then, according to Dr Donald Avery of BNFL, when the original uranium fuel for those reactors had been derived from non-safeguarded sources obtained prior to the Non-Proliferation Treaty. Officially too, the plutonium derived from the electricity boards' reactors is kept in storage on site until required for recycling either in thermal reactors or in the prototype fast reactor. The intention, too, is to win contracts for reprocessing spent fuel from abroad. A contract has already been signed to import Japanese spent fuel and much of the rationale for building the Thermal Oxide Reprocessing Plant (THORP) was that it would largely be paid for by overseas customers.

workers in the nuclear industry. In 1958, at the Second United Nations Conference on the Peaceful Uses of the Atom, Dunster told delegates,

"The intention has been to discharge fairly substantial amounts of radioactivity . . . the aims of this experiment would have been defeated if the level of radioactivity discharged had been kept to a minimum."

He went on to say that the discharges were deliberately maintained at levels . . .

"high enough to obtain detectable levels in samples of fish, seaweed and shore sand, and the experiment is still proceeding. In 1956 the rate of discharge of radioactivity was deliberately increased, partly to dispose of unwanted wastes, but principally to yield better experimental data."

In fact, as a future disclosure in 1964 in *Health Physics* made clear, the experimental discharge of radioactivity into the Irish Sea began in May 1952, and was continued for several years. The stage was already set for the much greater discharges of radioactive waste that were to come more than a decade later with the operation of the B 205 reprocessing plant and the accumulation of spent magnox fuel from Britain's first nuclear power programme.

An Appalling Record

Sellafield's record has not been a good one. Various installations on the site have leaked, some for years before being detected, and that after many thousands of curies have run off into the soil. A silo containing the cladding from spent magnox fuel leaked for at least four years before the leak was discovered, by which time as much as 50,000 curies of radioactive waste had escaped, most of it caesium. Some pockets of soil were found to be giving off absorbed dose rates of up to 1,200 rads per hour, enough to cook an unsuspecting individual. Another leak from a building containing high activity waste was discovered in 1978 by which time as much as 100,000 curies of waste might have escaped. That particular leak was the result of considerable bungling, a line for emptying a sump containing high level waste being cut and capped when it should have been left intact. To compound the error the wrong size gauge was fitted which indicated that the sump was nowhere full when in fact it was overflowing. For once the Nuclear Installations Inspectorate was openly critical of BNFL, stating that the management had been 'lacking in the level of judgement and safety consciousness expected'. Nevertheless, it did not prosecute the company.

Opting for the Cheapest Means of Disposal

As we know today, reprocessing spent reactor fuel is a relatively expensive item in the nuclear fuel cycle, especially when proper care is taken to control discharges and to dispose of higher activity waste. As Dunster himself remarked, the rationale behind the discharges of the 1950s was not just experimental curiosity but also to get rid of 'unwanted wastes'. To be able to dispose of wastes into the environment whether sea or atmosphere, was undeniably cheap and as long as the authorities in question gave their blessing, perfectly legitimate.

To-date, authorisations imposed on rates of discharge from Sellafield have had more to do with what the industry has been willing to achieve than with targets set by authorising bodies such as the Ministry for Agriculture, Food and Fisheries (MAFF). In 1968, the UKAEA needed an increase in the authorisation for discharge of highly toxic alpha-emitters such as plutonium-239 and americium-241. The limit was then 1800 curies per year (see Table 1) and it wanted 6000 curies—a threefold increase of an already considerable amount. Two years later, in 1970, authorisation was given; yet, the Fisheries Radiobiological Laboratory of MAFF did not start sampling for transuranics such as americium and plutonium until 1973—fully three years later.

In 1974, BNFL discovered that corrosion of the spent magnox fuel in the cooling ponds was contaminating the pond storage water with radioactive caesium, particularly the 137 isotope. MAFF had originally called for a limit on discharges of 10,000 curies per quarter of caesium-137, but BNFL held out for 15,000 curies on the grounds that tighter control would lead to additional costs. In the event the authorisation on caesium was never confirmed either way, which was just as well for BNFL, as by 1977 the quarterly discharge was up to 40,000 curies and the yearly discharge to more than 120,000 curies.

TABLE 1

RADIOLOGICAL UNITS

Unit or Quantity	Symbol	Brief Description
Curie	Ci	3.7×10^{10} nuclear transformations per second
Becquerel	Bq	1 nuclear transformation per second
Rad	rad	0.01 Joules/kg (100 erg/g)
Gray	Gy	1 Joules/kg (= 100 rad)
Dose Equivalent	H	dose X Q X any other modifying factors
Quality Factor	Q	Biological effectiveness of radiation
Rem	rem	rad X Q X any other modifying factors
Seivert	Sv	Gy X Q X any other modifying factors

By the early 1980s, BNFL had reduced annual discharges of beta activity—including caesium-137—to just under half the peak value of 250,000 curies discharged into the Irish Sea during the mid 1970s, when the corrosion problem in the cooling ponds was at its worst. Alpha activity was also brought down, some 1,000 curies being discharged in 1980 compared to as much as 5,000 curies a year between 1973 and 1975. Even so, as the Radioactive Waste Management Advisory Committee made clear in its 1984 annual report, radioactive discharges from Sellafield remained the highest of any nuclear installation in Europe, with certain local fish-eating members of the public receiving up to 69 per cent of the maximum dose level as recommended by ICRP—the International Radiological Protection Commission—and the NRPB.

Persistence in the Environment

Radionuclides such as plutonium-239, with long half-lives, will, once released into the environment, persist for tens of thousands of years. They are pollutants for all time, and are particularly dangerous on account of their intense radiotoxicity should they be taken up into the body. In the early days, scientists for the Atomic Energy Authority assumed that the plutonium and other toxic alpha emitters discharged into the Irish Sea from Sellafield would be trapped and locked in the sediment offshore. Yet, as Dr V. Bowen, who had been an analytical chemist on the Manhattan Project and was later at the Wood's Hole Marine Biological Station in Massachusetts, pointed out at the 1977 Windscale Inquiry, he himself had found that scallops caught off the Isle of Man—at least 35 miles away from Sellafield across the Irish Sea—had a plutonium burden 40 times and more higher than that found in plaice caught close to Sellafield off the Cumbrian coast. His finding was enough in itself, Bowen argued, to contradict official claims that transuranic nuclides which were incorporated into the sediments of the Irish Seas were not available biologically and therefore would not become part of the food chain. Should Isle of Man scallops be consumed at anything like the rates assumed for Windscale plaice, then according to Bowen, individual consumers would get as much as 10 per cent of their maximum permissible levels of plutonium from that one source alone.

Six years later, on October 6th 1983, BNFL announced that it would spend £10 million on a programme to reduce plutonium and americium discharges down from 1,000 curies to 200 curies. The factors involved in BNFL's decision, apart from public outcry at the discharges, were that the National Radiological Protection Board had come to the conclusion, after further research, that the absorption rate of plutonium by shellfish, including of scallops, was five times higher than it had maintained previously, that more shellfish was eaten than was previously thought, and that analytical methods for measuring plutonium contamination in shellfish had improved. In all, the NRPB decided that the contribution from plutonium to the critical group dose should be increased by a factor of 15.

But Bowen was not concerned only with radioactive contamination of seafood. The main body of his evidence dealt with ways in which transuranics such as plutonium and americium might find their way ashore. He suggested three pathways: plutonium contaminated dusts that escaped the filter systems in the exhaust stacks of the reprocessing plant; waste storage and fuel fabrication plant; the sediments that washed up on the beaches, dried out and blew away; and the atomization of alpha emitters by the action of waves along the shoreline. Bowen was amazed that the British authorities only began their examination of the inhalation pathway associated with the resuspension of radioactive substances from contaminated sediment in 1976, even though the Department of the Environment had considered such an eventuality in 1969, just at the time when it was considering BNFL's request for a threefold increase in alpha discharges. When the Department carried out a few tests it found the mean concentration of plutonium particulates in the Ravenglass estuary, some 10 kilometres to the south of Sellafield, to be ten times higher than that found in the immediate vicinity of the Sellafield site.

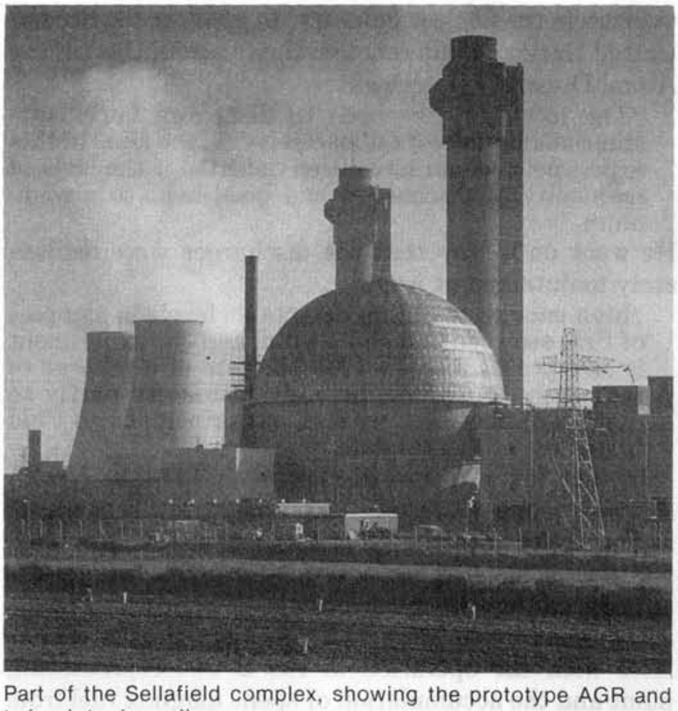
PHOTO: BARRY LEWIS

Part of the Sellafield complex, showing the prototype AGR and twin plutonium piles.

In November 1983, the Environmental and Medical Services Division of the UKAEA at Harwell reported the results of experiments which mimicked the action of surf on plutonium-contaminated sediment. It found the concentration of plutonium in the spray to be as much as 800 times greater than that of the seawater from which the droplets were formed. Americium was even more volatile, the concentration in spray being some 10,000 times greater than in seawater. The mechanism by which plutonium and other alpha emitters return to shore would therefore seem to have been confirmed.

Meanwhile, A.D. Horrill and his co-workers at the Institute of Terrestrial Ecology, have found enormous variability in radionuclide levels within a distance of a few hundred metres in the surface silt and vegetation of a grazed saltmarsh in the Esk estuary, which itself leads into the Ravenglass estuary. Such variability, for instance between 20 and 460 pico-curies per gram dry weight for caesium-137 (one picocurie is one trillionth of a curie), can lead to considerable errors in evaluating the extent to which the Cumbrian coast has become contaminated by the Sellafield discharges. Horrill, for instance, found americium levels to range from 4.59 to 232 pCi per gram and plutonium-239/240 to range from 11 to 240 pCi per gram dry weight.[1]

Tissues of ewes and lambs that had grazed over the contaminated Ravenglass saltmarshes showed varying concentrations of radionuclides. B.J. Howard and D.K. Lindley, also at the Institute of Terrestrial Ecology, found as much as a 50-fold concentration of caesium-137 in the liver of lambs compared with a control ewe and similar concentration factors in kidney and muscle. Up to a one-hundred fold concentration of plutonium was reported in the liver of ewes.

Because they are higher up the food chain, human beings are more vulnerable to radioactive contamination than are herbivores. Some members of the Cumbrian coastal community have been found to be avid eaters of fish and shellfish. Thus investigations by MAFF's Fisheries Radiobiological Laboratory (FRL) found that such individuals would consume up to 100 grams per day of fish, 18 grams per day of crustaceans and up to 45 grams per day of winkles and mussels. On the basis of the annual ICRP dose limit for members of the public, FRL calculated that in 1981 the critical group of fish and shellfish eaters would have received 69 per cent of the limit; in 1982, 54 per cent; and in 1983, 51.5 per cent, just through diet alone. For consumers of seafood caught further away, by the commercial fisheries associated with Whitehaven, Fleetwood and the Morecambe Bay area, the dose to the critical group was calculated as 19 per cent of the ICRP dose limit in 1981 and down to 13 per cent of that limit in 1982. For the average fish-eating member of the public consuming seafood caught by such fisheries, the estimated dose for 1983 was given as 1 per cent of the ICRP dose limit.

A person spending any length of time on the Ravenglass estuary (for instance, salmon garth fishermen), or on board boats moored in Whitehaven harbour will be exposed to external radiation. Taken the shielding afforded by the boat hull into account, FRL estimates that such a critical group may receive up to 8 per cent of the ICRP dose limit through that source, and another 4 per cent if they consume sea food. The alpha emitters, including plutonium, coming ashore, will also add to the dose of those exposed. Present calculations suggest that it is one per cent of the ICRP limit.*

Discharges—As Bad as the Bomb

The potential for plutonium contamination of the environment through activities at Sellafield is considerable, and according to a report in the *Gazette Nucleaire*, a French newsletter, could exceed the entire global inventory of plutonium deposited from the atmosphere from all the test explosions that have ever taken place. To-date, between 4 and 5 tonnes of plutonium has settled to earth from such tests, most falling out over the northern hemisphere. Nevertheless, Cumbrian coastal waters now show concentrations of plutonium and americium that are some 2,000 times higher than fall-out levels, while even the North Sea has double fall-out levels on account of discharge from Sellafield into the Irish Sea. In addition the United Kingdom embarked on a sea-dumping programme in which solid wastes containing considerable quantities of plutonium were ditched in the Atlantic Ocean some 500 miles off Land's End.

Between 1949 and 1977 as much as 140 kilograms of plutonium may have been dumped with another third of a tonne contained in 3,000 cubic metres of waste

PHOTO: MARTIN BOND

Local people fishing in front of the Sellafield reprocessing plant. Discharges into the Irish Sea have made it the most radio-active in the world.

awaiting similar disposal. Meanwhile, between 1968 and 1979, an additional 180 kilograms of plutonium were discharged into the Irish Sea from Sellafield. BNFL's present plans to reduce alpha discharges down to 200 curies and ultimately, when its 'enhanced actinide removal plant' is operational, to 20 curies per annum, will undoubtedly much reduce the alpha contamination build-up in the Irish Sea and Cumbrian silt. Nevertheless, the plutonium waste problem will not have been eliminated, merely transferred, and BNFL will undoubtedly seek to dump the sludges and plutonium-contaminated resins from the actinide removal plant at sea after some form of "waste conditioning". There is no other place for it to go.

The Worst Reputation in the World

BNFL has not fared well when comparisons have been made between its own operations at Sellafield and those of comparable plants elsewhere in the world. The closest in type of operation and in plans for the future is COGEMA's plant at Cap de la Hague on the Cotentin peninsula overlooking the English Channel in Normandy. Not only have discharges into the Channel from the French plant been lower by a factor of eight for beta emitters and a factor of more than 200 for alpha emitters—particularly during the mid 1970s—but worker exposure within the plant has been one half or less that registered at Sellafield. During 1980, for instance, the average dose to 2,671 workers at La Hague was 0.241 rem—therefore approximately twice the background radiation, while in 1982, one of BNFL's better years for radiation exposure the average dose for 5,223 workers was 0.64 rem.

Another way of indicating worker exposure is to relate it to the quantity of electricity generated from the fuel. Again the difference between the French and British reprocessing plants—the only two left in the western world with any commercial pretensions—is telling. Between 1971 and 1975 external irradiation

* In the United States such exposures of members of the public to radiation from man-made sources would not be permitted on a routine basis. There the maximum allowable exposure from fuel cycle activities is 25 millirem, hence 20 times less than that allowed in West Europe. Meanwhile those most exposed members of the public in Cumbria will have received four or five times the US limit.

alone at Sellafield amounted to 1.2 man-rem per megawatt (electrical) year and that for some 4,171 tonnes of magnox fuel reprocessed and 120 tonnes of thermal oxide fuel. The equivalent value for La Hague was 0.51 and that for 3,944 tonnes of magnox fuel and 356 tonnes of oxide fuel reprocessed.

Since 1977, COGEMA has managed to bring down both individual doses to workers and the dose/energy relationship at La Hague, the latter being little over 0.22 man-rem per megawatt year in 1981. Meanwhile the man-rems per megawatt year at Sellafield for 1982 had been reduced to 0.93. The collective dose for the workforce at Sellafield has remained relatively steady over the years, the reduction in individual dose being achieved by increasing the workforce. In 1982 the collective dose was 3,370 man-rems, hence more than five times higher than the collective dose at La Hague. Per tonne of magnox fuel reprocessed BNFL's record at Sellafield has been at least 2½ times worse than COGEMA's. (Peter Bunyard, Evidence to Sizewell Inquiry.)

After considerable criticism, both during the Sizewell Public Inquiry and outside, BNFL has embarked on a costly programme to reduce its discharges. As much as £190 million was spent on control of beta emitters and caesium in particular, the SIXEP treatment plant bringing total beta down to 30,000 curies when operational, supposedly during 1985. On December 18th 1984, BNFL announced that a further £150 million was to be spent on a new plant which "should cut total liquid discharges from Sellafield, including those from the THORP oxide reprocessing plant now under construction, to a target of less than 20 curies a year of long-lived alpha radiation emitters, compared with 383 curies in 1983. Annual discharges of mainly short-lived beta radiation emitters should be reduced to a target of 8,000 curies a year, compared with 67,000 in 1983."

The result of all the treatment plants working as planned will be, BNFL stated, to bring Sellafield discharges down to a level comparable with Cap de La Hague. Meanwhile criticisms are still voiced over discharges, such as they are, from La Hague, and over keeping the total down once attempts are made to keep abreast of the spent fuel coming from an ever-expanding nuclear power programme, and therefore of having to use a number of reprocessing plants in parallel. At La Hague, for instance, COGEMA has plans for two new thermal oxide reprocessing plants, UP 2 - 800 and UP 3 A, each with a nominal capacity of 800 tonnes of spent fuel per year. With regard to the emissions from those plants and their effect on the environment, the Castaing Commission—a body equivalent in France to the Royal Commission in Britain—stresses that:

1) krypton-85 will be emitted in its entirety, approximately 11,000 curies per tonne for PWR fuel;

2) liquid tritium discharges will increase from some 60,000 curies per year to one million curies, a factor increase of nearly 17;

3) permissible liquid discharges of beta and gamma radionuclides will remain as they are, namely 45,000 curies per year (excluding tritium).

CREDIT: RICHARD WILSON

". . . and finally, a MAFF scientist loses his job after warning mothers to keep their children away from the Sellafield beaches."

Given the expected increase in throughput of thermal oxide fuel to be reprocessed, COGEMA will have to improve its control of discharges by a factor of four. Just to keep abreast of COGEMA's expected performance BNFL would have to improve its containment of beta emitters, including plutonium-241 which gradually transmutes into the highly toxic alpha emitter, americium-241, by 30 fold, and of alpha emitters by some 1,000-fold compared to its average over the mid 1970s.

Even if both companies achieve containment considerably better than has ever been achieved before they will be far from the zero discharges called for by the European Parliament's Committee on the Environment, Public Health and Consumer Protection. In response to the unusually high incidence of cancer in the vicinity of Sellafield, the Committee put before the European Parliament a resolution including a demand that the UK government impose a zero discharge of radioactive wastes into the Irish Sea, and that gaseous emissions of radioactive substances, including Krypton-85, carbon-14 and tritium, be controlled in accordance with available technology. The Committee also called for a ban on the transport of spent fuel until discharges had been brought down to a technically achievable level and only when a final storage place for radioactive waste had been made available.

What to Do with the Waste

Much of the plutonium-bearing wastes remain in various forms on site at Sellafield and in need of conditioning. In 1974, as much as 500,000 curies of alpha wastes were contained in high-level waste storage tanks, in silos stocked with magnox cladding from stripped fuel elements and in various other radioactive sludges and wastes. The 500,000 curies of alpha waste containers in the high level waste storage tanks alone must amount to at least 3 tonnes of plutonium.

The aim is to solidify the high level waste, through vitrification, and then dispose of it. One idea is to bury it in the ocean bottom, another on land. Concern has grown internationally over the use of the sea for the dumping of radioactive waste, and in February 1983 a consultative meeting of parties to the London Convention on Sea Dumping passed a resolution which called for a halt to the sea disposal of low-level waste pending further scientific investigation into the possible effects on man, and on the environment.

The UK Government, although it agreed to a temporary ban on dumping, has made it clear that it sees few obstacles on scientific grounds to the resumption of dumping. On the contrary, if international opposition to dumping could be circumvented or ignored, then it is more than likely that Britain would use the Atlantic for getting rid of most, if not all, its nuclear waste, including pieces of derelict reactors. Even high-level wastes could legitimately be dumped if diluted sufficiently in the conditioning material, whether borosilicate glass or synroc, and if the release rates of radioactivity through leaching could be shown to be sufficiently low. Both the International Atomic Energy Agency (IAEA) and OECD's Nuclear Energy Agency are in favour of using the sea for dumping, singling nuclear waste out for special favour from all other potential pollutants of the marine environment. In its revised definition of 1978, the IAEA maintains that all waste from nuclear activities could be dumped provided that the release rates met certain criteria and that total quantities of waste did not exceed more than 100,000 tonnes per annum at any single dump site.

As the Political Ecology Research Group, an independent watch-dog committee, points out:

> "current regulations will allow a 100-fold increase in beta/gamma activity and a 50-fold increase in alpha. With suitable packaging, the UK could therefore dispose of all its fuel element cladding, sludges and alpha-contaminated waste within a few years, with no effort being required to retard release of the activity at depth . . . High active liquid disposal would require demonstration of retarded release rates, otherwise 450 years would be required for wastes generated by the year 1985 alone."

In 1976, Grimwood and Webb of the National Radiological Protection Board advised the UK government:

> "No overriding reason connected with the radiological protection considerations has been identified which would preclude the disposal of suitably conditioned high-level waste on the ocean floor."

Meanwhile the government has been ordering new ships specially designed for dumping nuclear waste from the hull, hence overcoming the difficulties of dumping drums of waste over the side when being hassled by members of Greenpeace in rubber dinghies. To counter any such development, the National Union of Seamen has declared its refusal to handle any nuclear waste destined for dumping in the Atlantic. The final straw for the UK government has come with the majority decision at the September 1985 meeting of the London Convention to maintain indefinitely the ban on dumping.

Throughout the world nuclear wastes are now accumulating and no long term solution for their safe disposal exists. The trend too, especially among those countries determined to make a stand against nuclear weapons proliferation, is to keep spent nuclear fuel intact rather than reprocessing it. Temporary 'engineered' disposal sites for the storage of packaged spent fuel, are now being constructed in countries such as Sweden. While such storage fails to provide a long term solution, at least it offers a better alternative than reprocessing.

Meanwhile the contamination of the environment and living organisms continues, whether through routine discharges or through accidents. For the British public and the European community the spate of accidents at Sellafield and its associated waste dump site at Drigg during the early part of 1986 have been the last straw.

The incidents involved the discharge of half a tonne of repprocessed uranium into the Irish Sea, an accident with much in common with the discharge of radioactive crud that contaminated 20 miles of beaches in November 1983; the escape of plutonium nitrate through a faulty valve into a building manned by reprocessing workers, a number of whom became internally contaminated; a fire at Drigg, apparently not involving the release of radioactivity; and finally a leak of radioactively contaminated drainage water from the Magnox storage and decanning plant.

The Irish in particular have been incensed by the continued polluting of the Irish Sea, Dr Garret FitzGerald, the Irish Prime Minister, calling for the plant to be shut down while the EEC carries out monitoring of BNFL's activities at Sellafield. Some of the strongest words against the plant came from the German member of the European Parliament, Undine Bloch von Blottnitz. "Europe is being polluted for the sake of a few jobs," she told her fellow members. "The least we can do is tell the UK to close down its dump."

As a result of the pressure on the government the Health and Safety Executive is to carry out a six months' intense inspection of the Sellafield site. Simultaneously studies will be carried out to test whether food in the locality has been contaminated. Nevertheless the government has brushed aside appeals for the plant to be shut down until the Health and Safety Executive has made its findings public, as has been requested by some members of the European Parliament and environmental groups such as Friends of the Earth.

As part of general policy, BNFL has consistently underplayed the nature and danger of its accidental discharges, claiming that the general public have not been put at risk. After the escape of plutonium nitrate

SELLAFIELD AND NUCLEAR WASTE— FRIENDS OF THE EARTH'S TEN POINT PLAN

REPROCESSING AT SELLAFIELD

1. Abandon the construction of the Thermal Oxide Reprocessing Plant (THORP).
2. Commence the immediate construction of dry storage facilities for spent Magnox and AGR nuclear fuel at both Sellafield and the sites of nuclear power stations.
3. Phase out Magnox reprocessing over a three year period in tandem with the construction of dry storage facilities.
4. Reduce radioactive discharges into the Irish Sea to zero, using the Best Available Technology as agreed under the auspices of the Paris Commission, within a three year period.
5. Redeploy the Sellafield workforce in line with its amended status as a 'centre of excellence' for nuclear waste management, de-contamination, de-commissioning and spent fuel storage.

NUCLEAR WASTE DISPOSAL

6. Construct above-ground storage facilities for low and intermediate level nuclear waste on the site of nuclear power stations. Such storage facilities to take the small quantities of waste produced by medical/research establishments.
7. Suspend the current proposals by NIREX for shallow and deep disposal facilities for nuclear waste.
8. Phase out the use of the inadequate Drigg disposal site in line with the phasing out of Magnox reprocessing at Sellafield, and severely restrict the range of wastes disposed of at the site.
9. Make major modifications to the institutions involved with radioactive waste management. NIREX should be constituted to reduce representation from the nuclear industry itself, and to include representatives from the Department of the Environment, the TUC and environmental organisations. The remit of NIREX to be widened to include the management of High Level Waste. The Radioactive Waste Management Advisory Committee (RWMAC) to be made more representative of the general public through major amendments to its membership, and made more independent of the nuclear industry and Government by having an independent secretariat, the ability to commission its own research, and to have statutory responsibilities.
10. A major research programme into future land disposal routes for all nuclear wastes to be embarked upon over the next ten to fifteen years. The findings of such research to be open to full peer review and independent scrutiny, before a Planning Inquiry Commission considers the alternative disposal options.

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which led to an 'amber alert', BNFL management made a statement that no more than two workers had been contaminated, one of whom had received more than the annual maximum permissible dose according to ICRP standards. Later information revealed that as many as 15 workers had inhaled plutonium into their lungs. And with regard to the uranium discharge BNFL's Managing Director, Con Allday, claimed that it was a mere drop in the ocean compared with what was already there. Again he was invoking the 'discharge, disperse and dilute' approach. Yet as ex-Harwell scientist M.E.J. Gilford pointed out, the truth was somewhat different, the localised dumping of radioactive uranium leading to far greater concentrations than naturally present either in sea water or in the top layer of the sea-bed. In a letter to *The Guardian* Gilford stated:

"According to Mr Allday 'The Irish Sea already contains many thousands of tonnes of naturally occurring uranium.' A BNFL spokesman also recently stated that the East Irish Sea contains about 1,000 tonnes of naturally occurring uranium in the sea water and 10,000 tonnes in the sea bed. My own calculations suggest that the sea water contains only 100 tonnes. Even if I grudgingly accept 1,000 tonnes in the sea water, I ask myself: Isn't the East Irish Sea rather a big place? Surely, a large proportion of the uranium will stay within 100 square kilometres of the outlet for a considerable time. Now, according to BNFL figures, 100 square kilometres of Irish Sea contains only about 5 tonnes of naturally occurring uranium (my own figures suggest half a tonne). Compared with this, half a tonne dumped in a single day looks a little more alarming.

Ah but, I hear Con Allday say, perhaps not all of the uranium is in soluble form; some of it will fall to the sea bed where there is already 10,000 tonnes. Well, it depends what you mean by 'sea bed'. If you mean the top 200 metres of the sea floor, then yes I agree—10,000 tonnes of naturally occurring uranium is about right. But if you mean the top 10 centimetres, where most of the living creatures reside, then I'm afraid the whole of the East Irish Sea contains only 5 tonnes of uranium, and the 100 square kilometres nearest the outlet contain a mere 25 kilograms. Compared with this, 440 kilograms dumped in a single day looks truly horrific."

We have now come to accept deceit and half truths from the nuclear authorities. Even Sir Douglas Black in preparing his report on the spate of childhood leukaemia cases in West Cumbria was misled as to how much uranium had been discharged into the environment between 1952 and 1955. He and his team of advisers were told that the quantity discharged was 400 grams. Two scientists who worked at Windscale in the 1950s have now revealed that the quantity was at least 40 times greater. And what about other, far more dangerous radioactive pollutants such as americium and plutonium? Can we accept the official figures of the discharges? One would have to be exceedingly generous to give BNFL and other members of the nuclear establishment the benefit of the doubt. The tragedy is we have created a site that will remain dangerously polluted for all time. Gross mismanagement is simply compounding the problem.

Notes

In the *Marine Pollution Bulletin* (Vol 12, No 5 pp 149-153, 1981) S.R. Aston and D.A. Stanners from the Department of Environmental Studies report on similar results. As they point out, 45 per cent of all the 27,478 curies of alpha activity discharged via the pipeline into the Irish Sea between 1968 and 1978 is made up of americium-241, which then gradually comes ashore associated with fine silt sediments brought in with the tides. As a result, the entire range of the coastline from Maryport in the north to Wyre in the south has measurable activity, the greatest values being in the Ravenglass estuary where sediments from inner sections of the estuary reveal a seven fold higher concentration of americium than has been reported for some Irish Sea sediments. Meanwhile plutonium levels 60 kilometres to the south of Sellafield in the Wyre estuary appear to be one quarter of those for Ravenglass, the transport of the radionuclide taking six years from discharge to sweep down the coast. Much of the plutonium appears to be associated with organic matter in the sediment suggesting that movement through the food chain may be somewhat easier than if it were totally bound up with inorganic matter.

THE VICTIMS OF RADIATION

by Jean Emery

The victims of radiation are not just statistics to be wrangled over as Jean Emery reminds us.

Jean Emery holds a geiger counter to a pile of radioactive mud from the Ravenglass Estuary near Sellafield. The mud was dumped in Whitehall as part of a protest.

To tell about the lives of radiation victims is never easy. Sadly there are so many cases and in not having the time to give the full details of every case you feel you are denying those people something of their existence, their history, their own unique and individual life. Sometimes those who are suffering are too close to us for us to be able to talk about the issue. Sometimes we are the victims. For those who have been contaminated it is very difficult to convey the silent fears to a world which demands evidence of physical harm before it will react. For those who have the cancers and illnesses, for these people who satisfy the 'statistical demand' or refute the hypothetical cases, it is too late—they are too far gone for our help.

In my home town of Barrow we have a long history of shipbuilding, building ocean going cruise liners before the war, but since 1940 we have concentrated on the building of warships and submarines. In the early sixties Barrow built the Polaris nuclear armed (and powered) submarines, we then moved on to the conventionally armed, but nuclear powered hunter-killer submarines and now, we are also to build the Trident submarines. But to start my tale I would like to go back to the early fifties. At that time Windscale was in its infancy and the skilled workers required to build the Calder Reactors simply were not available from the local rural community. Many men came from the industrial towns of Barrow and Millom to work on the plant. They were so ignorant of the dangers that one wonders how they survived some of the incidents at the plant. The supposed experts of the day were only one step ahead of the workers. Windscale had several accidents in the first few years of operation, but 1952 was the year of the first recorded 'incident' of any significance. In that year the Windscale management, the United Kingdom Atomic Energy Authority, decided to release a large quantity of iodine-131 via the cooling towers to see the effect of such a release. The only reason we know of this is because two of those who were sent out to track the release, found large quantities in their own children. All of this was kept secret, until recently, under the thirty year rule which governs military installations. We shall probably never know who those two innocents were and we shall probably never discover why their parents lacked the courage to speak out.

The next major accident was in 1955. Windscale's plutonium reactors had already been fixed over 300 times by robotic operations, but in 1955 a piece of the monitor which scans the face of the reactor had been pushed through the fuel rod enclosures. To fix it needed men to crawl through to the foot of the reactor; 250 men volunteered their help. They were led in this operation by the plant manager, H G Davey, that rare creature who was prepared to take the same risks as his men. Many BNFL workers do not know of this accident; in fact it was CORE who discovered it. No attempt was ever made to carry out a follow-up health survey of the men involved, although the accident must be relevant to many compensation cases. The men were only allowed 25 minutes working-time near the reactor. They each received a dose equal to three weeks permissible dose. Doses in 1955 were three times the levels permitted today. H G Davey died of multiple myeloma in 1960. Most people felt that his death could not be due to his work as they only knew of his involvement in the 1957 accident and three years seemed too short a time for the disease to take its toll of his life. No consideration was given to previous accidents.

When the 1957 accident happened what can only be described as panic broke out. Firemen were sent in without the correct breathing gear. It took three days to bring the fire under control, it took three days for the authorities to warn the public.

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Non-essential personnel were allowed to go home. Those skilled workers, who were needed, were forced to stay on site. The management drew peoples' names out of a hat to see who would go in to the stricken reactor. Many of those involved have had cateracts, cancers, early heart attacks and rare diseases of the nervous system. One man who suffered such a disease is Arthur Wilson. He was the man who found the fire and ran to alert the management. Their reply was to tell him "Don't be so bloody stupid and stop fooling about". Arthur was one of the men who helped to fix the thermocouples to the reactor. He now has a disease of the central nervous system, his doctors cannot diagnose, but most blame it on his part in the Windscale fire.

Cumbria—the Cancer Risk

In April 1983 20/20 Vision, an independent TV company screened the programme 'Dying for an Answer'. This revealed the following health figures: In 1974-1980 in Copeland, SW Cumbria and Barrow all cancer deaths were: 25 people aged 15-24 or 39% above the expected for the UK, 47 people aged 25-34 or 32% above the expected for the UK, 110 people aged 35-44 or 5% above the expected for the UK, 402 people aged 45-54 or 13% above the expected for the UK. In the Barrow area all male cancers in general were 60% above the national average. In South West Cumbria in general, from 1967 to 1977 male cancers were 10% above the national average, blood cancers in males and females were 12% above the national average. Multiple myelomas were high; 20 females had the disease, 26% above the average and for men there were 28 cases, 76% above the average. From 1969 to 1978 there had been 643 cases of skin cancer, an increase of 44%. From 1979-80 all cancers, in males and females, were up 14-22% above the average, blood cancers were 32% higher than expected and another seven cases of multiple myeloma meant that the level of that illness was 60% above the average. In September 1983 the NRPB published a paper showing that the 20 excess cases of multiple myeloma in SW Cumbria, between 1974-80 were equal to all the excess cases of multiple myeloma expected world-wide in all radiation workers since 1920!

In January 1984 Maryport council added another problem to BNFL's list. This council had dredged the harbour, in order to build a marina to attract tourists. They had planned to sell the silt to Whitehaven council for a children's playground. As a result work by Dr Richard Scott (and our campaigning) we managed to get the NRPB to report on the silt. In it the NRPB said that the silt could not be used for a playground and that the safest thing to do with it would be to dump it back in the sea. So, the Government had to issue a special permit to dump the waste back into the Irish Sea.

Les Jenkins, who had come from BNFL's Capenhurst plant to help fight the fire, has multiple myeloma. He tells of how he came out of the reactor with his monitor badge blackened. The health physics department was in chaos, and badges and records lay scattered about the room. *When Les applied for compensation for his illness BNFL told him he had never worked at Windscale!* It took six months of legal wrangling to get BNFL to admit he had worked there. It took national publicity of his case to get BNFL to pay him compensation. He received £23,000, the price BNFL put on a loyal and brave worker's life. They still deny any liability.

In 1957 the public were far more ignorant than the workers. The personal accounts we have of that time are legion, the cancers and illnesses suffered are quite horrifying. One vital witness is Tyson Dawson, who farmed the land bordering Windscale. He tells of how he stood at his farm and watched the people running around the plant "like ants under attack". He tells of how they could taste the cold iron (iodine) and how they all felt tired. The fire started on Thursday afternoon; at 2.00 am the following Sunday morning Tyson was woken by men knocking on his door. They told him to destroy all his milk. He lost many animals over the years he spent farming next to Windscale. Some died of cancers, other were born deformed. Some died due to the 1957 accident, others from drinking water and eating food contaminated by Windscale's daily releases.

1957 was a worrying time for Cumbrians. Of course we did not know the full facts, we just had a 'gut reaction' to anything nuclear. We now know that Windscale released 100-1,000 times more iodine-131 than the Three Mile Island accident. Indeed, as the cloud passed over London, three days after the fire started, it trebled the 'natural background rates' of the city in one hour. An international row broke out behind the scenes as the Dutch Government realised what had happened. Actually it would be wrong for me to give you the impression that I remember the fire, I was 'around' then but not "alive". My mother was carrying me when the fire happened and because she had three young children and was pregnant she was allowed two tins of milk a day. My father, who had worked on the building of Calder Hall, was sick with worry that my elder sister and brother would eat fresh fruit on the way home from school.

Anne Todd was a house-mother at a local school in 1957. She lived in the small town of Broughton-in-Furness. She lost her son through leukaemia following the fire, so did two other women with whom she worked. All blame Windscale. Kevin Barry Murphy was on holiday near the plant when the fire happened. He died of leukaemia in Manchester when he was eleven, some nine years after the fire. Bob Benson's son was diagnosed too late for treatment to be any good. He died aged eleven, he had been on holiday from Barrow at Seathwaite reservoir when the fire broke out. He drank the water from the fresh water lake. It had rained very heavily on the days of the fire, all surface water in the area becoming contaminated. Yet no one was told to avoid drinking the water.

The 1960s brought many more 'incidents' and illnesses, many of which have been revealed only through our research. Contamination of areas outside the plant occurred, because of accidents and deliberate discharges. Cancer became the modern TB, people did not want to talk about it—this new plague was too deadly; people thought it was contagious.

In 1973 Windscale tried to reprocess some oxide spent fuel from Japan. It was an experiment, and it resulted in the famous 'Blow-back' incident in which more than 30 workers became contaminated with ruthenium. This is the story of one man caught up in the 1973 accident. He was a health physicist who believed very deeply in Windscale and its purpose. He smelt Butex, a solvent bred in the reprocessing of spent fuel, in the room where the reprocessing was taking place. He ran towards the dissolution tanks. He knew the smell shouldn't be there. He knew something had gone wrong. Where was the smell coming from? His badge went black, the alarm bells began to ring. He then did something which went against all his training. He ran back into the plant and made sure that all his work colleagues got to safety. Whatever one thinks about this man, because of what I am about to say, you cannot deny he was a brave man, that he cared about his fellow-workers. He went to the medical department for a check up.

He arrived home, late. White faced and blood stained he wore the white work clothes normally left at the plant. The health physics people had tried to decontaminate him. They had scrubbed his chest and stomach until they bled, they thought he had suffered only from external contamination—they discovered the high radiation readings were coming from inside him. I will spare you some of the more personal details, this man's claim is not yet settled. But I shall tell you of the management's reaction. When somebody is contaminated they are taken off 'active' work and because they are put on ordinary work they lose pay. This health physics man was a close friend of many of the top management, he was sure they would see he was looked after. He didn't have to go through the usual union procedure, he got his extra £2,000 per year, no questions asked. The management took a close personal interest in him. He told them, "You look after me and I won't go talking to the press".

Meanwhile he had kept a detailed account of what was happening to him, what the readings were from his body. He died two years later, a wasted and changed man, having collapsed of a heart attack while playing golf. His wife, on the basis of the records he had kept sued for compensation. She knew Windscale had killed him. She went to see the BNFL doctor. She knew that BNFL had been present at the post-mortem and that they had taken her husband's internal organs for analysis. She also knew that some of the medical people had refused to do the work because the samples were so contaminated. Dr Schofield, the chief medical officer, told her that her husband's death was not connected with Windscale as he had died of a heart attack (he had received a 300 rem dose in the accident).

John Troughton died of multiple myeloma in 1975. His slow and agonising death made his wife fight hard for compensation. She eventually received £22,000 for her husband, although the only known cause of multiple myeloma is radiation. Joan King, in the first public compensation payment, received £8,000 for her ex-Windscale worker husband's death. There are some 170 compensation cases outstanding at Windscale. Meanwhile the level of multiple myeloma at the plant is 7 times the national average.

Janet Sineidy is 34, she was six when the accident happened at Windscale. She was born and raised in Millom. Recently she developed cancer of the leg and breast, both of which were thought to be cured. She now has cancer of the liver. She also understands what is happening to her, she understands cancer. She also understands why she has lost so many relatives at an early age with cancer. She *knows* Windscale is to blame. Like many people she accepts the sad, but inevitable, passing of an old relative. She can accept that they have had their lives and that you can only hope to make their last few years as pleasant as possible. But what she will not accept is that so many young people have to die and all for the weapons programme. Janet is a brave and courageous fighter against nuclear power, despite the fact that she is ill.

Glenys, like Janet, was a young woman with everything to live for. Her tale is not related to any one incident in particular, but we believe her death was due to many factors. Glenys died when she was 31. She had lived on Walney all her life. This island, just off the tip of Barrow, is heavily contaminated as a result of the marine discharges from Windscale. The channel in between Barrow Island and Walney Island, is the worst affected area in our part of the country. The school Glenys went to was next to the hot-spot on the channel that is regularly visited by 'radiation monitors'. Like many Barrow children she spent a lot of time playing on the beaches and swimming in the sea. When she married she continued to live on the island, which is hardly surprising as we do have some very beautiful (supposedly) unspoilt beaches. Glenys had three children and, after two miscarriages, she was sterilised when she was 22. In 1977 she was diagnosed as having breast cancer, on a milk duct. Her parents were told no more about the issue until she became seriously ill. Their daughter kept quiet to save them from worry. The doctors who dealt with her before her death felt that she might have been saved had she gone to them earlier. Glenys worked in the Vickers shipyard as a cleaner. Her father remembers that on cold winter mornings she would lean up against the warm nuclear waste flasks as they were unloaded in the shipyard. She was one of four in a cleaning squad which cleaned out an area of the shipyard belonging to the DTO section. This section can deal with very menial tasks right up to looking after the PWRs on the submarines. Glenys and her friends worked on cleaning up the changing rooms for the men who would come off the reactors contaminated. As they cleaned up contaminated overalls it never occurred to them that they did not have any protection themselves. Of those four young women who worked in that section one died of a brain tumour (aged 30) another was diagnosed as having breast cancer and when she went into hospital to have the cancer removed, she then collapsed and was found to have bone-marrow cancer. She died aged twenty nine.

Glenys worked up to six weeks before her death. On 27 November 1981 x-rays showed her to have a secondary cancer of the brain. Her mother can never forget the way her daughter died. Wracked with pain she cried out to be allowed to die. Her mother would press her hands to her daughter's head to help ease the pain. "It's as if she thought I could force the pain away. She would cry to God for help." These people now have three young grandchildren as a reminder of their own beautiful daughter. In fact, Glenys' mother remembers how, in 1957, when the warning came about the milk, she threw away the milk she had in the house and then went out and bought some more. As she said, "we were so ignorant then, but we've learnt our lessons."

The Economics of Nuclear Power

by Peter Bunyard

Nuclear power's unique advantage, according to its promoters, is that it can provide mankind with almost limitless sources of cheap energy. In its efforts to prove this, the CEG resorted to an accounting system whose shortcomings were exposed in our CSENE report of 1981. The CEGB was forced to accept our criticisms. Nevertheless, in the Sizewell Public Inquiry, it resorted to other accounting devices for perpetuating the myth of cheap nuclear electricity.

Britain's civil nuclear power programme came into being because of the government's determination in the 1950s that Britain should continue to develop its own deterrent while keeping the cost down. The two Windscale Piles, in operation during the first half of the 1950s, were expensive to run and produced no electricity to offset the costs; consequently after the 1957 fire in the Number One Pile, the government was quick to order the shut-down of the Number Two Pile and leave the production of weapons-grade plutonium to the Calder Hall and Chapelcross magnox reactors.

Although the public had been led to believe through an intense public relations exercise that nuclear power produced cheap electricity, the reality was otherwise and known as such both within the government and the newly formed Electricity Generating Boards. Critics of the magnox programme, including Fritz Schumacher, who was then economic adviser to the Coal Board, claimed that by the late 1960s the civil nuclear power stations had cost the electricity consumers and taxpayers an extra £20 millions (in 1960 currency) per year over and above that which they would have had to pay if the generating plants had been operated on coal. In 1967, the chairman of the Coal Board, Alfred (now Lord) Robens told the House of Commons Select Committee that the magnox programme had led to the loss of 28,000 jobs in the mines because of the Electricity Boards' diminished demand for coal, and had cost £525 million more in capital costs alone that the £225 million an equivalent-sized coal generating capacity would have needed.

Faulty Accounting

The civil nuclear industry has been heavily subsidised from the very beginning, not only through grants from the Treasury for research and development, but also through the sharing with the Ministry of Defence such facilities as the Sellafield reprocessing plant and the Capenhurst uranium enrichment plant. Moreover, the initial optimism over the likely costs of nuclear power was based on faulty calculations. When planning a new coal or oil-fired plant, for example, the CEGB always took account of site development and central engineering charges, incorporating them into the total capital costs. Yet, the nuclear planners completely overlooked such costs, which amounted to between 5 and 10 per cent of total station costs, when drawing up the designs for the magnox reactor programme in 1953. Interest charges on capital borrowed were also up to 6 per cent by 1961, two per cent up from 1954; such charges affected nuclear power plants, with their comparatively high construction costs, much more than they did conventional power stations. In fact, the capital costs of fossil fuel plant had been coming down spectacularly between 1955 and 1965 from £60 per kilowatt to £30 per kilowatt.

To cap it all the government then decided to reduce the "plutonium credit", based on the putative value of plutonium, as fissile material, extracted from spent fuel. Originally, the credit had been evaluated at 0.3 old pence per kilowatt-hour (p/kWh); now, it was to be more than 0.05 old pence—thus worsening, in one stroke, the overall cost of nuclear electricity by one-third. It is surely of some relevance that Britain was then negotiating to exchange plutonium for enriched uranium and tritium from the United States—for mutual defence purposes—and it might have been embarrassing if the CEGB had received credit for such an exchange (see p.201).

Rigging the Costs

The original undervaluation of the cost of nuclear electricity established a pattern of rigging the costs so that nuclear power would be seen publicly to be a valid competitor with other forms of electricity generation. For instance, during the mid and late 1970s the CEGB announced that electricity from its magnox reactors was cheaper than that from other generators. "The Board's nuclear power stations produced 11.4 per cent of the electricity supplied by CEGB power stations during the year, and the electricity they produced was the cheapest on the system," the CEGB proclaimed in its 1979/80 *Annual Report.* In Appendix 3 of that same report, the CEGB indicated that electricity generated by the magnox stations had cost 1.3p/kWh, while that from coal-fired and oil-fired stations respectively had cost 1.56 and 1.93p/kWh. In the following *Annual Report,* that for 1980/81, the CEGB indicated that electricity from magnox stations was 0.2p/kWh cheaper than electricity from coal-fired stations. Electricity from the new Advanced Gas-cooled Reactors (AGRs) was said to be 0.4p/kWh cheaper.

As Dr Colin Sweet shows in his book *The Price of Nuclear Power,* the costing of electricity from the CEGB's magnox stations had gone completely awry. Conventional thinking on nuclear power had it that the high capital costs of nuclear power stations would be more than offset by cheap nuclear fuel cycle costs—the overall cost being cheaper than the capital and fuel cost components of coal-fired stations. For instance, in the mid 1970s, Sir John Hill, then chairman of the UK Atomic Energy Authority, stated that while capital and operation charges for a nuclear power station were 0.41p/kWh, fuel costs were just one-fifth of the total—0.12p/kWh. But during the latter part of the 1970s, nuclear fuel costs began to soar, primarily because of sharp increase in reprocessing charges and by 1979/80 according to the CEGB's own *Statistical Yearbook,* they had reached more than 90 per cent of total generating costs. Thus of the 1.3p/kWh given for magnox generating costs, 1.19 were fuel costs. In effect, the published figures showed that while fuel costs had increased 8-fold, capital and operating costs had decreased by a factor of nearly three, falling from 0.28p/kWh in 1971/72 to 0.11p/kWh in 1979/80.

No Account Taken of Inflation

Such topsy-turvey figures, which make a complete nonsense of conventional thinking on the economics of nuclear power, were the result of the CEGB's statisticians massaging the figures to make nuclear power appear the best economic bet of its thermal generating plant. The figures relied on "historic cost" accounting: in effect, no account whatsoever was taken of the effects of inflation, since construction costs and fuel costs were not adjusted to present-day values. Indeed, a £100 per kilowatt difference in the capital cost of the two kinds of plant in the 1960s would appear insignificant in the money of 1980, unless adjusted to take account of inflation. Moreover, much of the uranium fuel for the initial loading of reactors was acquired and paid for when the magnox programme was launched; consequently its cost, which was generally incorporated into the capital cost component, would not be a true guide as to cost of purchasing that fuel today.

The CEGB is Taken to Task

The CEGB's attempt to misguide the public and government on the true cost of nuclear power was revealed in 1980, when the House of Commons Select Committee on Energy began investigating the Board's accounting procedures. After hearing evidence from the CEGB, the Committee commented:

> "The historic cost method used by the Board to justify past investments distorts the effect of inflation on capital costs, rendering the resultant figures highly misleading as a guide to past investment decisions and entirely useless for appraising future ones."

The CEGB at that time was in the process of launching its campaign to promote the Sizewell B Pressurised Water Reactor (PWR) and one of its main arguments was the significant savings to be had should the PWR be built "in advance of need".

Adjusting the Figures for Inflation

Undoubtedly one of the most devastating critiques of the CEGB's presentation of its comparative generating costs came from Professor Jim Jeffery, a crystallographer at the University of London. His analysis formed the basis of the report *Nuclear Energy—The Real Cost,* which was published by *The Ecologist* in 1981. Jeffery disentangled the jumble of different cost figures and then adjusted them for the effects of inflation using the retail price index. He was thus able to show that the cost of building the CEGB's magnox reactors (in constant money brought up to 1979/80 values) was four times greater than indicated in the CEGB's published figures (even without taking interest during construction into account). The adjusted figures brought the magnox generating costs up from 1.3p/kWh to 2.25 and coal-fired up from 1.56 to 1.75p/kWh—a considerable switch from the data in the 1979/80 *Annual Report.* The difference between coal and nuclear widened still further when Jeffery took account of the considerable increases in the cost of reprocessing magnox fuel which had taken place during the latter part of the 1970s, as a result of serious problems associated with spent fuel corrosion in the cooling ponds.

A similar exercise on the generating costs of the CEGB's most successful operating AGR—Hinkley Point B—indicated that far from giving cheaper electricity than Drax A coal-fired station, as the CEGB claimed, Hinkley Point B was some 40 per cent more expensive to have built and operate. The other AGRs—and especially Dungeness B, with their substantial cost over-runs—were even less economic.

A year after *The Ecologist*'s Report, in February 1983, when the Sizewell public inquiry was already underway, the CEGB produced its *Analysis of Generation Costs.* The CEGB analysis confirmed *The Ecologist*'s figures. Indeed, the generating cost given for magnox, 3.37p/kWh and 2.28p/kWh for coal, were very close to those published a year before in *The Ecologist* when updated to March 1982 prices.

New Plants, New Costs

Clearly there comes a time when older plant must be replaced. For a station that has not yet been built, a number of variables and assumptions have to be considered before any conclusion can be drawn as to its economic viability. How much will the station cost? Will it be built to time, since delays will lead to extra interest charges and probably capital charges too? What will be its fuel cost, initially and over its lifetime, and how long will it operate? Will it operate to expectation? What rate of interest should be applied to the capital investment? And what rate of return should be expected? Equally, similar questions have to be asked of alternatives to the project in mind.

The Sizewell Inquiry

It does not necessarily follow, however, that new plant, of whatever kind, will lead to electricity becoming cheaper. It may well be more expensive. But that is not how the CEGB presented its case for building a pressurised water reactor (PWR) at Sizewell on the East Anglian coast.

In its statement of case for the Sizewell PWR, the CEGB gave three main reasons why new plant was required and why in particular it should be a PWR. First, a considerable amount of generating plant would become 'time-expired' within the first decade of the new century and would have to be replaced. Second, a pick-up in world economic growth in general, and in Britain in particular, with electricity gaining a greater share of the energy-use market, would mean that more plant would have to be built than that needed simply to replace decommissionings. And thirdly, the introduction of the Sizewell PWR into the system would lead to substantial savings. Not only would the PWR be the cheapest plant to operate within the system, the CEGB stated, but the savings to be made in its operation would make it worthwhile to construct the plant before it was needed—'ahead of need'—so that more costly plant could be withdrawn from the system.

One of the main planks of the CEGB's economic case for the PWR was the cost of coal and the savings to be made through reducing the overall coal-burn of the generating system, in particular through the phasing-out of thermally inefficient, older plant. Indeed the CEGB's argument leant heavily on the speculation that the cost of coal would rise sharply during the first few years of the PWR's operation during the 1990s, and would continue its rise throughout the 35-year lifetime given for the reactor (see Fig 1). As Professor Jeffery pointed out in his evidence to the Sizewell Inquiry, because of the effects of discounting, a sharp rise in the cost of coal during the first few years of the Sizewell PWR's operation would prove far more effective in boosting the advantage of the nuclear plant in terms of coal saved than a rise which comes later. Thus a 40 per cent coal price which coincides with the commissioning of the PWR would be equivalent in terms of present value savings—hence discounted, annuatised savings—to a trebling of coal prices over the entire operating lifetime of the PWR. In that respect it surely cannot be idle coincidence that with each postponing of the forecast commissioning date of the PWR—from 1986 to 1994—the CEGB has forecast that a sharp burst in the cost of coal—up to 40 per cent—will take place just before commissioning.

Since the economic viability of a new station depends not solely on its own costs, but also on those

THE NET EFFECTIVE COST (NEC) OF BUILDING NEW NUCLEAR AND COAL POWER STATIONS

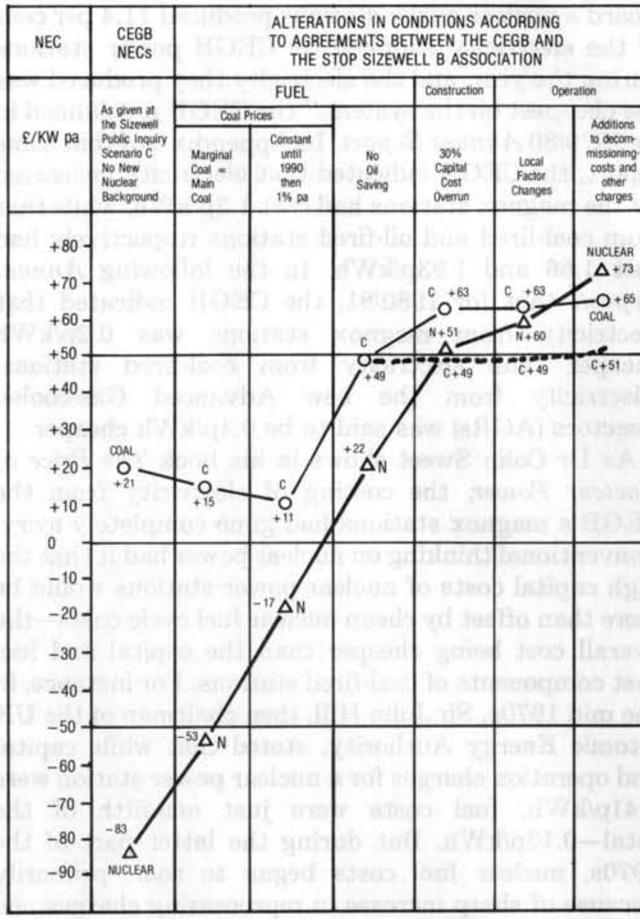

Fig. 1 The changes in Nuclear and coal NECs arising from the alterations in conditions indicated at the head of each column. These alterations were jointly agreed by the CEGB and SSBA during the course of the Sizewell B Public Inquiry (held between January 1983 and January 1985). As the graph indicates, nuclear power, seemingly much cheaper than a new coal-fired station, becomes more expensive when more realistic assumptions are made about fuel and capital costs. The dashed lines for the coal NEC shows the result with zero capital cost overrun for a coal-fired station.

affecting other stations in the system, the CEGB has attempted to calculate the NEC or Net Effective Cost of different plant in the overall generating system. NEC of zero would effectively indicate that there would be neither advantage nor disadvantage from an economic point of view in building and operating the plant in question over its intended lifetime, given that all the assumptions fed into the analysis were reasonably correct. A negative NEC, on the other hand, indicates overall savings—the reason being that the assessed cost of construction, of interest, of fuel, of maintenance and of operation amounts to less than the cost of the fuel needed to fire an alternative plant. Consequently the consumer would pay less for electricity than if the plant were not introduced into the system. A positive NEC would mean more expensive electricity than that generated by the existing system, and factors other than economics would have to weigh in the decision-making.

Coal: The Critical Fuel

In its evidence to the Inquiry, the CEGB argued that a new coal-fired station would raise the cost of electricity by £1 billion over its lifetime, owing to the increasing cost of coal. By contrast, the proposed Sizewell B nuclear power station would save Britain £3.5 billion because of nuclear power's avowed lower fuel costs.*

Decommissioning and Reprocessing Costs Underestimated

Just as costs and savings early on after commissioning register strongly in the present value of the PWR, costs incurred after its final shutdown, put by the CEGB at 35 years, including decommissioning costs, reprocessing of spent fuel and nuclear waste disposal, are whittled away by discounting for 40 years and more. For instance, costs incurred 25 years after shutdown register as one-tenth of full costs, and Jeffery finds that all the post-shutdown nuclear costs comprise no more than one-seventh their full value. Since decommissioning and reprocessing of spent fuel are relatively expensive items, their real significance in the Sizewell NEC is much reduced.

One way around the discrepancy would be to evaluate all post-shutdown costs as if they took place during the plant's lifetime. In my evidence to the inquiry, I used such a methodology. I also suggested, in line with the government-sponsored *Castaing Report* on reprocessing in France, that reprocessing was likely to cost at least 40 per cent more than the figure provided by British Nuclear Fuels Ltd., (BNFL) for its yet unbuilt thermal oxide reprocessing plant—THORP. Environmental considerations alone, which have become far more pressing since the 1977 Windscale public inquiry, were likely to raise costs.

I also disputed the CEGB's use of a large credit for the uranium extracted from spent fuel, pointing out that the value of any reprocessed uranium was much diminished by the presence of the uranium isotopes, U-236 and U-234, both of which mop up neutrons and effectively poison the chain reaction. Recycled uranium also contains significant quantities of uranium-232, which is a potent emitter of gamma radiation. Extra precautions have therefore to be taken in handling reprocessed uranium and the question arises whether it should have any value ascribed to it.

When a higher cost of reprocessing is taken into account, when the uranium credit, which the Board has made equivalent in value to 40 per cent of the total cost of post-irradiated fuel management, is taken away, and when the process of discounting is carried out within the operational lifetime of the PWR, the effect on the fuel cost is to increase it from +£36/kW pa to +£56. Decommissioning too increases from +£1/kW pa to +£9 and the NEC for the Sizewell PWR becomes +£74/kW pa, indicative that the extra lifetime cost to the UK of introducing the reactor will be some £3 billion.

Coal—the subsidised industry

At the Sizewell Inquiry, the CEGB attempted to give reasons for its expectation that fossil fuel prices, mainly of coal and oil, would rise at the rapid rates forecast. With regard to the present price of NCB coal, the CEGB remarked that it has been held down only "with the help of significant and increasing deficit grants from the government." It went on to argue that if such subsidies were removed, but the level of social grants were maintained, then the current pithead price would rise by more than 10 per cent. In its evidence to the Monopolies and Mergers Commission in 1980, the CEGB told of its expectation that the government grants to the coal industry would dry up during the 1980s, and that the NCB would therefore be forced to achieve a measure of profitability. Consequently the CEGB expected the pithead price of coal to rise by some 4 per cent per annum from 1980 to 1987, and, from then on, by 2 per cent per annum until the end of the century.

The Miners' Strike

The crippling coal strike of 1984 over the question of pit closure and of what should be termed "an uneconomic pit", certainly indicated the present government's intention to pare the coal industry down to suit the market conditions of today. The abandoning of older, "uneconomic" pits would leave millions of tons of coal irretrievably underground; yet, if all worked out as the government intended, a coal industry would be generated that should appeal to the private sector. Breaking the power of the National Union of Miners would have to be a first, essential step in any plans for the future privatisation of the coal industry, and the government clearly had every intention of succeeding in its aim—despite the enormous social and economic cost to the country. We hear of massive losses in the steel, railway and electricity supply industries because of the strike—£1.75 billion in the latter alone—and

* By far the biggest single factor in the claimed economic benefit of the PWR results from the savings to be made in the displacement of both coal and oil-fired generating capacity. Indeed, the combined fossil fuel savings are −£221/kW pa against a total expenditure, including capital, operational and nuclear fuel costs, of +£138/kW pa.

As Jeffery argued, the Board had not only weighted the savings by assuming substantial increases in the price of coal to coincide with the first years of the PWR's operation, it used a 'marginal cost' of coal that was some 18 per cent higher than the cost of National Coal Board coal to a central coal-fired station. Meanwhile, as if it did not want to know what its left hand was doing, the CEGB recently concluded a further 'understanding' with the NCB in which, in return for taking 68 million tonnes of coal per annum, the price would stay at the same level in real terms as it was in 1980. Furthermore, the NCB promised to make reductions in the price of coal taken above that amount. Instead of being more expensive as marginal cost theory would suggest, 'marginal coal' would be cheaper.

By taking the CEGB's estimate for the price of NCB coal to a central-fired station rather than its putative higher cost, 'marginal coal' reduces the savings by £57/kW pa. But even that conclusion is unreasonable, says Jeffery, because of the present 'understanding'. In addition, he argues, that by bringing on stream the Board's new coal and nuclear stations before the PWR begins operation, the need for any oil burning (other than that essential for firing coal stations), would be obviated. Hence no oil will be left in the system to be saved, and the CEGB cannot legitimately incorporate oil savings into NEC calculations. It so happens that the CEGB has postulated that high cost oil will be 'saved' just in those first early years after commissioning the PWR, when such savings will have maximum effect on the NEC.

With no oil left to be saved, and with coal prices stable until 1990, after which they increase by a linear one per cent per annum, Jeffery finds that the savings are reduced by another £65/kW pa and the NEC of the Sizewell PWR swings from net savings of −£83/kW pa to +£43, suggesting a net loss of £1.5 billion over the station lifetime.

that not taking account of the policing of the strike, nor of the substantial loss of earnings of the miners themselves.

Walter Marshall (now Lord), chairman of the CEGB, has stated that Arthur Scargill succeeded in promoting the case for nuclear power as he himself could never have done. That simplistic statement would perhaps have been better founded had the miners struck for more pay. Instead they struck for their jobs and the saving of their pits from closure. Nor did Marshall add that one reason for the decline in the fortunes of the British coal industry had been the coming on stream of the AGR stations, each one of which displaced annually some 3 million tons of coal from total requirements. In addition to the five AGRs now working, two more are under construction. Indeed, if total demand for electricity in England and Wales stays at its present level of around 210 terawatt-hours per year, then with the Sizewell B PWR in operation, total coal requirements could be down to 55 million tonnes per annum, well down from the record 80.6 million tonnes consumed during 1979.

Coal Imports

A prime reason for the deficit grants paid by the government to the NCB is to bring its average coal costs in line with cheaper imports so that the Electricity Boards will continue to restrict their consumption of overseas coal and maintain a high burn of NCB coal to support an indigenous industry. In its evidence at the Sizewell Inquiry, the CEGB maintained that world demand for coal would put up the cost of imported coal to levels even higher than that of UK coal—even with the deficit grant lopped off. Heavy oil, too, according to the CEGB, would also show a massive price increase. Thus the CEGB projected that heavy oil would rise in price from its 1980 level of 237p/gigajoule (gigajoule = 10^9 joules) to 570 in 2000—and as high as 760p/GJ in 2015. The price of internationally traded coal delivered to the Thames was projected to rise from 120 p/GJ in 1980 to 300 in 2000 and up to 450p/GJ by 2030.

Even with demand for oil growing by 2.5 per cent per annum, Professor Peter Odell of Rotterdam University, giving evidence for the Town and Country Planning Association (TCPA), suggests that over the next 30 years, oil need never reach or surpass the highest ever price of $30 per barrel paid in 1981. In his view: "There is little more than a one in ten chance that oil prices will be as high even as the lowest oil prices which the CEGB uses as the basis for its calculations."

Meanwhile Mr Steenblik, also for the TCPA brought evidence to bear that international coal prices may fall in real terms by as much as one-sixth by 2000 from the 1980 figure of $60 per tonne. He expected steam coal prices "to rise very little in real terms for at least the first 30 years of the 21st century."

Should such energy experts be proved right—and they have given far more accurate forecasts of the oil and coal markets over the past decade than has the CEGB—then a main plank for nuclear power in Britain will effectively have been destroyed.


PHOTO: CEGB

Stacking coal in power station yard

Capital Costs—Reality rather than Fiction

The CEGB's assessment of the capital costs and of the time taken for construction, as well as of the hoped-for performance of the Sizewell B reactor, also came in for criticism, particularly from the Electricity Consumer, the TCPA and the Council for the Protection of Rural England (CPRE). With American experience of building Westinghouse reactors in mind, the CPRE claimed that the CEGB would be lucky to build the Sizewell PWR in less than 108 months, compared with the 90 months given as a central estimate in the CEGB's statement of case. Moreover the station would probably cost just under £1,600 million (March 1982 prices) compared with the Board's central estimate of £1,147 million. The addition to capital costs alone would add £35/kW pa to the Net Effective Cost. With a load factor—hence the degree to which the plant is used over its lifetime—of 58 per cent, instead of the 64 per cent given by the CEGB, and a lifetime of 25 years rather than 35 years, another £14/kW pa are added to the NEC.

By the time the criticisms of the various objectors are taken into account, including the increased 'back-end' nuclear fuel and decommissioning costs, the NEC of the Sizewell project swings from a net saving of —£83/kW per annum given by the CEGB to a net loss of +£92/kW pa; by comparison the NEC for coal deteriorates from the net loss of +£21/kW pa given by the Board to +£65/kW pa. Hence, compared with keeping older plants going on the system the Sizewell PWR would lose more than £3 billion. By comparison, a new coal-fired station would lose close to half that amount.

In essence, objectors to the Sizewell B PWR argued that the project would be considerably more costly to the Board and to the electricity consumer than pursuing other alternatives—including conservation, refurbishment of plant when it reached the end of its life, a proper planning for a non-growth situation, and the

Economic catastrophe could be around the corner if Britain pushes ahead with its nuclear programme. Obsession with nuclear power, and determination to crush the National Union of Mineworkers, have clouded the government's judgement as to what is best for Britain.

use of energy-efficient methods such as combined heat and power. That the kind of growth envisaged and hoped for by the government and the CEGB would be unlikely to materialise was expressed by all objectors; and even were a station the size of the Sizewell PWR to be built, the very earliest it would be needed would be the end of the century.

Colin Sweet, a witness for the TCPA, pointed out the crippling financing that would be required to meet the expectations of the CEGB's "middle of the road" scenario. Against the high nuclear background, hence the background most sought after by the CEGB, £1.75 billion would have to be spent on average each year for at least 17 years:

"If these capital expenditures were added to the non-nuclear capital expenditure currently being undertaken by the Board, then the capital requirement annually could be in excess of £3 billion by the middle 1990s (in 1982 prices) . . . In broad terms a requirement of this magnitude would equal about 30 to 40 per cent of the level of fixed capital investment for the entire UK manufacturing sector of the economy."

Nuclear Power, France's Waterloo

The French example is often cited as a major success story, where through an aggressive nuclear power programme, not only has fossil fuel consumption been brought down, but electricity has been made cheaper. The real facts tell a very different tale. To begin with, the main purpose of the nuclear power programme, which has led to more than 50 per cent of France's rapidly expanded electricity consumption being met by nuclear power in just over a decade, was to reduce substantially imports of crude oil. Yet whereas between 1973 and 1982, France succeeded in reducing its total oil consumption by 27 per cent, the reduction in the UK over the same period was 33 per cent and in Denmark 35 per cent. And while electricity prices doubled—between 1975 and 1984—primarily because of inflation—in Britain and the Netherlands, and rose by a smaller amount in West Germany, in France they tripled. Equally, with its losses of up to 8 billion francs in 1982—and substantial losses in all years since 1975—Eléctricité de France (EdF) is the only electricity supply industry in Western Europe and the United States to have consistently made a loss in its trading. The 200 billion francs borrowed by EdF for its nuclear power programme has also made France one of the heaviest borrowers of foreign exchange in the world.

Given that history, it is clear that economic catastrophe could be around the corner if Britain pushes ahead with its nuclear programme. Obsession with nuclear power, and determination to crush the National Union of Mineworkers, have clouded the government's judgement as to what is best for Britain. At the Sizewell inquiry, there was no proper appraisal of alternative strategies for supplying electricity. No one, for instance, tackled the question as to what would be the Net Effective Cost of introducing small combined heat and power (CHP) coal-fired plants into the system; neither were the NECs of other energy supply alternatives considered.

The economic answers are in fact staring the CEGB and the government in the face. They include an active conservation policy with emphasis on improved end-use of energy; a refurbishing when necessary of older coal-fired plant with the possibility of introducing fluidised bed burning, or at any rate some method of controlling flue-gases; investment in CHP schemes; and in alternative energy, including wind power. Meanwhile the CEGB should retain its oil-fired capacity, both as a stand-by and for use when the cost of low sulphur heavy oil falls to economic levels.

SUPERPHENIX: THE REALITY BEHIND THE MYTH

by Monique Sené

"France will be able to build atomic weapons of all kinds and within every type of range. At relatively low cost, she will be in a position to produce large quantities of such weapons, with fast breeders providing an abundant supply of the plutonium required. Lucky Europe and lucky France—at long last in a position to engage in an enlarged nuclear deterrent of their own, thus guaranteeing their security."

General Jean Thiry (*Adviser to the French Atomic Energy Commission CEA*)

Superphenix, France's demonstration Commercial Fast Reactor (1350 MW) was started up in September 1985, two years late. Despite the delay in commissioning French politicians are convinced that Superphenix is evidence of French supremacy in the nuclear field, putting France into the leading group of nuclear powers and above all guaranteeing the future of the "force de frappe," France's nuclear strike force. Indeed with 5.5 tonnes of plutonium derived from five European countries in its core Superphenix will, if it works as planned, produce 300 kilograms of excellent weapons-grade plutonium in its blanket—enough for 60 nuclear weapons per year. Just how France's, British, Belgian, Dutch and West German partners in Superphenix will view the diversions of plutonium from an ostensibly civil use of nuclear power to a primarily military one remains to be seen. To date the European partners have remained conspicuously silent.

And what about the costs? From a civil electricity generating point of view Superphenix is a financial disaster, having cost between £2.5 - 3 billion, which is two to three times more than France's light water reactors. Yet its apologists argue that it is only a prototype and one would expect some of the problems incurred during its construction. As a result, the CEA (Commissariat a l'Energie Atomique) is pinning its hopes on Superphenix 2 becoming the first of a commercial series.

Superphenix means reprocessing, that being the only way it can obtain its plutonium fuel. Despite unresolved problems over nuclear waste disposal the French nucleocrats proclaim that Superphenix is the solution to all energy problems. Theoretically fast reactors should multiply by 50 the quantity of energy that can be extracted from uranium insofar as the 238 isotope can be used to generate fissile material in addition to the much rarer 235 isotope. However such energy gains presuppose that reprocessing of high-burn up fuel has been mastered; and there is no evidence to suppose that this is so.

For the French nucleocrats the important thing is to maintain the momentum, which they have achieved through establishing in 1983 a technological alliance between France, West Germany and Great Britain. They are also seeking an agreement between the governments of Britain, West Germany, Italy, France and Belgium for the joint pursuit of a fast-breeder reactor programme. In addition they no longer conceal the connection between the civil and military aspect of nuclear power. It would appear that both the British and French governments have become so sure of the majority in favour of nuclear deterrence that concealment of this connection between the so-called peaceful use of the atom and its dark weapons side has become unnecessary.

The European Agreement

The CEA knows that to make French politicians follow a certain course there is nothing better than an international agreement. Strictly speaking, the nuclear industry is all in the hands of private companies, a situation which does not usually lend itself to state intervention. However, the involvement of the CEA in most of these companies and substantial State investment makes control possible, irrespective of who has the majority shares. In addition the concept of "private company" actually helps keep transactions secret, because French law prevents public access to contracts. The European agreement means that another fast-breeder can be built by France with foreign capital. France originally undertook the whole of the fuel cycle including reprocessing and fuel manufacture, but Britain, through BNFL, has just claimed its share of the cake. Given the go-ahead, contingent on the outcome of the public inquiry, reprocessing will take place in Dounreay, in the North of Scotland. Reprocessing is by far

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the most polluting phase of the cycle assuming no accidents in the reactor, but if the fast breeder is located in France, the transport of heavily irradiated material will have to be organised from one site to the other about ten times a year. Easier said than done, particularly since fast reactor spent fuel needs to be immersed in sodium for rapid heat dissipation. The agreement not only guarantees the fast breeder's future in France, it also prevents the disbanding of the skilled teams. This is a great asset to the nuclear industry, which can act as a powerful pressure group; undoubtedly the miners and steelworkers would have liked to be in the same position.

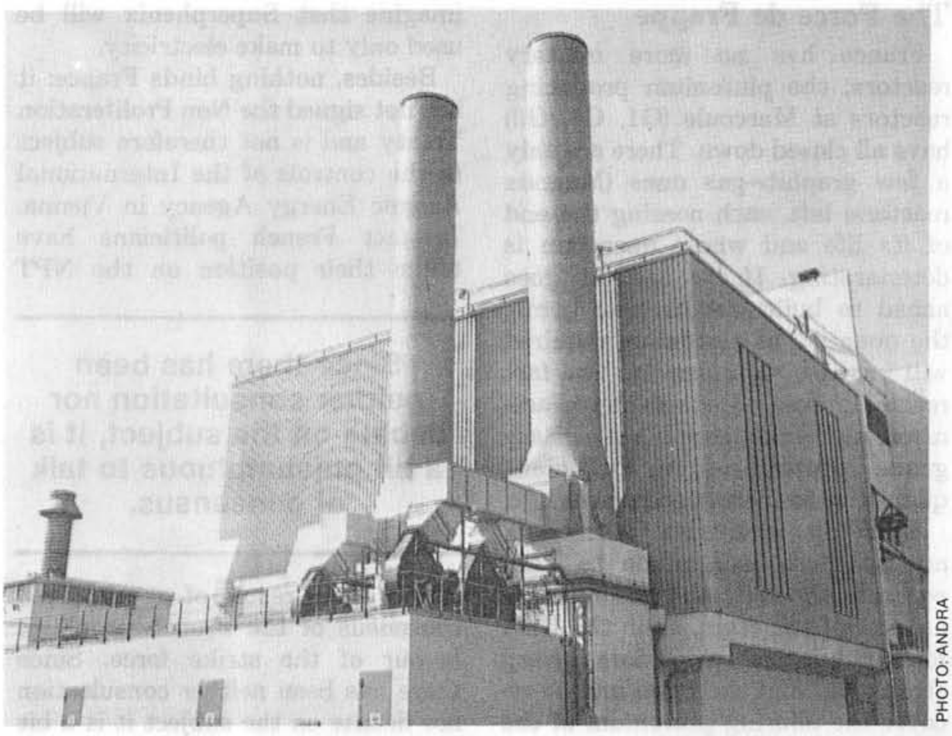
The nuclear industry, whether civil or military, has harboured the same delusions as other industries planning and dreaming growth in exponential terms. Today all the predictions have turned out to be wrong for the simple reason that rapid growth cannot be sustained beyond the point of saturation. But instead of reconsidering the future, high estimates of growth are always preferred to realistic ones.

Despite the high cost of Superphenix and the saturation of the electricity market in France, the nucleocrats cannot bear to pause. Therefore the importance of the European agreement for even though it is not a complete guarantee, it provides strong backing for a totally redundant piece of machinery.

Rather more surprising is that the other signatories to the agreement (Britain aside?) do not seem to have realised the support they are giving to France's military industry. Not all the plutonium will be used by the fast reactor: in effect the agreement will enable France and Great Britain to overload themselves with nuclear bombs once they set the programme in train, and all with German capital. This could be the birth of a third force which would complicate the difficult negotiations between the USA and the USSR, and make the Non-Proliferation Treaty even more of a dead letter.

Reprocessing—Achilles Heel

Reprocessing, which is indispensable to the realisation of a fast reactor programme, is the weak link in the technocratic plan. La Hague is presented as a marvel of French technology, but although it started with a throughput target of 800 tonnes in 1976, COGEMA—the operators— have since had to reduce the throughput to 400 tonnes owing to practical constraints. In fact COGEMA only celebrated its 1000 tonnes of reprocessed PWR fuel in 1985, which, even ignoring the first two years, gives an annual average of 140 tonnes reprocessed in its seven years of service. Such a low throughput hardly augurs well for fast reactor fuel reprocessing. Indeed fast reactor fuel reprocessing is now carried out in the pilot reprocessing plant at Dounreay under such a veil of secrecy that no one outside the magic nuclear circle has any real idea of throughput or cost: nor indeed of the real plutonium losses in the system. In France reprocessing was studied in 1982/83 by the Castaing Commission, a body of relatively independent experts. Its report was uncompromising; reprocessing was in a state of crisis. Indeed between 1985 and 1989 France will have installations at La Hague able to reprocess at the most 250 tonnes of PWR fuel, and at Marcoule installations intended to reprocess 400 tonnes of graphite-gas fuel. Marcoule is already behind in its planning schedule, and in spite of official assurances it is not at all certain that the new plants planned at La Hague—UP3-A (800 tonnes) and UP2-800—will keep to schedule, and be in service in 1987 and 1988. To date the ponds have been built, and spent fuel can be stockpiled there. The delays in reprocessing pose a serious threat to the production of plutonium from spent PWR fuel. And that does not say much for spent fast reactor fuel which is even more intractable. But if the core of a fast reactor cannot be easily reprocessed then goodbye to the multiplication factor as far as uranium is concerned. Fast reactor core material can probably be reprocessed, but so slowly that fast breeding will remain a tantalising myth. Indeed fuel storage times are part of the calculation of the period, known as the doubling period, which one fast reactor needs to breed the fuel for another.



Marcoule Reprocessing Plant and site of France's vitrification effort for high level wastes.

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The Force de Frappe

France has no more military reactors; the plutonium producing reactors at Marcoule (G1, G2, G3) have all closed down. There are only a few graphite-gas ones (Magnox reactors) left, each nearing the end of its life and whose operation is deteriorating. If the decision goes ahead to build the neutron bomb, the quantity of plutonium required will increase significantly. The fast reactor makes an excellent replacement, its blanket supplying military grade plutonium in sufficient quantities to meet requirements.

Even in countries where an attempt has been made to keep separate the civil and the military aspects of the atom, as in the USA for example, the temptation is very strong to bend the rules and to recover the alluring plutonium of the fast reactor blanket. Of course, in France, where the lines of separation between the military and civil are so exquisitely vague it is impossible to imagine that Superphenix will be used only to make electricity.

Besides, nothing binds France: it has not signed the Non Proliferation Treaty and is not therefore subject to the controls of the International Atomic Energy Agency in Vienna. In fact French politicians have taken their position on the NPT simply as a result of a purported consensus of the French people in favour of the strike force. Since there has been neither consultation nor debate on the subject it is a bit presumptuous to talk of consensus.

> **Since there has been neither consultation nor debate on the subject, it is a bit presumptuous to talk of consensus.**

Moreover no-one has thought of pointing out the shift in attitude from a 'deterrent strike force' to a 'tactical strike force' which the neutron bomb implies. At the same time no-one has thought of explaining to the French that in the case of a successful strike, should the Russian defences permit it, 20 million Russians would be killed, but at a cost of 55 million French.

Surely there must be a consensus. Are we ready for war and what kind of war? Are we ready to risk two billion dead on earth? And what price will we have to pay for our umbrella of defence, the strike force? The very disappearance of the France we think we are defending? Amid all these unanswered questions the need for Superphenix is hardly obvious. But as the advocates of the bomb are also keen defenders of civil nuclear power, it is difficult to distinguish between their motives. Indeed in April 1982 Electricité de France, in its journal *Energy* stated: "Superphenix is clearly becoming the technical base of the French strike force . . ."

THE EXPORT OF WEAPONS GRADE PLUTONIUM TO THE USA

by Nick Kollerstrom

By switching on electric lights, Britons have been contributing to the build-up of US nuclear warheads, in that the reprocessing of spent magnox fuel has led to the production of plutonium, some of it good enough quality for weapon-making. Some of that reprocessed plutonium, a hefty amount as it turns out, has been exported to the United States in an agreement which allows for no other destination of that plutonium than a military one. Given the lack of international surveillance over the destination of Britain's plutonium, we can only conclude that the distinction between civil and military nuclear reactors is wholly artificial.

In the latter half of the 1960s the entire CEGB network was functioning as a US bomb factory, in terms of the plutonium exported.[1] Since 1971 however the process has been restricted so that only 780 kg—enough for some 200 cruise missile warheads—has been exported to the US, supposedly from the 'military' reactors at Calder Hall and Chapel Cross.[2]

The root of the problem appears to be that Britain signed two formally incompatible documents. The 1958 Mutual Defence Agreement was signed between Britain and the US, and together with its 1959 Amendment it specified that UK plutonium exported to the US should be used "for military purposes" and allowing for no alternative.[3, 4] This Agreement has been renegotiated every 5 years to allow for the arrangement to continue, and the last plutonium shipments documented were in 1976 and 1978.[5]

On the other hand, the UK is party to the IAEA, International Atomic Energy Agency, which exists for the purpose of inspecting civil nuclear installations, and Article 2 of its Statute specifies that the export of fissile materials "shall not further a military purpose". The attempt to reconcile these two agreements leads to schizophrenic behaviour, especially from that Janus-faced organisation, British Nuclear Fuels Ltd.

For American politicians, Britain's attitude over the 1958 Mutual Defence Agreement has been puzzling. When it was signed, the US Congress was informed that:

> This will benefit the UK by eliminating the need for that country to expend large sums of money for the construction and operation of expensive diffusion plant. The US will benefit by obtaining the needed plutonium for its small weapons programme.[6]

Britain received enriched, fuel-grade uranium, which was cheaper to process in America, for powering its Polaris submarines, in return for weapons-grade plutonium from British Magnox reactors: a fair deal! More recently, Reagan administration officials have refused to give the assurance that plutonium obtained from the UK under a defence contract will not be used for the purpose mandated by the terms of the Agreement.

A recent estimate of the total quantity of plutonium exported to the US from the UK is 6½ tons.[7] The evidence is that two to three tons of this have been *put into bombs,* while the rest, the House of Commons was told, awaits processing so that it can be used to that end—being presently stored in a "fast reactor critical assembly".[8] With 17,000 extra warheads on order, the US is going to need all the plutonium it can get.

The British plutonium in the US awaiting processing is said to be 'fuel-grade', i.e. of higher isotope purity than reactor-grade but lower than weapons-grade, a convenient in-between category which can be used either way. It is likely to be transformed into weapons-grade either by blending with an extra-pure sourse of plutonium (defined by 239/240 isotope ratio) or by laser isotope separation, soon to become operational, which will be a quantum leap forward in separation technology.

The US's "small weapons programme" did not mean that the programme was small, far from it, instead referring to the way bombs could be more compact if made from plutonium rather than from uranium. As the plutonium came from Britain, it was felt appropriate that it should end up in Euro-bombs.

As Commissioner Vance said in 1958, before a Congressional Hearing[9] "it is thoroughly consistent that the plutonium which they produce and sell to us could be used for making the very weapons that they want."

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The US takes the position that it has no records of whether the plutonium imported from Britain was derived from civilian or military sources. However there is evidence, confirmed by a recent Parliamentary answer, that most plutonium exported to the US prior to 1971 derived from the UK's civil programme. This was largely because far more plutonium of suitable isotopic content was produced by the 'civil' programme than by the 'military' reactors—the latter not owned by the CEGB, but nonetheless supplying electricity to the national grid.[10] Indeed, a more obscure reason indicates the labyrinth complexity of the issue. The civil Magnox stations were designed for on-load refuelling, so that fuel batches could be removed after short exposure, (which gave the high isotopic purity required for weapons) whereas the military reactors at Calder Hall and Chapel Cross being 'batch fuelled', needed to be shut down to change the fuel. Therefore, as ex-CEGB employee Dr Ross Hesketh argued:

> In regard to load factor and in regard to consequent economics, it is preferable to use the civil system for brief irradiations such as would produce weapons-grade plutonium, and it is preferable to run the military system on the longest possible cycle, i.e. the civil cycle.[11]

Meanwhile to exonerate itself the Government argued that a "sizeable quantity" of plutonium exported to the US was used to make the artificial element californium, employed for medical purposes.[12] Yet californium can be generated from spent uranium, of which there is no shortage, so why should expensive plutonium be used?

As to the CEGB's oft-repeated claim made at Sizewell that "no CEGB plutonium has been used for a military purpose," it provoked a stern rebuke from Lord Hinton, former CEGB chairman and a man revered throughout the nuclear industry for his integrity and keen judgement. He said, specifically concerning the above claim, that "what is important is that they (i.e. the CEGB) shouldn't tell bloody lies in their evidence."[13] However, Lord Hinton, a man who could probably have cast more light on the matter than anyone else, died a few months after making that remark.

If the UK nuclear facilities come under IAEA safeguards, should that not prevent any interchange between the civil and military programmes? According to John Baker of the CEGB, when giving evidence at the Sizewell Inquiry, UK nuclear power stations are subject to inspection both by IAEA and Euratom to verify that no 'diversion' of fissile material for weapons-use has occurred. Yet it transpired that the only two UK facilities which the IAEA actually inspect are a storage pond at Sellafield containing spent fuel from foreign reactors, and a plutonium store containing 1.7 tonnes of plutonium from foreign reactors. The rest is out of bounds![14] The prototype Fast Breeder Reactor at Dounreay was also under IAEA safeguards until 1982. It was then withdrawn from IAEA safeguards. In fact blanket-bred plutonium in a fast reactor has an excellent isotopic content for weapon-making, being rich in PU_{239}. (See page 198).

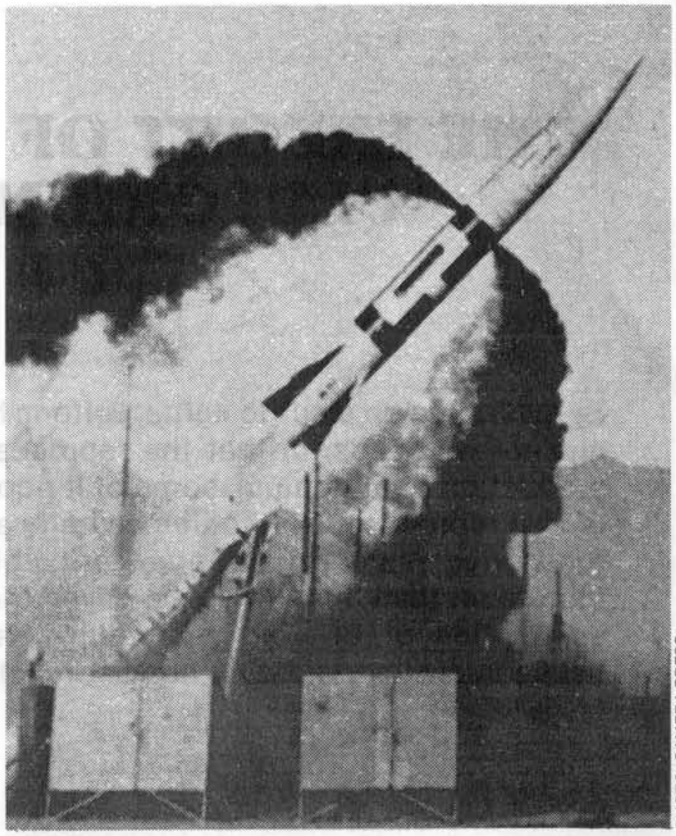

PHOTO: CAMERA PRESS

In April the British Government finally admitted to the export of plutonium for US nuclear warheads.

But even if the IAEA is not allowed to inspect premises, can it check records of throughput of fissile materials for quantities and isotope composition? In fact the inspection processes agreed upon do *not* permit the IAEA safeguards authorities information on the quality i.e. isotope composition of any UK plutonium, but only on its weight. Indeed while being cross-examined by CND at Sizewell Inquiry a BNFL spokeman confessed that ever since the UK joined the EEC and hence should have been subject to Euratom safeguards, the UK Government and Euratom have been at loggerheads that the Sellafield reprocessing line which handles both civil and military plutonium, sometimes at the same time, is not subject to any safeguards at all (Day 274, p.61).

Official misinformation on the subject seems to have continued in much the same vein since the Queen was used to cover-up the purpose of Calder Hall, in her speech opening the plant in 1956. Calder Hall, due to become Britain's chief source of atom bomb material, was opened with her words:

"It may well prove to have been among the greatest of our contributions to human welfare that we led the way in demonstrating the peaceful uses of this source of power."[15]

Furthermore a recent government statement makes it clear that information on plutonium production is not supplied to EURATOM (Hansard 1.4.85 Col 465).

Tony Benn, as Minister of Technology, Minister of Power and Energy Secretary in successive Labour governments, over a total of eight years, has been *the* man responsible for nuclear power for longer than any other minister. It is perhaps to be expected that no one drew his attention during that period to the terms of the Mutual Defence Agreement,[16] mandating a military use for any plutonium exported. More surprising is that he was kept in ignorance that any plutonium was being exported to the US! "I did not even know about the plutonium deal", he stated at Sizewell, Day 150.

In his 'Arguments for Democracy' Benn states the view he held in good faith, that the UK nuclear power programme was 'a classic case of beating swords into ploughshares.' He changed his mind after Ross Hesketh showed him the text of the Mutual Defence Agreement, specifying that civil or any other plutonium shipped to the US, ". . . *shall* be used . . . *exclusively* for the preparation or implementation of defense plans . . ." What has come to be called the Mutual Defence Agreement is entitled, quite explicitly, an Agreement "for Co-operation on the Use of Atomic Energy for Mutual Defence Purposes."[17]

When still a CEGB employee, Dr Ross Hesketh wrote a letter to *The Times* (30.10.81) containing the statement that selling plutonium to the Reagan administration would tend to blur the civil-military distinction. Having stirred a hornets' nest in the CEGB he lost his job, but after a vigorous public campaign on his behalf he was then promised his CEGB pension rights on condition that he did not speak in public about the grounds for his dismissal.*

Hesketh's submission to the Sizewell Inquiry, CNP/P/1 is required reading for anyone wishing to fathom the complexity of the subject, and indeed to comprehend why the UK nuclear power programme exists. The present study has been drawn from it. *It is fortunate that one man had not merely the ability, but also the stamina and courage, to find his way through three decades of official misinformation in seeking the truth.*

To recapitulate, a 1958 US document "Hearings on amending the Atomic Energy Act of 1954" makes it clear that the 1959 Amendment to the US-UK Mutual Defence Agreement was intended to provide some 7 tons of weapons-grade plutonium from the British civil system when that became operational, at an anticipated date of about 1963. In June 1958 the UK Minister of Defence informed the House of Commons that unconstructed "civil nuclear power reactors" would be modified so as to produce weapons-grade plutonium, although the subject of export was not mentioned. MP Arthur Palmer objected, in a parliamentary debate of 11.7.58, estimating that for CEGB nuclear power stations to produce weapon-grade plutonium would cost twelve to fifteen million pounds annually per station. Further, he found it "not entirely respectable" for the Ministry of Defence to have made such a remark over a supposedly civil power programme.

In the event, UK civil reactors only managed to supply some 3 tons of weapons-grade plutonium to the US, and the remaining 3.5 tons is to date in storage in the US because it is not quite weapon-grade, the terms of the exchange having nevertheless specified that it be used for no other purpose than a military one. Meanwhile no weapons-grade plutonium appears to remain in the UK civil stockpile. At the same time the UK Government refuses to endorse a bill being proposed by US Congressman Ottinger to prevent the use of British plutonium for American weapons. (A Parliamentary Answer to Tony Benn, December 1984).

A recent *Nature*[18] article has provided a degree of support for Ross Hesketh's claim, made at Sizewell, that two to three tons of UK civil plutonium has already been 'put into bombs' in the US'. Using several independent computation techniques, the authors were able to estimate total UK civil plutonium production over the years, concluding that 6.3 ± 0.8 tons *above* the official UK figures for civil plutonium had been generated. This quantity, they concluded, one-sixth of the total civil stockpile, had in all likelihood been transferred to the US under the terms of the Mutual Defence Agreement. The US sites at present stated to be storing UK civil plutonium probably have less than four tons, from published date. Hence, two to three tons must have been disposed of elsewhere.

Their figures agree well, they note, with the 6.67 tons as the maximum agreed in the US-UK exchange under the US enabling Act. They compute that altogether four tons of Plutonium with less than 15 per cent of the 240 isotope has been produced by UK civil reactors: this is the approximate range of isotope purity suitable for weapons use, given that blending with isotopically pure plutonium can lower the fraction of the 240 isotope to that suitable for weapons use. These figures are significant because the UK government has stated that there is presently no plutonium containing less than 15 per cent Pu_{240} in the UK civil stockpile.

The first of the three methods which the authors employed for modelling UK plutonium generation, in 'civil' nuclear reactors, '(i.e. owned by the CEGB or the SSEB)' is based on published data on the degree of burn-up for discharged fuel; whence the quantity of plutonium extracted from the used fuel-rods is inferred. The second method, which they regarded as the 'preferred' method, used spent fuel discharge data, but also the total thermal energy produced by UK reactors, from which the degree of burn-up could be computed. Thirdly, they computed the quantity of uranium transmuted into plutonium purely from total thermal energy produced, without using any data on spent fuel, by assuming an 'ideal refuelling line'. The three methods agreed remarkably well, giving within one ton the present UK civil total production figure of 47 tons (5 kilograms is a critical mass).

An early draft of the *Nature* report was submitted at Sizewell, and so the authors were able to incorporate criticisms which the CEGB made of the earlier report, even though the Department of Energy forbade the CEGB from putting figures into its criticisms! The authors also criticise the remarkable failure of the government to supply data on plutonium production to Euratom as it is supposed, the only data supplied

* After a public campaign, he was re-engaged for nine months—not re-employed as some suppose. In August 1984 he was to take early retirement on a pension provided by the CEGB—and all this on condition that he did not speak in public about the grounds for his dismissal (according to the Sizewell transcript). Hesketh is presently a professor of physics at a Nigerian University. As yet he has received no pension whatever from the CEGB.

being the dispatch of plutonium from one site to another. Emphasis is placed on the conflict which has apparently been going on ever since Britain joined the EEC between the government and Euratom, concerning the completely unsafeguarded Magnox reprocessing line at Sellafield which handles both military and civil plutonium. This clearly negates both the spirit of the Non-Proliferation Treaty and the letter of the Euratom agreement.

Recent Developments

A startling change of tune has come from the CEGB, even before the Sizewell Inquiry report has been published. In a TV interview (March 20th 1986), Lord Marshall, the CEGB Chairman, blandly remarked that plutonium from the CEGB's "early reactors", by which he meant pre-1969, had gone into the "military stockpile". On the programme he seemed under an impression that the government had admitted the fact, as if it had not been strenuously denied by the CEGB and by the Energy Secretary, John Moore, throughout the Sizewell Inquiry. Such official denials have continued, for example a recent statement in *Nature* that ". . . no plutonium produced in CEGB reactors . . . has been exported for use in weapons . . ." (p.318, 406, 1985.)

The same TV programme featured an interview with US congressman Ottinger who explained that the shift in US priorities might require stored UK plutonium to be used for star wars research. Although the British plutonium is temporarily in a 'civil' stockpile, associated with fast breeder research, it is only on loan there from the weapons department of the US Department of Energy (DoE), the DoE having a dual function, making nuclear warheads as well as concerned with fast breeder research. Presently the UK government faces the problem of the cover-up of the destination of the CEGB's plutonium having been blown.

Mrs Thatcher, in a Parliamentary Reply on April 15th, was only prepared to affirm that no plutonium had been transferred to a military stockpile "during the lifetime of the present government"; in essence she was no longer prepared to confirm what her own ministers had repeatedly stated. Summing up on behalf of the CEGB at the Sizewell Inquiry, Lord Silsoe exclaimed that "CND has charged the Board with lying and Government ministers with misleading parliament." The answer is "yes", they have all told lies, half-truths and falsehoods. Unfortunately, as we have seen from the official reaction to the Chernobyl accident, the predilection for distortion appears to have become pathological.

Notes and References:

1. Day 305 of Sizewell Inquiry (summing-up of CND case) p.63.
2. Day 305, p.51. Energy Under-Secretary John Moore told the Commons on 21.12.81 that all 1280 kg of plutonium exported abroad since 1971 was 'civil', meaning of CEGB origin, stressing that he was "choosing his words with great care." However, it emerged from the Inquiry that 780kg exported to the US since 1971 was of 'military' origin, i.e. from Calder Hall and Chapel Cross, Mr Moore's words being described on Day 47 as "a slip of the tongue." NB the adjectives 'civil' and 'military' as here used do not tell one anything about isotope composition.
3. Cmnd 733, United States No. 2, HMSO, 1959.
4. Though the 1958 Agreement does have an escape clause, "except as may be otherwise agreed for civil purposes," this is not present in its 1959 Amendment, which specifies merely that "special fissile materials" shall be exchanged "for military purposes." There is in any case no record of the above clause having been revoked over any US-UK exchanges.
5. According to officials of the US Department of Energy, quoted in the *International Herald Tribune* (CND/P/1, p.85). However this tends to contradict a UK Department of Energy document submitted to Sizewell stating that "*no* exchanges of plutonium for highly enriched uranium have taken place for over a decade." (Ibid).
6. Quoted in "The British Nuclear Deterrent", P. Malone, London 1984, p.61.
7. J. Simpson, "The Independent Nuclear State: The United States, Britain and the Military Atom," London 1983, p.294; also *New Scientist* 2.2.84, p.5.
8. Technically this 4 tons or so of CEGB plutonium is being "used" in US fast reactor research, but such "use" little affects its quantity or composition, leaving open the feasibility of its later re-use for military purposes by isotope blending. See "British plutonium may fuel US bombs," *New Scientist,* 15.3.84.
9. In hearings on "Amending the Atomic Energy Act of 1954", 1958, quoted in CND/P/1, Sizewell evidence, p.50.
10. They presently supply 15% of UK nuclear electrical power.
11. CND/P/1 p.14.
12. Parliamentary Answer of 27.7.82 by Mr John Moore, quoted in "END Papers" 7, *Spokesman* 1984, p.87. In a latter Parliamentary Answer, the 'sizeable quantity' became 200kg (9.3.83).
13. CND/P/1 p.43.
14. It has since been disclosed that the IAEA also inspects the BNFL depot at Capenhurst (Commons, 3.12.84, c.23).
15. Quoted in R.F. Pocock, "Nuclear Power: Its Development in the UK," London 1978, p.36.
16. Private communication; see also Benn's evidence at Sizewell, reprinted in "END Papers 7," *Spokesman* 1984, p.7: "I personally feel betrayed that I was never told of this arrangement . . ."
17. Cmnd 537, Treaty Series No. 41, 1958; xerox copies of this and ref. (3) available from HMSO.
18. 'The Production and Destination of UK Civil Plutonium,' *Nature,* K. Barnham, D. Hart, J. Nelson, and R. Stevens, 19 Sept 1985, pp.213-217.

HIGH LEVEL WASTE: No Technical Solution

by
Ivan Tolstoy

In spite of all its assurances, the nuclear industry has not yet found a safe way of disposing of nuclear wastes. In fact, according to Professor Tolstoy the proposals put forward by the nuclear establishments of the world are both unscientific and irresponsible'. Some solution will have to be found for the wastes generated so far, but the real answer is to do away with nuclear power.

There are technical problems in our society which cannot be resolved by technique alone. The reasons for this are mostly known: *one* is that modern technology is so powerful and affects so many lives that its problems merge inevitably into social and political issues. High technology can also be very dangerous: recent history is peppered with technological fiascos—Seveso, thalidomide, the nuclear accident in the Three Mile Island, fall-out from nuclear tests, the Challenger tragedy, the Chernobyl disaster, etc. A public which not long ago put its trust in experts and in science is now more sceptical.

Disasters or near-disasters of this kind are, all too often, due to ordinary mistakes—in design or execution. It has been suggested that in assessing technologies we incorporate, somehow, a margin for human error. We should, says Professor Laura Nader, "build technologies that recognise human frailty. If there's one thing that social science has documented, it's that people make mistakes. Build that into technology, and accept or reject technologies on that basis."[1] Yet this cannot be done quantitatively; any such appraisal is coloured as much by faith and value judgements as by technical arguments—it must always be, to some extent, a political act.

Another important if less appreciated cause of uncertainty is, ironically, purely technical: it is the scientific fact that the universe we live in can be *intrinsically* unpredictable. Indeterminism has long been recognised on the submicroscopic scale of the atom; today we are finding it also in the macroscopic, everyday, Newtonian world of our lives. Modern developments in Applied Mathematics, in Fluid Mechanics and in some branches of geophysics have demonstrated the existence of intrinsic uncertainties in the functioning of our environment.[2]

These features—the social implications of high technology and of human error *plus* indeterminism in the environment—are awkward for our technocrats. Their instinct, usually, has been to sidestep the issue. This they do, frequently, by hewing to the old-fashioned line that one's inability to forecast the future is temporary—due to a touch of ignorance, perhaps, to be dispelled by further research—that most magic of modern rituals.

The geophysicist has always been aware of the limitations of his science as a predictive tool. He used to ascribe his difficulties to the sheer complexity of his problems, to errors in measurement, inadequate knowledge, and insufficient computing facilities. Today, if he has had contact with certain branches of his field—particularly those touching upon fluid flow theory—he understands that, in some cases, his troubles are of a more fundamental sort. He accepts now that some forms of environmental unpredictability are intrinsic and ineradicable and, furthermore, that there are well-established mathematical and physical explanations for this. *The disposal of high-level radioactive wastes in rock or in the seabed is a largely indeterministic problem of this ilk.*

High-level radwaste is extremely radiotoxic. It consists basically of what is left of the reactor fuel after its useful energy has been extracted. It comes either in the form of burnt-out fuel rods or as the tail end of some reprocessing procedure. There are two chief types of component in this waste:

Fission products, which are elements produced by the splitting of uranium nuclei in the reactor. Principally beta emitters, most are relatively short-lived: strontium 90 and caesium 137, two of the main components, have half-lives of about 30 years. After 600 years these elements have decayed to about one millionth of their original concentration and may then be

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considered harmless. But other fission products have longer half-lives, e.g. technetium 99 (200,000 years) and iodine 129 (16 million years). Fission products account for the bulk of radioactivity and heat generated by the waste for the first few centuries. Quantities of the order of a microgram and less imbedded in tissue will generate cancers.

Fission by-products, on the other hand, are elements produced from uranium by neutron capture, and consist chiefly of the actinide series—isotopes of plutonium, americium, neptunium, etc. They are mostly alpha emitters and decay more slowly. Thus plutonium 239 and neptunium 237 have, respectively, half-lives of 25,000 and 2 million years. Such substances clearly require isolation over geologic time-spans. Here again microgram quantities are carcinogenic.

Growing quantities of high-level waste in the USA, Europe, the USSR and the Third World may, by the end of the century, lead to the need for disposing of as much as 150,000 Megacuries of radioactivity in a score or more of such disposal sites.

The riddle is simply stated: how can one guarantee that this immense amount of concentrated radioactivity will not be a threat to future generations? While a variety of disposal methods—up to and including disposal in space—are under study, the present consensus among supporters of nuclear power in Europe and the USA is that, after some form of processing, burial in geological formations on land or under the seabed, will be sufficiently safe. This philosophy was born largely under the pressures of having to convince a worried public that the nuclear industry *knows* how to dispose of its wastes. I submit that in fact the industry *cannot* know and that its attitude is self-serving and irresponsible.

There may occur two kinds of contamination of the environment by high-level wastes:

Air contamination by explosive or by slow release of gases from an underground disposal site is theoretically possible. There is unfortunately no reliable way of estimating this danger—there are too many uncertainties concerning actual methods of burial and of possible chemical interactions within a real environment. According to the Russian biologist Zhores Medvedev, a serious accident of this kind took place in the 1950s in the Urals.

Water contamination is generally taken as the most likely mechanism of pollution in connection with waste disposal in rock. Underground waters may come in contact with the wastes, leach out radioactive elements, transport them and contaminate the biosphere, and specifically, the drinking water of local or distant communities. In isolating high-level wastes by burial in geologic formations the primary problem is therefore to ensure that no significant amounts of radionuclides are leached out by underground waters and transported to the biosphere. This problem has two distinct aspects, corresponding to two lines of defence or *barriers* against leaching:

1) A first *artificial* barrier is to be provided primarily by treatment of the waste. Ideally, this will be encapsulated in a form which makes it impervious to leaching. Present thinking revolves around the fabrication of a solid waste product of very low leachability—although there is no consensus on what form this should take.

2) The second *natural* barrier will be the rock formation in which this solid waste is to be buried. The idea is to put it in deep underground chambers or holes in dry, impervious rock and hope for the best. This can be refered to as the *geological barrier*—which might also be conceived as a mass of rock or sediment under the ocean bed (burial at sea).

There are serious unresolved and in some cases unresolvable difficulties with both kinds of barrier.

In the USA research on the *artificial barrier* has centred on trying to incorporate the waste radionuclides in glass or in a variety of ceramic matrices. There is no unanimity on the matter, but many seem to think that, under conditions likely to prevail in a geological disposal site, ceramics are more promising than glass. Glass, nevertheless, is the easiest to produce on an industrial scale and may be opted for as a first generation solid matrix for high-level waste disposal.[4] Vitrified high-level waste is already being produced commercially at Marcoule in France and will soon be manufactured at Windscale in Britain. But it has been pointed out, notably by US workers[5] and by Ringwood's Australian team[6] that glass performs poorly at high temperatures and pressures (300°C and 300 Bars). Although storage prior to burial and dilution of waste may in principle ensure that temperatures will not exceed 150°C or so, one can nevertheless envisage potentially disastrous scenarios in which warm, stagnant water becomes radiolysed in the vicinity of the waste, possibly dissolving minerals from the surrounding rock and turning into a highly corrosive acid solution (a possibility suggested by Professor Wranglen of the Royal Swedish College of Technology). This would make short shrift of the waste blocks; so would hot brines, in the case of disposal in salt formations. The life of the waste blocks may be prolonged by encasing them in corrosion resistant jackets—e.g. of stainless or titanium steel—but the long-term effectiveness of such precautions under adverse conditions remains to be ascertained.

Since artificial barriers to leaching cannot be fully relied on, the integrity of the geological barrier becomes a vital issue.

An excellent survey of the potential problems to be encountered in selecting the *geological barrier* was published in 1978 by the US Geological Survey (Bredehoeft et al[7]). It emphasises that, to avoid the primary danger of waste transport by water, one must:

(1) Have a *tectonically stable site,* with slow groundwater movement and long flow paths to the surface.

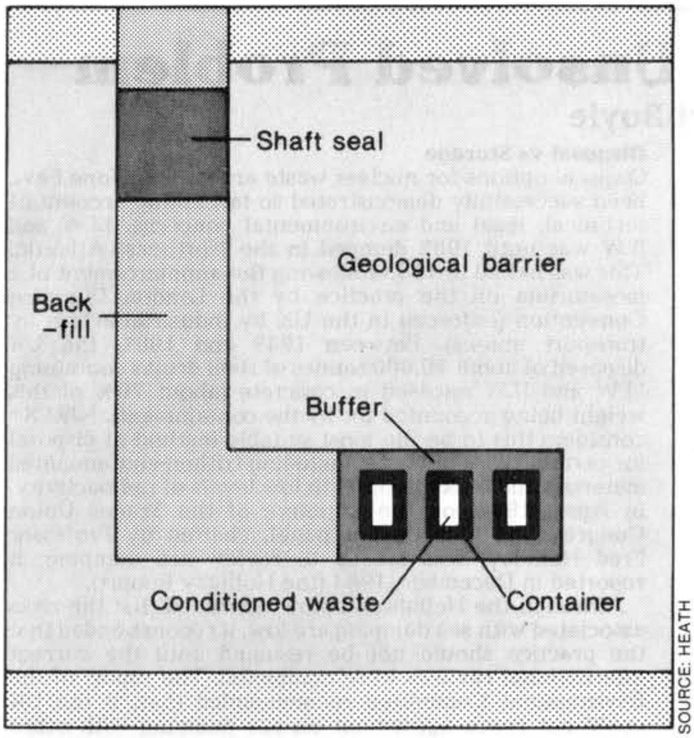
(2) Carry out intensive subsurface exploration of the site to *determine hydrology and geology.*

(3) Be able to *predict future behaviour of the repository,* on the basis of initial conditions and various assumptions about the future.

(4) *Evaluate the risks* associated with these predictions.

(5) Judge whether these risks are *acceptable.*

Criterion (1) is the only one that can be reasonably



The nuclear industry's seemingly neat solution to an intractable problem.

well obeyed. One can establish present and past stability of an area with a fair degree of confidence. *Future* stability, however, cannot be guaranteed. As for (2), understanding of hydrology and geological structure cannot be derived solely from a study of surface features. But many critical subsurface features are subtle and liable to escape detection. The USGS pamphlet points out, for instance, that small faults, and notably strike-slip faults, can remain undetected or, if detected, may be impossible to date. It is probable, too, that the necessary degree of confidence in the lithological integrity of a site cannot be assured without a number of core holes large enough to threaten this very integrity—a sort of macroscopic uncertainty principle, leading to unresolvable unpredictabilities. Excavation of the repository and presence of hot wastes will themselves perturb the hydrology of the site. A great many potential mechanical, chemical and thermal disturbances can be listed. A number of recent computer model studies which attempt to define possible levels of pollution of surface waters due to the presence of underground wastes show that these are very sensitive to rock parameters (such as sorption of various elements) the values of which are, in the current state of the art, essentially unknown.[8,9] Criterion (3) is unlikely ever to be satisfied, even approximately: geological predictions over long time periods are not credible as a matter of principle. Consider, for example, the question of earthquakes. The future seismicity of an area, resting as it does on the operation of poorly understood redistributions of both global and local stress patterns, is unknown. Yet relatively minor seismic events could destroy the integrity of a site, introduce new fractures, reactivate old ones, and change the hydrology in drastic ways. Such events are perhaps particularly unpredictable for stable areas, for which we have no quantitative, reliable models of regional seismicity. A study of the seismically stable area of New England has revealed that, during the last 250 years, its level of seismicity has varied suddenly and spectacularly[10]—for unknown reasons.

Major climatic events such as ice ages or severe pluvial episodes can also seriously affect underground flows: the hydrology down to depths of hundreds of metres could be severely altered.

The following verbatim quotes from the USGS paper represent the considered conclusions of a group of America's most competent geologists on the predictability problem for high-level waste repositories:

"Models of natural systems that have come into use in recent years fall into four categories (Holcomb Research Inst., 1976): (1) simple and predictable, such as agricultural crop patterns; (2) complex and predictable, such as river hydrology and short-term weather patterns; (3) simple and unpredictable, such as an ecosystem response to natural disasters; and (4) highly complex and unpredictable, such as interrelations among the species of an ecosystem or, we believe, the fate of radioactive wastes in geologic repositories. The unpredictability of radioactive waste models stems from the lack of a method for determining the future rates of many events and processes, such as tectonism, and from the current lack of adequate data needed to allow the model to function from start to finish—for example, the data needed to characterise ground-water flow systems."

This makes it clear that criterion (4) cannot be carried out in any meaningful way and thus (5) cannot even be discussed.

From this it follows that the proposals by the nuclear establishments of the USA, Europe and the British Isles are *both unscientific and irresponsible* (few details are available for the USSR; but from what filters out, they hardly seem to be doing any better[11]).

In disposing of high-level waste we seek containment for millenia. Any experiment to prove the theory of safe disposal in geological formations must last at least this long. To pretend, as the nuclear establishment often does, that a few more experiments, test bores or geological surveys is all it needs is simply disingenuous or scientifically illiterate or both. Adequate proof will take millenia.

Yet the nuclear power industry is talking of burying high-level wastes in the United States, in Germany, France or in the British Isles *now*—that is to say, during the next few decades. Scientifically this is indefensible for it represents the willingness to accept a model, or theory, without waiting for the experimental proof. If this involved no danger to the public, if it concerned merely some arcane point of theoretical physics, it would not matter—the debate could be safely confined to the pages of some scientific journal. Unfortunately much more is at stake—human lives, the quality of our environment and that of future generations. In other words what the nuclear establishment is proposing is not merely unscientific, it is also irresponsible: even the most detailed programme of research, test bores and geophysical studies, cannot alter the fact that one can neither guarantee the future

Nuclear Waste—The Unsolved Problem

by Stewart Boyle

Prior to the nuclear accident at Chernobyl in the USSR in April this year, one of the major concerns of the public in relation to nuclear power was the problem of nuclear waste. After two serious setbacks in 1981 and 1985, which resulted in the Government abandoning a drilling programme for High-Level Waste (HLW), and a deep disposal site for Intermediate Level Waste (ILW) at Billingham, plans for Low-Level Waste (LLW) disposal are now encountering fierce public opposition at four potential sites.* Nuclear waste is an issue which pits communities with little previous experience of the nuclear industry against the mighty battalions of nuclear scientists and politicians anxious to get rid of a problem. It is an issue which produces voluminous reports and weighty polemic but little real progress. It is also recognised as a major headache for the nuclear industry since it inhibits its desire for expansion. As the 1976 Royal Commission Report on nuclear power stated ". . . there should be no commitment to a large programme of nuclear fission power until it has been demonstrated beyond reasonable doubt that a method exists to ensure the safe containment of long-lived, highly radioactive waste for the indefinite future". The nuclear industry would find it difficult to argue that they have made sufficient headway to justify further expansion at present.

What is Nuclear Waste?

Uranium mining produces huge amounts of liquid and solid waste. For every 1,000 tonnes of uranium fuel 100,000 tonnes of radioactive solid waste (known as tailings) and 3,500,000 litres of liquid waste are produced. The radioactivity, carried by wind and water, can contaminate the environment and increase the local rate of cancers.

Enrichment and fuel fabrication facilities produce liquid, solid and gaseous wastes, but these are generally of low activity, since the uranium has yet to undergo the fission process in a reactor. Nuclear reactors themselves generate solid LLW and ILW wastes, as well as regular discharges of radioactive liquids and gases into the environment. The PWR proposed for Sizewell would, if built, produce around 600 cubic metres of solids per year, 135,000m^3 of liquids and 12,000 cubic metres of gases. Much of the liquid and gaseous waste is tritium and carbon-14.

Reprocessing—the Billion Pound Problem

Reprocessing has always been an integral part of the British nuclear programme. It has never seriously been justified on economic or waste management grounds, even at the 100-day Windscale Inquiry in 1977. The Environment Committee report seriously questioned the practice, and called for a reassessment of the new THORP reprocessing plant. This recommendation was rejected out of hand by the Government.

The Environment Committee were right to raise concerns over reprocessing. The operation dramatically increases the volume of LLW and ILW, by spreading radioactivity from the spent fuel rods onto liquids, machinery, clothing and other materials. It increases the overall volumes of LLW and ILW by at least a factor of 10. It produces some 76% of LLW and 62% of all ILW. It also produces many of the more difficult plutonium contaminated wastes (PCM).

Evidence produced for the Environment Committee demonstrated that reprocessing is neither technically necessary, nor is it economical compared to other options such as long-term storage or the direct disposal of spent fuel. Indeed, recent contracts signed between BNFL and CEGB/SSEB, which are of the order of £1.6 billion, are at least £1 billion more than these alternative options, even where fresh uranium has to be bought on the world market.

*The sites are located at Fulbeck in Lincolnshire, Bradwell in Essex, Killingholme in Humberside and Elstow in Bedfordshire. All are located in the clay belt in Southern England.

Disposal vs Storage

Disposal options for nuclear waste are varied. None have been successfully demonstrated so far, taking account of technical, legal and environmental concerns. LLW and ILW was until 1982 dumped in the Northeast Atlantic. This was halted in 1983 following the announcement of a moratorium on the practice by the London Dumping Convention (enforced in the UK by industrial action by transport unions). Between 1949 and 1981, the UK disposed of about 70,000 tonnes of steel drums containing LLW and ILW encased in concrete (about 70% of this weight being accounted for by the containment). NIREX* considers this to be the most suitable method of disposal for certain types of waste, including tritium-contaminated materials and bulky items with low levels of radioactivity. In April, 1984, on the initiative of the Trades Union Congress, an independent panel, chaired by Professor Fred Holliday, was set up to review sea dumping; it reported in December, 1984 (the Holliday Report).

Although the Holliday Report concluded that the risks associated with sea dumping are low, it recommended that the practice should not be resumed until the current international reviews were completed. The report of the Environment Committee recommended that, if the UK could not reach agreement on sea dumping with other nations, the practice should not be resumed, and that the existing stockpiles of packaged waste, previously destined for disposal at sea, should be repackaged.

The 1985 London Dumping Convention voted by 25 to 6 to suspend sea dumping until detailed studies into the social, economic and legal factors could be scrutinised and it be proven that sea dumping was harmless. This will have the effect of an indefinite suspension of dumping at sea.

The disposal option receiving by far the greatest attention is the geological isolation of radioactive waste in suitable rock formations, either beneath the seabed or on land. Geological disposal would involve emplacing suitable packaged waste in underground "repositories" from which the migration of radionuclides following leakage from their containment would be inhibited by the surrounding impermeable rock.

Two options are being considered for disposal beneath the deep ocean floor, both involving emplacement of vitrified high level waste into the clay deposits of the abyssal plains; one in which the waste is placed in boreholes drilled into the ocean floor, the other using free-fall penetrators dropped from the ocean surface. The UK's interest in these options is as a member of the Nuclear Energy Agency's International Seabed Working Group. This work, still in its early stages, represents the only research being carried out by the UK at present into the long-term disposal of HLW. Two areas of the Atlantic floor are receiving particular attention, Great Meteor East, west of Madeira, and the Nares Abyssal Plain, north of Puerto Rico. However, the political prospects look less promising; research into the penetrator option was interrupted in October 1984, when members of the National Union of Seamen refused to load the torpedo-like penetrators onto the Natural Environment Research Council's ship *Discovery* at Falmouth.

A further sub-seabed possibility, proposed by ENSEC Limited has also proposed for the disposal of ILW the drilling of boreholes (about 1m in diameter and perhaps 1,000m deep) into the UK continental shelf. Suitably packaged waste would be placed to within about 300m of the top of each borehole, and the hole would then be sealed with oilfield cement. A feasibility study into offshore borehole disposal was launched by NIREX in 1985.

Shallow land disposal sites for nuclear waste have been tried in a number of countries. The track record so far is not an auspicious one. In 1958, a serious accident occurred at Kyshtym, in the Urals. Hundreds of square miles were left uninhabited as a result of a steam explosion

*Nuclear Industry Radioactive Waste Executive; who have the responsibility of LLW and ILW disposal.

which contaminated the surrounding area. A smaller incident at Rocky Flats, in the USA sent plutonium into the local environment. Whilst both these incidents involved material contaminated with plutonium. LLW dump sites have also had a number of problems.

In the USA, three out of six shallow dump sites have been closed due to off-site contamination of breaches in packaging and transportation regulations. In 1975, the West Valley site in New York state was closed, as a result of tritium contamination of the surrounding water table. At Maxey Flats in Kentucky, plutonium was detected three-quarters of a mile off-site within 3 years of the start of operations. The three remaining sites are located in relatively arid parts of the country. At one of these, at Barnwell, South Carolina, which is used as an example of good waste disposal practice by NIREX, some cobalt-60 and tritium movement has already taken place.

Here in Britain, the only operating disposal site for LLW is at Drigg, near Sellafield. This site was designed on the 'dilute and dispersal' principle, allowing rain water to drain through and take contamination away into the near-by Irish Sea. The Environment Committee were unhappy about Drigg and concluded that it was "not an acceptable model for any future disposal site". This is one of the few recommendations accepted by the Government.

Research and institutional change: the priorities

NIREX was formed in 1983. It has responsibility for LLW and ILW disposal, but no remit for HLW or storage. Contrary to the recommendations of the 1976 Royal Commission Reports, NIREX is made up entirely of representatives of the nuclear industry: British Nuclear Fuels Limited (BNFL), the Central Electricity Generating Board (CEGB), the South of Scotland Electricity Board (SSEB), and the UK Atomic Energy Authority (UKAEA). NIREX have indicated that they have utilised a five stage site selection procedure (a "meticulous five step") which takes geological, population, conservation and accessibility factors into account in selecting "areas of search" within which specific disposal sites are sought. Such a procedure sounds very reasonable but relies for success on an adequate knowledge of each of the four factors. As there has been no systematic study of the suitability of the rocks of the UK for disposal, it cannot be claimed that the first of NIREX's site selection criteria has been applied in the selection of any of the specific sites so far announced: NIREX's view that "the geological barrier is a known quantity" finds little support in the geological community.

Conclusions

The problems of nuclear waste are best summed up by two recent observations. In abandoning proposals to dump short-lived ILW in shallow disposal sites, the Government stated that this was not justified on scientific grounds but on the basis that "many people would be reassured" if such sites were used only for LLW. In fact many of the objections of local people in the four potential dump sites were based on substantive technical and scientific issues, utilising the experience of geologists, engineers and radiobiologists. The problem was not "the gap between scientists' assessment of risks and the honestly held perceptions of the local communities", but the total lack of credibility of statements by NIREX, the CEGB and the Government that such disposal options could be guaranteed for a period of 300 years.

In 1984, the Beijer Institute carried out a major review of HLW disposal. It looked at the state-of-the-art in eight major nuclear countries and concluded that the "solution" of the HLW problem is "transcientific" (ie beyond the bounds of science), and that the adequacy of any perceived solution would depend on subjective factors such as "the values and mores of society". The reason for this conclusion is that the enormous time span involved reduces the relevance of empirical data to a low level. Nuclear waste differs from other wastes in this respect. It is a problem which we are continuing to create for future generations. Until an adequate solution has been found which is acceptable to the general public, then the very least we can do is to stop creating further quantities of it.

Stewart T Boyle, *BSC, DMS National Energy Campaigner, Friends of the Earth Ltd.*

integrity of a waste depository nor assess, in any meaningful way, the risks attendant to its failure.

To opt for waste disposal in the continental United States, or in Europe or in the British Isles is short-sighted and irresponsible not only because it creates unknown dangers for future generations, but also because there are obvious alternatives. One could, for instance, find burial sites in the rock formations of the Antarctic mountains or in an uninhabited Arctic island—where leaching and leakage would be a far less serious matter. Both of these possibilities would doubtless call for a certain amount of international negotiation; yet surely it would be worth the effort. In the USA, NASA has an ongoing project for the disposal of high-level wastes in space: this too may be a real choice for the future. Geologic burial in sediments or rocks beneath the ocean floor is worth further study. And there is the option of temporarily storing solidified waste near or on the surface, pending the development of a technically and socially acceptable solution. The nuclear establishment, however, wants desperately *to be seen* to have solved, or to be on the verge of solving, the high-level waste disposal problem; only then will it have established the social and political prerequisites for expansion. Besides, burial sites close at hand should, in immediate cash terms, be the cheapest alternative. One hesitates to contemplate the value system of any body of men and women who might espouse such a solution on these grounds alone.

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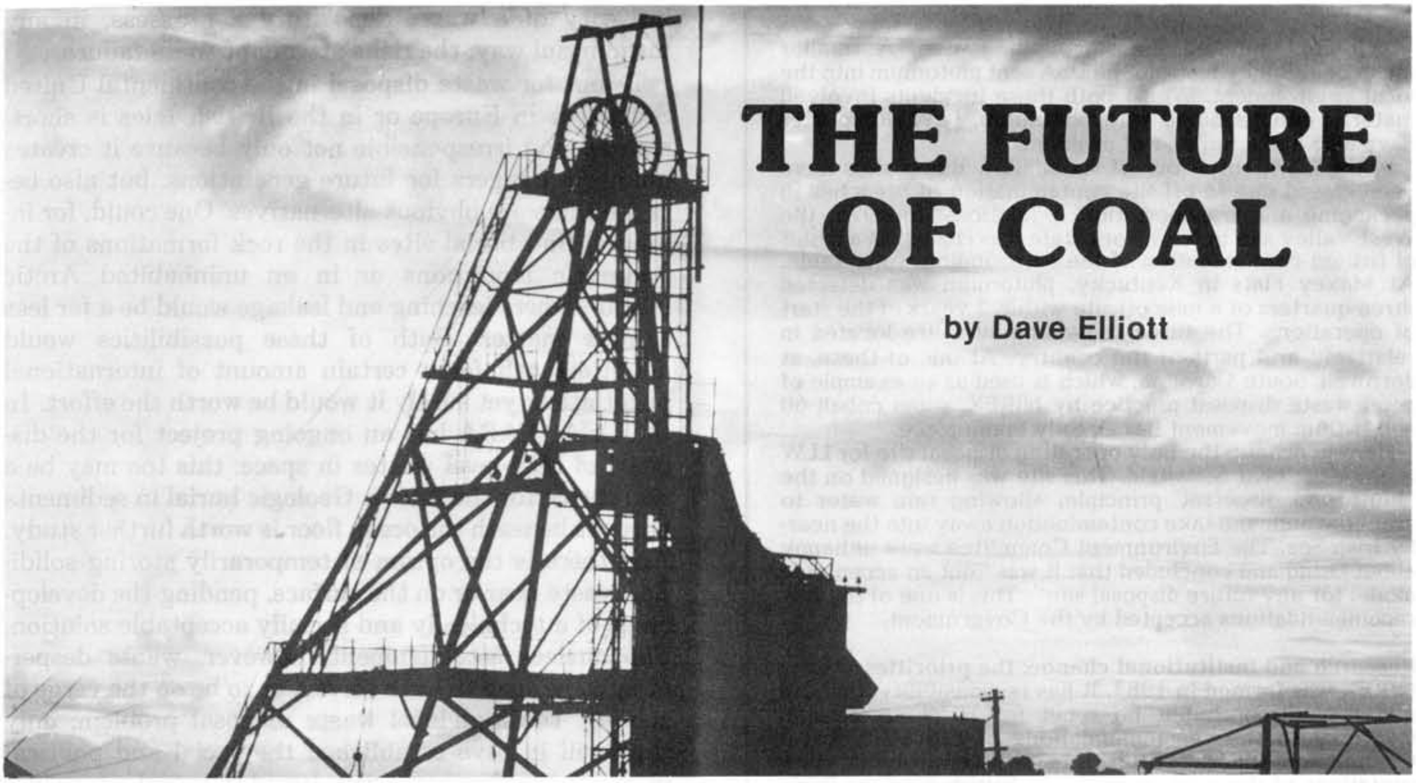
THE FUTURE OF COAL

by Dave Elliott



The dramatic fall in oil prices earlier this year was seen by many observers as yet another nail in the coffin of the coal industry. Certainly the Conservative Government has favoured nuclear power as the only major 'new' energy technology for the future. Since it took power, all orders have been for nuclear plants and the CEGB has continued with its programme of coal fired plant closures. Already it has shed some 50,000 workers through natural wastage and redundancies. The plants being closed are the small, older units often in inner city locations—just the plants that would be candidates for conversion to combined heat and power operation. Worse still the CEGB is selling off the sites with their coal handling capacity and rail links, so that the CHP option is being foreclosed.

The policy of making the way safe for nuclear power is even more visible when it comes to the coal mining industry. That's what the 1984/5 miners' strike was, in part, about.

Dave Elliott looks at the way the UK's mining industry has been savaged over the years, and at some of the alternative options.

In 1913 the one million British miners then employed in the coal industry—representing one in ten of the male workforce—produced 287 million tonnes of coal. More than one-third of this total was exported.

By 1950 coal still provided 90 per cent of the United Kingdom's primary energy, with output running at over 200 million tonnes per year.

Partly due to competition from gas and cheap imported oil, this figure had declined to 124 million tonnes by 1978.

The massive closure programme of the 1960s and 1970s in the meantime had cut manpower from 697,400 in 1956 to 252,000 by 1974.

The "oil crisis" of 1974 did, however, bring about changes: the National Coal Board's 1974 "Plan for Coal" proposed a programme of investment which would lead to a total output—including open-cast coal—rising to 170 million tonnes by the year 2000.

To some extent investment in modernisation did go ahead, even if a sense of urgency was absent because of the short-term availability of North Sea oil and gas.

Despite this, British coal has remained the cheapest deep-mined coal in Europe even given the UK's continuing low level of subsidy.

Some idea of how disadvantaged the coal industry is in this country compared with other Common Market producers can be gleaned from the following figures.

In 1980, West Germany allocated the equivalent of £30.60 per tonne in operating subsidies and social aid grants—including redundancy payments.

France's contribution was £63.33 per tonne and Belgium £88.89. By comparison, the British government subsidised coal to the tune of a mere £1.85 per tonne produced.

In that year, the total subsidies paid out by these three EEC countries were actually more than the entire UK production costs!

But some Australian and United States coal is cheaper still—and we have seen growing levels of imports from these countries as well as Poland.

The cash price, of course, hides the real environmental and social costs—open cast mining in Australia, the conditions in the private US mines and the repression of independent unions in Poland.

In Britain, the fall in demand for energy resulting from the recession, means that the demand for UK coal is now estimated at 105 million tonnes for 1985.

The result has been a crisis in the coal industry. Profits have turned

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into losses and subsequent calls for pit closures.

The first attempt to initiate a closure programme for 50 older pits, involving the loss of 30,000 jobs, was fought off by the National Union of Mineworkers in 1981.

The recent NCB attack was much more concerted and was accompanied by talk of the Central Electricity Generating Board cutting its order from 80 million tonnes to a mere 20 million tonnes in the next quarter of a century.

Today there is talk of cutting back to 50 million tonnes per annum. Thousands of jobs will be at risk.

Alternative Options

In the long term, the UK coal industry should have a future. Britain has at least 300 years worth of coal and mining and combustion technology is developing rapidly so that coal can be mined and burnt much more safely in the future.

With North Sea oil and gas likely to be exhausted in the next few decades—and an uncertain future for nuclear power—coal ought to have a central position in our energy plans.

The problems come when we look at the short-term future for coal.

Oil and gas have replaced it in the domestic and industrial heat market while, under current government plans, nuclear plants are meant to challenge coal in the electricity production process.

Nuclear power is very much Margaret Thatcher's secret weapon. As a leaked cabinet memo put it, "a nuclear programme would have the advantage of removing a substantial proportion of electricity production from the dangers of industrial action by coal miners and transport workers".

Coal could still beat these challenges—at least on economic grounds—by switching to "combined heat and power", CHP as it is known. The effect would be to make use of at least 50 per cent of the 70 to 80 million tonnes of coal the CEGB burns each year.

Switching to CHP would allow coal to challenge gas as a heat supplier at the same time as producing electricity.

Coal could also be used to produce gas—synthetic natural gas—to replace exhausting North Sea supplies, although at relatively low efficiencies.

In addition, coal has a very significant potential as a direct fuel or indirect chemical feedstock for industry.

This will become increasingly important as oil—despite short term price cuts—becomes ever more expensive and scarce.

Obviously, energy conservation can and should cut demand, but even so we are going to need some fuel to replace gas and oil and, at least for the immediate future, coal is the obvious option.

Technically, nuclear power is just a non-starter. There have been three decades of virtually unlimited funding—£2.2 billion so far just on one reactor prototype, the fast breeder.

Yet nuclear power still produces only four per cent of our energy requirements.

Quite apart from unresolved problems of nuclear mishaps, the indefinite storage of nuclear waste and the risk of proliferation of weapons-making capacity, globally we have only around 40 to 50 years worth of uranium-235 for our "burner" reactors.

Even though the fast breeder reactors are supposed to be able to "stretch" uranium supplies, their exploitation would bequeath to humanity insuperable problems for all time to come.

None of this is, however, necessary. As long ago as 1980, the NUM, mindful of the dangers of the nuclear power programme, called for a co-ordinated energy policy "based upon coal, North Sea oil and gas, and other indigenous resources, such as wind, wave, solar and geothermal energy".

If the nuclear cul-de-sac is avoided, we can look towards a future in which renewable energy resources, such as wind, wave and tidal power, can begin to replace fossil fuels.

Ultimately, according to official estimates, renewables could provide energy up to the equivalent of 200 million tonnes of coal a year.

This is the same as we are now getting from North Sea oil and gas. It is even possible that a point could be reached where offshore winds provide 50 per cent of our electricity.

All this is in the future, but an increasingly diverse range of renewable energy resources could easily fill the bill presently assigned to nuclear power and the gaps left as North Sea supplies run out.

In the meantime, we have all the coal we need to give us time to prepare such a future.

Problems

Coal clearly has its problems. No fuel or technology can avoid having environmental impacts. Sulphurous emissions, leading to acid rain, are a current major concern.

The economic cost of the damage presently being caused, quite apart from the effect on health, has been put at as much as £3,500 million a year for the whole of Europe.

Britain is a major polluter. Yet the technology already exists to reduce these and other pollutants—opting for "fluidised bed" coal combustion, for example, can reduce emissions by 80 per cent.

More immediately, a crash clean-up programme, involving the retrofitting of "scrubbers" to all existing coal (and oil) plants would cost no more than one nuclear power plant.

West Germany has already launched a £2,000 million clean-up programme, so the fact that coal is "dirty" does not mean we have to opt for the even more undesirable nuclear option. It means we should clean it up.

Given all this, it makes no sense whatsoever to close pits, especially since once closed they are difficult, if not impossible, to re-open.

Obviously, some pits will be worked out, but it is surely foolhardy to close mines forever purely on "current fuel price" grounds, since these take little account of our future need for coal.

Instead we can insure ourselves against the uncertainty of the world fuel market with a programme of gradual expansion along the lines of "Plan for Coal".

A key issue is the timing of any expansion programme. It takes time to sink new pits, but, equally, it will be some time before oil and gas are depleted and the demand for coal increases.

Some people argue that the early stages of an expansion programme might best be served by investing in new "high technology" pits, like that at Selby, while mothballing some older ones.

On the other hand, some of the new mining technology is ideally suited to our smaller, older pits; it could give them a valuable new lease of life.

And one factor that should not be left out of the various economic equations is that the coal from the threatened older areas—particularly Scotland and Wales—is generally lower in sulphur content.

Burning Scottish and Welsh coal produces a 50 per cent less sulphurous emission than using coal from the central region around Nottinghamshire.

Quite apart from the local employment issue and its effect on the mining communities and their surroundings, there is thus a very good argument for developing these older pits for the next decade using new technology, especially if we really are serious about controlling acid rain. In the next ten years we could thus extract all our low-sulphur coal, rather than losing it forever.

By then, hopefully, the CEGB would have installed less polluting coal burning systems.

The "dirtier", higher-sulphur coal from the "easier" areas could be used without continuing to devastate the environment.

By then, the demand for coal would have increased again—gas and oil being depleted.

And by then the NUM would have had the opportunity to negotiate a sensible "technology agreement" which would allow the industry to benefit from innovations and still protect employment.

For probably the most important single issue—obscured by the current emphasis on specific closures—is the longer term employment issue.

A recent study by the Working Environment Research Group at Bradford University has estimated that the new technologies being introduced into mining could have a devastating effect on employment.

More than 100,000 job losses are predicted, representing some 74 per cent of those working in the industry if new mine control systems like MINOS were widely deployed.

It is worth noting that the new Selby pit will employ only 4,000 workers. Yet it will mine the same tonnage as is presently produced by 20,000 miners in the older pits.

The NUM is well aware of this threat. During the 1984/85 dispute it pushed for a technology agreement to stem losses in the longer term.

Within the context of an overall expansion of the industry, the NUM proposed a four-day week, with no loss of pay, early retirement and other benefits.

The Coal Board, however, was unmoved. It wanted to keep technology agreements off the agenda and to focus on straightforward productivity deals and redundancies.

What is clear is that a planned future for the coal industry must involve avoiding closures, maintaining current output levels for a decade or so, and clearing the low-sulphur coal from the smaller, older, "marginal" pits, investing in the latest technology suitable for their conditions.

Only then, when demand is increasing, do we invest in the rapid expansion of output of coal from the "dirtier" but larger pits in the "easier" central region, using large-scale, advanced, high-productivity equipment.

Such a programme is not based on "current cost" calculations but on energy, environmental and employment considerations.

Ultimately, of course, the level and continuity of employment in the mining industry will depend on the scale, timing and balance between, on the one hand, expansion in gross coal output and, on the other, labour-saving productivity increases due to the introduction of new technology—hopefully softened by technology agreements.

The Future

The coal industry will not disappear overnight, but perhaps the most worrying aspect of the present situation is that, with the NUM defeated, the way is clear for investment in the high productivity super pits which mine the easily won high sulphur coal from the central region. That approach, essentially a myopic one, may be highly profitable but it is very wasteful. It means abandoning the coal in the Scottish and Welsh pits (which will rapidly become impossible to reopen) and ripping out just the easily won coal using giant coal cutters in thick seams. The result could be that instead of us having 300 years worth of reserves, in practice we could be left with only 50 years worth. Then nuclear power might look like the only viable option.

COMBINED HEAT AND POWER (CHP): THE NEGLECTED ENERGY PATH

by Norman Jenkins

Neither conventional, thermal nor nuclear power stations make any use of the waste heat they generate. This waste heat represents at least 50 per cent of the total energy produced, while massive power stations cannot make efficient use of such heat small power stations built and sited within built up areas are ideal for such purposes. The technology involved is well known and is currently used in many European cities including Copenhagen and Hamburg. Why is greater use not made of it in the UK? The answer is that its use would lead to the dismantling of the vast bureaucracy that is the CEGB. Rather than seeing its empire dismantled the UK Electricity Supply Industry continues to pretend that CHP is not economic, worse still it has systematically sought to obtain control of district heating schemes and to close them down, even after years of successful operation.

If there is ever to be any sensible, overall, energy strategy in the UK, serious consideration must be given to the efficiency of the use of fuel. In the production of electricity alone from fuel—whether coal, nuclear, gas or oil—two-thirds are lost irretrievably into the cooling system.

Yet, this wasting of heat can be avoided by balancing the steam turbines to produce a two-to-one heat and power output simultaneously, with the heat distributed as hot water in district heating schemes. And why not?

The Pimlico CHP Scheme in London, which operated in the 1940s, was a great success: the cheapest heat in the UK and electricity produced at 80 instead of 25 or so per cent efficiency. Those turbines could have gone on for their full, normal life of 50/60 years, not the 30 at which they were written off.

The Electricity Supply Industry (ESI) claims that CHP is inefficient because of a loss of electricity when heat and power are balanced at the turbine. It quotes a loss of anywhere between 14 and 20 per cent and, that all calculations must allow for this "loss" to be replaced elsewhere in the electricity system.

In fact the whole object of CHP is to balance heat and power in order to maximise the energy produced from fuel. Therefore that loss of 15 per cent actually turns into a benefit because in a CHP heat distribution scheme heat is the cheaper product and replaces much more expensive electricity, especially when that is used for heating purposes. In fact in CHP the overall energy gain is double that of electricity production alone. It is therefore deliberately misleading to claim a loss, but the purpose clearly is to boost electricity at the expense of CHP.

The ESI also claims that CHP requires more complicated and expensive equipment. Yet, the turbines used for CHP are much simpler and smaller with none of the massive turbine wheels needed to exhaust steam at below atmospheric pressure. Nor does CHP require to discharge water at temperatures that cooling towers can cope with. Indeed CHP dispenses with the need for cooling towers.

In general there has been an establishment conspiracy against CHP. Thus the gas industry claims that CHP would lead to 15 years of traffic dislocation. Mains take a week or two at most to install in any city street and the laying gang moves on—just as with laying gas mains. Pimlico, for one, proved the practicability of district heating as long ago as 1948, but the lessons learned were quickly buried. Nottingham and Slough have wholly successful CHP schemes.

The strategy to centralise power production has led to massive multi-unit power stations with their tall chimneys, giant cooling towers, multiple lines of massive transmission towers and acres of switchgear and transformers.

CHP scales all that down and leads to the siting of a small number of small power stations in or near city centres. Thus, giant monstrosities in the countryside are reduced in size by precisely seven-eighths.[1] Yet if the ESI continues to get its way it will increase the size of power stations and double transmission lines.

Small city-centre power stations eliminate the large numbers of individual gas, oil and coal-fired equipment used at present and enable full control of emissions, minimising, if not eliminating, nitrous oxides—by operating at temperatures lower than the oxidising point—and sulphur dioxide by the use of lime in fluidised bed combustors. All the European capital cities relying on CHP for integrated public supply of heat and power maintain constant atmospheric pollution measurement surveys; their records show steady and continuing reduction of SO_2 and of other contaminants.

While none of those cities have complete consumer saturation—and therefore a completely clean atmosphere—a comparison of those cities with CHP and those without is

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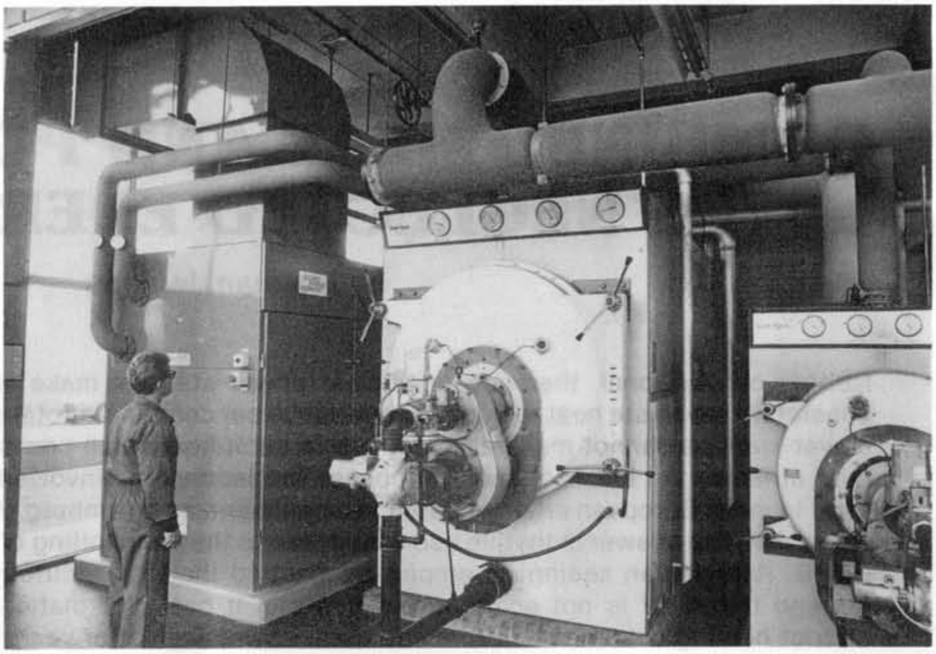
dramatic in terms of pollution and environmental impact.

At the same time cheap energy from CHP has done much to foster city-centre renewal and maintenance in European cities thus avoiding urban dereliction now rampant in the UK. New town programmes of the fifties to seventies encouraged outward movement and dispersal, thus killing the energy justification for CHP.

The UK ESI, concerned only with advancing its own industrial and commercial interests, has helped break up the original city centre power units that could have been connected to CHP. The continued up-grading of the power station building programme with its increasing unit sizes has left perfectly serviceable generating plant redundant after relatively few running hours, and all in aid of bigger and bigger, de-centralised, countryside-dominating factories that have proved only marginally more efficient at producing electricity and much less so at providing integrated energy supplies. The outstanding factor in European energy patterns is the number of city-centre power stations built in the early days of overwhelming demand for electricity that have been readily converted to CHP. The UK electricity industry has to bear a heavy responsibility for its obsession with electricity, and consequent neglect of the joint service that should have developed here as it has elsewhere.

In its organised campaign to combat the installation of public service CHP utilities in the UK the ESI appears to be favourable to the idea in theory, but not in practice. The Marshall Committee set up in 1974 and reporting in '79 suggested a lead city experiment, having totally ignored the Pimlico example, and only on a 'large' scale. Yet, the surest route to disaster is to attempt to set up a 'large' unit equivalent to a modern central, solo-electricity, generating unit. The CEGB can only speak in gigawatt sizes, one electrical gigawatt producing 2,000 MW of heat. At 10 KW per household or equivalent that means two hundred thousand dwellings to be connected in the time it takes to assemble the turbines. A recipe for certain disaster, and an impossiblity they know would never be attempted.[2]

Indeed the Marshall report has been singularly effective in delaying decision.



A 135 Kwe mini-CHP station. Many such stations now operate in European cities.

CHP—Abroad

There are eleven non-communist countries represented in the 100-plus membership of the International Union of Heat Distributors —UNICHAL. UNICHAL has just released, for the first time since its inception in 1954, statistics for a year's operation. Ten countries provided extensive data. The co-ordinated totals indicate not only complete success for many years of CHP operation but a complete refutation of the claims and submissions to the contrary continuously put forward by the UK's energy industries. Britain meanwhile made a nil return.

UNICHAL as a whole has a total of installed equipment capable of meeting an energy load of 114 GW, these 114 GW representing both heat and power. Heat is the larger element or component in the ratio of 9:1 heat to electricity. This nine to one ratio has vital importance. Indeed cities in which hot water is distributed can do away with the use of gas and electricity for space and water heating, and under such circumstances both gas and electricity as national supply industries lose much of their prestige and much of their local-urban-business. On the other hand the domestic cooking load, motor drives, electronic equipment and lights remain as legitimate, premium uses for gas and electricity, but supplied only as minor adjuncts by the comprehensive local energy authority.

Another important reason why local energy authorities should be part of the overall national energy strategy is because they are better able to include those users of CHP that are now being spoken of as *micro CHP* and *co-generators*. These small CHP loads are essential to a rapid system build-up, allowing for diversity. Both micro and co-generation are grudgingly welcomed by the ESI because it can still control the electricity produced, while remaining disinterested in either the heat produced or the effect of CHP on the overall energy pattern.

Lack of integration with the state electricity system is one reason for the nine to one average ratio within UNICHAL's members. With the proper use of a steam turbine the ratio becomes two to one. However when a fully autonomous, local energy authority is authorised and directed to make the most effective contribution possible to its national energy strategy then the heat load it has to satisfy must produce some four times more electricty than it

MINI-POWER STATIONS

Very small CHP stations (mini-power stations) are now available as a fully proven developed, economic alternative. Two hundred units have already been installed in this country, all non-Electrical Supply Industry capital. In Holland there are six hundred, some of which have been installed by the Dutch ESI. Germany is about to follow suit, and many thousands are planned for the USA.

A mini-power station usually consists of an industrial gas engine driving a generator—just like an ordinary power station, but only a tiny fraction of the size—typically 40 kwe compared to a CEGB power stations 2,000,000 kwe. Note that 1kwe or one kilowatt of output is enough to run a 1 bar electric fire.

An industrial gas engine is similar to a car except that it is much more heavily built—and overall is designed for extremely long life, and low running and maintenance costs.

They can be small enough to be installed inside buildings where the waste heat from the engine can be captured in special heat exchangers and used for central heating and hot water.

A recent report from the Open University Research Group showed that the technology could be used in existing houses with one 40 kW(e) unit shared between 40 houses with buried hot water pipes linking them. This would result in about 1 kW(e) of mini-power station per house. Since there are roughly 20 million dwellings in Great Britain, then mini-power stations could provide an output of about 20 million kilowatts, which compares with the CEGB's average output of 25 million kilowatts.

According to the South Bank's Centre for Energy Studies the following advantages of mini-power stations were described by academics and engineers who had studied them:-

- Completely safe
- Capital costs ⅓ that of the proposed Sizewell B nuclear power station
- Power produced at ⅓—⅔ the cost of Sizewell
- Low pollution levels
- Three times as efficient as a conventional power station
- Could produce all UKs power without increasing UK fuel bill
- Could be built and installed much more quickly than conventional power stations (2 months rather than 10 years)
- Use only proven technology.

A number of ill-founded criticisms have been made of mini-power stations mainly by the ESI who quite cynically attempt to mislead journalists and politicians enquiring into this issue:-

1. Too many engines would be required. Wrong. To take over the entire CEGB production would require about a million engines of 40 kW(e). This apparently large number has to be compared with the 20 million similar sized road vehicle engines already in use in the UK and the annual UK production of 2 million engines.

2. They would not be reliable enough. Wrong. Analysis based on the CEGB's own methods show that this is not true. A large number of small stations is more reliable than a small number of large power stations. Put another way, when did all the UK road vehicles last break down simultaneously?

3. The engines would not last long enough. Wrong. Industrial engines used in mini-power stations have been used in the oil industry for over 50 years. They are designed for very long lives and there are examples that have clocked up the equivalent of 30 years continuous running.

4. Maintenance costs are too high. Wrong. Industrial engines have very low maintenance costs. A 40 kwe unit has maintenance costs of about 20p an hour, including oil, labour and parts. This is equivalent to about 0.5p per kw hr —the normal domestic consumer is charged about 5.5p per kw hr. One kw hr—(kilowatt hour) is the amount of electricity needed to run a one bar electric fire for one hour.

5. Mini-power stations are only economic because of low gas prices, a situation which will not last for long. Wrong, again. Since they convert gas into heat as efficiently as existing gas boilers, and thus do not consume any extra gas for generating electricity, the price of electricity produced is largely independent of the gas price. Over the past ten years electricity prices have risen four times faster than gas prices. Modules are also available which will run on coal dust if gas becomes, prohibitively expensive. The known reserves of uranium are similar to those of natural gas.

What about overall costs of mini-power stations compared to the alleged costs of nuclear power? When comparing costs of different generating technologies three factors must be taken into account: Capital costs, power production or running costs, and hours per year at full load, or availability.

Capital Costs

This is the initial building cost of the technology. Since power stations come in different sizes, then it is normal, for comparison purposes, to divide the total building cost of the power station, in pounds, by the eletrical output, usually expressed in kilowatts. Here mini-power stations have clear advantage of nuclear power, in that nuclear costs about £1500 per kwe, whereas mini-power stations cost a mere £500 per kwe.

Power Production or Runnng Costs

This is the total cost, in terms of fuel, maintenance and labour needed to produce each unit of electricity, or kilowatt hour. With present boiler technology, mini-power stations do not have any fuel cost, since they are using the same fuel that the boilers are using. Thus the only power production cost is the cost of maintenance, and this is about 0.5p per kw hr. As more efficient modern boilers are introduced, then it would be fair to include a small extra fuel cost, even assuming 90% efficient condensing boilers CHP still comes out cheaper than nuclear. And this ignores the fact that over the period of their introduction, the heat efficiency of CHP will rise to about 70%, and the capital costs will probably halve.

Availability

Clearly the number of hours that a power station can run each year affects the cost of the power it produces. The capital cost of the station has to be shared out amongst all the units it produces each year. The more it runs, the cheaper the electrical units are in terms of capital charges. The average availability of the mini-power station in the UK is about the same as the average availability of the CEGB's, and, during the winter, it is and can be much higher.

Discounted cash flow analysis is the method used by the CEGB and others to combine capital costs, power production costs, and availability to produce a single figure for the costs of a unit of electricity. The latest figures from the CEGB are contained in the "Analysis of generation costs—1983/84 update". If we extract from this document the costs of generation of current coal and nuclear stations under construction, and those of the proposed Sizewell reactor, we can compare these costs with those of mini-power stations. Such a comparison reveals that the latter are very much cheaper.

	Nuclear Sizewell	Nuclear Heysham 11	Coal Drax B	Mini-Power (a)	Mini-Power (b)	Mini-Power (c)
Capital	1.99	2.11	0.81	0.7	0.7	0.46
Running	0.95	1.25	2.08	0.5	1.94	1.19
Total	2.94	3.36	2.89	1.2	2.64	1.65

These calculations are conservative for the following reasons.

1. Large central power stations incur 9% losses, in transmitting and delivering power to the final user, thus increasing both unit costs and capital costs by 9%.
2. Many thousands of small power stations, overall are much more reliable than one large one. So to get the same effective capacity, much fewer mini-power stations would be needed, leading to lower costs per effective kwe of capacity.
3. To cope with the unreliability of large power stations, the CEGB has had to build pumped storage schemes like Dinorwic; construct the Cross Channel link; and to keep a large fraction of power stations, standing by, consuming fuel to no good purpose (spinning reserve and hot standby). These measures increase the real capital costs, and running costs of central power stations.

It must be noted that such calculations are based on CEGB's own figures, which as repeatedly shown (see Sir Kelvin Spencer's CSENE report in *The Ecologist*, Vol 11 No 6 and P. Bunyard's article on p. 192 of this issue) have been vast understatements. Why, we must ask, does the ESI show no interest of any kind in CHP and in particular mini-power stations? How can they reconcile their policy in this respect with their statutory obligation to provide consumers with the cheapest possible electricity?

David Andrews

The nuclear figures have come from the CEGB's Analysis of Generation Costs—1983/84 update. The costs for Heysham 11 and Drax B, power stations under construction, are derived by using the fuel figures for the equivalent existing operating stations, in the same document, table III, and substituting in table V.

(a) This is for a mini-power station, at £500/kwe, with a thermal efficiency of 65%, electrical 25%, competing with a boiler with a seasonal efficiency of 65%.
(b) This is for a mini-power station, at £500/kwe, with a thermal efficiency of 65%, competing with a condensing boiler with a seasonal efficiency of 90%.
(c) This is for a mini-power station at £330/kwe, with a thermal efficiency of 70%, competing with a condensing boiler with a seasonal efficiency of 90%.

needs within its high-density heat load boundaries.*

In fact local energy authorities, having been given full autonomous powers, should form part of a national energy strategy. Where such central direction exists the winter surplus of cheap electricity is fully maximised. Taken to its logical conclusion, a focus on a national energy strategy would actually produce the cheapest electricity at times of maximum peak demand instead of making for the most expensive tariffs as is the case under present ESI policy.

Apart from UNICHAL, there is no agency to promote CHP as the basis of either national or international energy strategy. In fact the relative influences on present-day policies and discussions are grossly out of balance. The International Energy Agency, the EEC, OECD and the UN have virtually no energy strategists, no independent view. Significantly the EEC energy division even has a logo epitomising electricity as synonomous with energy, ignoring, perhaps unaware, of the larger part heat should be playing. One EEC department has even been established to ensure the substitution of electricity for fuel-burning—rather than to see how hot water could be substituted for electricity. To call this crazy is no exaggeration.

Meanwhile the House of Commons Select Committee, has been exemplary in its support for CHP and the new Energy Act of '83 has been a positive step forward. Yet even that has been emasculated by an undercover agreement between the ESI and the Department of Energy. Thus as long as the *status quo* remains unaffected, CHP would be welcome and the ESI will do as it is told—"adopt and support"—but not, *promote.*

The Select Committee believes that the ESI, and possibly the Area Boards, should be directed to promote CHP. Yet how can they adopt a business that must at all points conflict with everything they have built up over more than 40 years? Is it any wonder they must continue to obstruct?

The only real solution would be a Central Energy Authority to determine all choice and priority, to differentiate between fuels and services, to maximise energy reserves and minimise reserves depletion, to optimise conflicts between utilities, including amenity conservation; to police new legislation authorising local energy undertakings with full powers to operate as one all-urban engineering services in limited areas, thus maximising power generation on the back of heat distribution. An *energy council* to ensure these functions is the only sensible and, ultimately, the only workable solution.

The cooling tower of a modern ESI power station—A Heat-Wasting Plant.

* The CEGB has an electrical capacity of 51.127 GW. Computed on the basis of slight increases of thermal efficiency year by year since 1947, and increasing fuel prices, some £26,000 million has been sent to waste. At £20 per ton the current (1985) annual waste is no less than £229m. A full committment to CHP would avoid this waste and also use less fuel.

References

1. For a full explanation, calculation and diagram see the Select Committee's report 314/2 Appendix 24. Credit: Henrik Harboe, Stal Laval GB Ltd.
2. Explained in greater detail in the Select Committee's recently issued Paper No. 235, Memo 10.

N.B. Both of the above publications should be read in conjunction with this article. Apart from the UNICHAL statistics published in July, 1985 for the first time, many more references to the history of these developments are quoted.

The Potential for Renewables

by Michael Flood

The potential for renewable energies has always been underestimated and derisory sums provided for research. Instead most of government funding in energy has gone for nuclear power, the lion's share on the fast reactor. With energy conservation and improved efficiency Britain's overall energy needs can be substantially reduced and increasingly met by relatively benign sources of power.

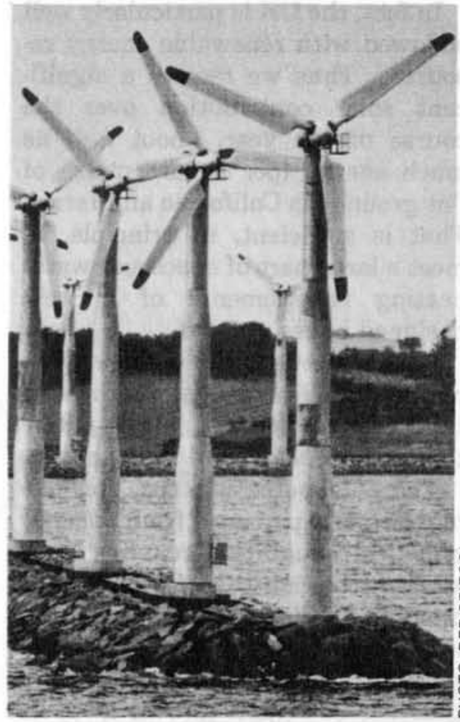


PHOTO: DER SPIEGGL

All those involved in the energy field have their own pet views about how energy should be supplied and used in the future, and about what is desirable and what is possible. Some are in favour of an increased role for nuclear power, others argue for the rapid introduction of the renewables, those technologies that capture energy from the sun, the wind and the waves. Most agree that improved energy efficiency is desirable but disagree fundamentally on what improvements are possible and how a programme of measures might be implemented.

It is my belief that renewable energy technologies could and should play a more prominent role in helping to meet this country's energy needs in the future. Meanwhile we must reduce our dependency on fossil fuels and nuclear power through the implementation of policies designed to improve fuel efficiency and encourage the introduction of selected renewable energy technologies.

Undoutedly such a strategy would be difficult to implement and would take time, but the totality of technical, economic, political, social and environmental problems that would be encountered would be more manageable than those associated with conventional energy strategies.

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The Role of the Renewables

The renewables are important because they are indigenous and offer a secure source of energy supply; and have the potential to meet an important part of our energy needs in the longer term; they are diverse in character and relatively small scale, which offers greater flexibility in planning and reduces dependency on coal and oil; they are relatively benign—their use can reduce chemical, radioactive and thermal pollution; and they offer the prospect of major new export markets. Last, but not least, the renewables are popular—people like the idea of using the sun and the wind, even if, in practice, they do not always appreciate what this would mean.

Already the renewables play an important role in the world. Hydroelectricity currently accounts for about one quarter of the world's electricity, and biomass (in the form of fuel wood, crop residues and dung) is thought to provide about a seventh of the primary energy, hence half as much energy as oil, and two thirds as much as coal. Official statistics tend to ignore non-commercial fuels like biomass.

By listing the many attractions of harnessing the renewables, I would not wish to minimise the problems, some of which are quite formidable. The resources are often intermittent and variable—storage or back-up is therefore necessary if firm supply is required; they have low energy density—which makes it necessary to cover large areas. Many of the current generation of technologies involve financial risks because they are immature; high unit costs, because of small scale production; and more supervision, because they are more temperamental than conventional alternatives.

Conflicts of interest may also arise from environmental factors, for example, whether to build a tidal barrage which might upset an established wildlife sanctuary, or put wind turbines along a beautiful stretch of coastline. The technologies are also handicapped by a lack of established markets; a lack of institutional and political support; and a widespread ignorance of their nature and potential.

Setting the Context: The Potential for Renewables

Simply analysing the technical potential of each of the resources is not much use, although it does prevent wild claims from being made. It is far more important to investigate what possible contribution each technology might make in the context of an integrated and coherent strategy. Setting the context also avoids misleading comparisons being made between technologies that are of fundamentally different character and scale.

In fact, the UK is particularly well endowed with renewable energy resources. Thus we receive a significant solar contribution over the course of the year, about *half* as much energy (per square metre of flat ground) as California and Israel. That is sufficient, in principle, to meet a large part of space and water heating requirements of a well-designed house.

We are fortunate in having a *wind* regime that is amongst the best in the world; and there is major potential for both *wave* and *tidal* energy.

There is potential, too, for *biomass,* perhaps not from energy crops—although that remains to be seen in the context of the current crisis in UK agriculture—but from wastes. The energy content of the municipal and industrial wastes that are currently thrown away is equivalent to almost a tenth of primary energy use; and there is also energy available in agricultural and forestry residues.

But perhaps surprisingly the biggest potential of all lies in the rock beneath our feet; geothermal heat could meet all of our energy needs for hundreds, and perhaps even thousands, of years if Hot Dry Rock technology can be perfected.

However, technical potentials are not a very useful measure of a resource. What is more interesting is how much energy could usefully be recovered taking into account economic, social and environmental factors.

It is now quite possible to make some realistic assumptions about the contribution that the renewables could make in the future to energy supply in the UK.

We now understand better the opportunities offered by energy conservation and the renewables as a result of the work of a large number of organisations over the last ten years. These include the International Institute for Environment and Development (Leach et al), Earth Resources Research (Olivier et al), the Energy Technology Support Unit at Harwell, and countless independent consultants.

I should like to take as a starting point a hypothetical scenario (Fig 1, that is less demanding than some of the "hair shirt" scenarios developed by ERR, but which might still be regarded as "beyond the pale" by conventional policy analysts who cling to the belief in ever growing primary energy consumption.

It must be stressed that the scenario is very crude, and has not been worked out in detail. Its purpose is solely to investigate how much energy we could realistically get from the renewables forty years hence, and to identify what it might cost in environmental and social terms.

To do this I have assumed that vigorous efforts are made to improve overall conversion efficiencies in all sectors of the economy, in many ways this is *the* most important feature of the strategy; and that a coherent programme is introduced by the government which is designed to encourage the rapid deployment of renewable energy technologies.

I have also assumed that economies of large-scale production bring down the costs so that the renewable energy technologies become more competitive with conventional systems; and that energy investments that take account of the national good rather than the "quick buck" are encouraged by the government.

As a result of these measures primary energy falls by 30 per cent over the course of 40 years, from 8,325 PJ (313 mtce) in 1984 to 5,825 PJ (219 mtce) in 2025—a reduction of well under 1 per cent per year and that the contribution from the Renewables grows to meet 20 per cent of this demand, i.e. 1165 PJ (44 mtce) by 2025.

All of this could be achieved along with a significant rise in living standards, as is projected in several of the low energy scenarios that have been published.

In defence of the scenario it should be noted that we are a very wasteful nation, with plenty of slack in the system. Thus 60 per cent of the energy dug out of the ground is dissipated unproductively (as heat) during conversion, distribution and use; and despite the current crisis in the oil market, fuel prices are likely to increase in real terms over the period in question making people more aware of the importance of energy and forcing them to take greater care over its use. We will begin to feel the bite when North Sea oil and gas starts declining later this, or early next, century.

Which Technologies and Renewables?

Some 85 per cent of the energy would come from three resources, wind, biomass—essentially organic wastes rather than energy crops—and geothermal, with smaller contributions from solar, tidal, hydro and wave.

However, the precise mix of technologies and their contribution could be very different.

Wind

The scenario assumes that 1,000 large (4MW), and 3,000 medium-sized (500 kW) wind turbine generators (WTGs), are built on land; and that 2,000 very large machines (8MW) are built offshore. These supply an estimated 54 TWh of electricity, about a fifth of current annual demand (a little more than nuclear stations supply at present).

The turbines would be in dispersed arrays and provide some degree of firm power. (Variations in output would be gradual and could be predicted with a fair degree of accuracy.)

Such a programme would inevitably involve some environmental impact. Wind turbines can give rise to problems with noise and TV interference.

Modern machines can also be very attractive. They need not be noisy nor an eyesore, as I myself discovered last summer when I visited a number of wind farms at Altamont Pass in California where there are several thousand WTGs.

Erecting wind turbines on land does not prevent, nor seriously hamper, normal agricultural activities and can increase the economic return on land. (In the Altamont Pass it is actually proving more profitable than agriculture.) Erecting wind turbines at sea has minimal environmental consequence.

Careful attention would need to be paid to siting, especially with the larger machines where scale effects could be important. Multi-megawatt WTGs would probably be more appropriate in flat, open country.

At realistic array densities (with six 4MW machines, and twenty 0.5

MW WTGs to the square mile), 4,000 machines would occupy 325 square miles, roughly 0.34 per cent of the total land area of the UK.

The impact of such a programme would be small compared to that of our national grid—which, incidentally, would have to be significantly reinforced were more of our energy to be delivered in the form of electricity. We have grown accustomed to ugly pylons and power cables—we already have over 50,000 large pylons and 10,000 route miles of high voltage cables, and in addition, around a quarter of a million route miles of overhead low voltage cables.

Biofuels

Biomass, the second renewable resource in my scenario accounts for almost 150 PJ of heat (6mtce) and 10 TW of electrical energy per annum. This comes almost entirely from domestic and commercial refuse, industrial wastes and agricultural and forestry residues. This is equivalent to only about one third of *current* biomass waste arising in the UK. The energy would be recovered principally by direct combustion (in heat-only installations and a small number of CHP schemes), as well as in the form of biogas from the digestion of refuse at landfill sites, and some farm wastes. The contribution from biofuels would be equivalent to 50-60 refuse-burning plants, each of around 100 MW capacity.

Using wastes to provide energy is likely to *reduce* significantly the environmental impact associated with current waste disposal practices. It is also economically very attractive.

Geothermal

The third main contributer is geothermal energy. Some 230 small installations could be in operation in 2025, providing almost 180 PJ of heat and a small amount of electricity. This includes 30 Hot Dry Rock (HDR)—CHP schemes (each of 12 MWe/120 MWth capacity); 100 heat-only HDR installations (each of 50 MWth); and 100 small Hot Aquifer (HA) schemes (each of 5 MWth).

(The technology of Hot Aquifers has proved something of a disappointment in the UK because of unforeseen geological problems. This is why a bigger contribution has not been indicated.)

Small HDR geothermal schemes are not likely to have any significant environmental impact, especially when used to provide heat or combined heat and power since no unsightly cooling towers would be required.

The geothermal and biomass installations would provide firm power; and there would be some firm power also associated with the arrays of wind turbines, since it is rare that flat calm prevails over the whole of the country.

Solar

Five million passive solar installations could be installed, equivalent in number to roughly one quarter of the current housing stock; 3 million solar water heaters (4 m^2) using advanced vacuum tube technology, which is more efficient than that used in conventional flat plate collectors.

Tidal

One or more small tidal schemes with an output of 6 TWh per year, roughly the amount of energy that might be generated by barrages built across Morecambe Bay and the River Mersey (estimated at 4.5 TWh/yr (2.4 GW); and 1.26 TWh/yr (0.62 GW), respectively).

The proposed Severn Barrage, if built, would produce an additional 13 TWh per year.

Hydro-Electricity and Wave

150 MW of new, mostly small, unmanned (>10 MW) hydro-electric schemes, a very modest expansion of our existing 1,300 MW of capacity could be installed and 10 small (5 MWe) wave energy stations, perhaps using Lanchester Polytechnic/Sea Energy Associates' Clam technology, or scaled up versions of the Oscillating Water Column device recently completed by Kvaerner Brug in Norway. (Their prototype has a peak rating of 500 kW and is generating electricity at an estimated 3.4 pence a unit).

Is the Scenario Realistic?

I consider this scenario to be very modest compared with some that have been suggested. It would not be difficult to find ways in which the contribution from the renewables might be increased quite substantially. Even so, the question still arises; is it realistic? It is perhaps more appropriate to turn the question around and ask: is the scenario any *less* realistic than more conventional scenarios which are based primarily on increased use of fossil fuels and nuclear power?

Official definitions of radioactive waste

Low-Level Wastes

Wastes containing radioactive materials other than those acceptable for dustbin disposal, but not exceeding 4GBq/te alpha (about 100 mCi/te) or 12GBq/te beta/gamma (about 300 mCi/te).

Intermediate-Level Wastes

Wastes with radioactivity levels exceeding the upper boundaries for low-level wastes, but which do not require cooling to be taken into account in the design of storage or disposal facilities.

High-Level, or Heat-Generating, Wastes

Wastes in which the temperature may rise significantly as a result of their radioactivity.

Very Low-Level Wastes

Wastes whose very low levels of activity mean that they have been exempted from detailed control under the Radioactive Substances Act 1960 or, if subject to authorisation, can be safely disposed of with household refuse (dustbin disposal): up to 0.1 cubic metre of material containing less than 400 kBq (10 uCi) beta/gamma activity or single items containing less than 40 kBq (1 uCi) beta/gamma activity.

Source DoE

Conclusion

Energy efficiency measures could reduce primary energy use by 30 per cent and save energy equivalent to 95 million tonnes of coal; with a further 45 mtce being met by harnessing indigenous renewable sources of energy, making a total saving of around 140 mtce on current levels of energy use.

Meanwhile wind, biomass and geothermal would provide the bulk of this renewable energy (85 per cent); the remainder coming from solar, tidal and hydro-electric schemes with a small contribution from wave energy.

The importance of conservation is that it reduces significantly primary energy production and consumption. If 60 per cent of the 140 mtce of savings in a low energy strategy came from coal, then 84 million tonnes would be saved, equivalent to the output from 5-6 Selbys. Selby is expected to produce around 15 mtc/yr in the 1990s. The scenario avoids having to find the capacity. It would also avoid the release of 2.5 mt of oxides of sulphur and nitrogen and 250 mt of carbon dioxide.

To use nuclear power to provide the contribution ascribed here to Renewables—some 45 mtce—would require 35 Sizewells being built between now and 2025—and probably another Windscale or two, if nuclear fuel reprocessing were to be continued. This would be equivalent to building one reactor a year from 1990 onwards. Meanwhile conventional nuclear scenarios assume that many more stations would be built than that.

By way of comparison, the Renewables scenario would involve building 50-60 small (100 MW) refuse burning plants, 230 geothermal installations; and 6,000 WTGs, one third of them offshore.

In fact 3-400 small wind turbines were installed in Denmark in 1984, which has over 1,400 grid-linked machines in operation; 600 MW of wind turbines were installed in the United States (principally in California) over the course of just three years; and France has been installing hot aquifer geothermal schemes at a rate of 20-30 per year and now has over 40 in operation.

Yet, despite the promise from the renewables the Government currently allocates around £12-14 million per year to the Renewables and 20 times that on nuclear R & D.

Whether a low energy strategy will come about depends on how much people accept its logic and the appeal of low energy strategy including reduced energy wastage, greater diversity of supply, and more careful husbanding of natural resources, while objecting to current policies based on the increased use of fossil fuels and nuclear power.

The Contribution from Renewables in 2025

	Electricity Installed capacity (GW)	Electricity Units generated (TWh)	Heat (PJ)	Heat supplied or fuel saved (PJ) (figs rounded)
WIND				
onshore	5.5	12		>540
offshore	16	42		
BIOFUELS				
CHP	1.1	10	64	>250
heat only			83	
GEOTHERMAL				
HDR-CHP	0.36	2	72	>200
HDR-heat			95	
HA			10	
SOLAR				
Passive			50	>70
Active			20	
TIDAL	3	6		60
HYDRO	1.45	4		40
WAVE		<0.5		
Total	27.4	76.3	394	1160

SHUT THEM DOWN

by Colin Hines

Greenpeace launches a campaign to shut down all Britain's nuclear reactors in four years

Chernobyl has irrevocably shattered the illusion that nuclear power is safe. Public concern, in some cases panic, has led to a collapse in public confidence in the nuclear industry and its government apologists, and a new term 'lies, damn lies and official assurances' has entered the public domain. The opposition parties were forced, to varying degrees, to rethink their old pro-nuclear policies, and concepts like no new reactors and vague phase out timetables became the order of the day. Greenpeace is convinced this is a pitifully inadequate response and so is launching a campaign to shut all British nuclear reactors in the life of the next parliament. We are certain that Britain can be free of nuclear reactors *4 years after the next election.*

In addition to a Shut Them Down policy, Greenpeace is also calling for no new reactors to be ordered, the unopened reactors at Heysham and Torness to be mothballed, for all reprocessing at Sellafield to stop, for the fast breeder programme to be abandoned, for nuclear waste to be stored in a monitorable, retreavable form, on land (where feasible, in dry storage at Sellafield), until an acceptable, proven solution to the problem of waste storage has emerged.

It must be faced, however, that fearful as many people are of nuclear power, they still have not been able to shake off the worry, so carefully nurtured by the industry, that somehow Britain will freeze and starve in the dark unless we have nuclear power. In order to kill this myth, Greenpeace commissioned a study by Earth Resources Research*, to find out what was the earliest date that ALL nuclear reactors could be shut by, without dislocation of supply, given a political commitment to do so by the next government. The report assumes that all the usual democratic processes of parliamentary debate, select committee hearings and consultation with and comprehensive planning by the electricity supply industry have taken place, in order to compensate for the loss of the nuclear component. Given this, it concluded that following an election in 1988, all reactors could be shut down by the end of 1992, ie. ALL BRITISH NUCLEAR REACTORS COULD BE CLOSED IN FOUR YEARS, WITHIN THE PROBABLE LIFE OF THE NEXT PARLIAMENT.

The effects on electricity supply and costs of this shut down programme were calculated using a validated computer model developed by Earth Resources Research for the Sizewell Enquiry. It showed that assuming that all the Magnox reactors were shut by the end of 1989, and all AGR reactors by the end of 1991, then the years 1992 to 1994 will present the biggest problems until the first of the large new coal fire stations is opened in 1995. During this difficult three-year period, Greenpeace also insisted that any imports of up to 2 gigawatts of electricity that could be obtained via the French link would also be halted, since this would inevitably have a strong nuclear component, given that around 60% of France's electricity is generated by nuclear stations.

To compensate for the shortfall will require all the technical and managerial skills that the Electricity Supply Industry can muster. The transition from nuclear to new coal fired stations (fitted of course with pollution control equipment) will require a mixture of the following measures:-extending the notional lives of the existing coal fired stations as has happened in the past; doing likewise for the oil stations; reinforcing the transmission link to export surplus Scottish electricity to England; ordering two new 1.875 GW coal stations in 1988 to come on stream in 1995; ordering small coal combined heat and power (CHP) stations also to produce electricity in 1995; ordering new gas turbines, some to be associated with the new coal plant and some with small CHP/district heating schemes and running stations harder and longer than is normal. These measures are all under the control of the Electricity Supply Industry and many of the lessons learnt coping with prolonged abnormal shortfalls in electricity supply during the miners' strike can obviously be put to use in furtherance of this less divisive non nuclear goal. In terms of consumer habits, industrial combined heat and power will be encouraged, electricity demand during peak periods will be reduced by load management incentives and a modest programme of electricity conservation in domestic white goods, industrial motors and commercial lighting is assumed.

Greenpeace is aware that this transition will not be simple, it will require comprehensive forward planning and a strong political will. Towards the end of the 90's, comprehensive conservation measures, encouragement of alternative energy sources etc will allow for a more diversified and benign energy supply system to develop. The cost of this programme will be roughly equivalent to a 10% rise in electricity costs. Careful use of the usual creative accounting techniques by Government could minimise any adverse effects of this on the performance of British industry and could protect against fuel poverty.

In terms of jobs, the work required for decommissioning and waste management for new stations, plus the jobs saved in the coal industry will result in a new increase in employment. In terms of those employed at power stations, after early retirement and relocation, the job losses are unlikely to exceed 5,000. (The CEGB rationalisation programme has itself shed 50,000 jobs in the last 20 years.)

Finally, post Chernobyl, Greenpeace is convinced that any future British government must have an emergency plan to deal with a severe nuclear accident in Britain, before the total shutdown programme is completed. In addition to the evacuation plans and other measures necessary to cope with the accident itself, public clamour would demand a virtual immediate shutdown of all reactors. The practicalities of drastically reducing electricity demand will therefore need to be worked out in detail. The 'Shut Them Down' report outlines what form this emergency plan might take. After the Russian experience, no government can be 100% sure it won't happen here and so the need for such contingency planning must be of the utmost priority for the next government.

* **Shut Them Down**—a report of the practicalities of closing all Britain's nuclear reactors in four years' will be published in September, available from Greenpeace, 36 Graham Street, London N1 8LL.

Books

The Thirsty Destroyer

ECOLOGICAL AUDIT OF EUCALYPTUS CULTIVATION IN RAINFED REGIONS by Vandana Shiva and J. Bandyopadhyay, Research Foundation for Science Technology and Natural Resource Policy, Dehradun, India.

Some four million hectares around the world are under eucalyptus. Much of that land has been planted in an effort to halt desertification by reafforesting areas which have been denuded of tree cover in the quest for timber and firewood. Eucalyptus has been the favoured tree in such reafforestation schemes primarily because it is fast growing. It has also been promoted as a tree which helps build up the soil and conserve water.

Such claims are wholly misleading, argue Vandana Shiva and Jayanta Bandyopadhyay. They provide a wealth of data to back up their case, making it plain that eucalyptus has proved an ecological disaster when planted outside its native Australia. It is vulnerable to pests; it depletes the soil of nutrients; its shallow and thirsty root system prevents the recharge of groundwaters; it supports little wildlife; and it is no faster growing than many indigenous species of trees which are ecologically more appropriate to local conditions.

Eucalyptus was first planted on a large scale in India in the 1850s to supply fuelwood for European settlements. The second wave of large-scale eucalyptus planting came a century later "when the rapid expansion of pulp-based industries in India led to the destruction of conventional raw materials like bamboo stocks."

Thousands of hectares of tropical rainforest, mainly in the Western Ghats, was felled in order to plant eucalyptus, on the grounds that eucalyptus would "improve the productivity" of the area. Little thought was given to the ecological suitability of eucalyptus. It was only after nearly 40,000 hectares of eucalyptus in the Western Ghats had succumbed to the fungus *Cortecium salmonicolor* that foresters discovered that eucalyptus is vulnerable to pest attacks and disease when planted in areas of high rainfall and low altitude. One of India's top foresters now admits: "Eucalyptus suffer from many diseases. Major losses to eucalyptus in exotic locations are caused by indigenous pathogens against which eucalyptus has had no chance to develop natural resistance."

The failure of eucalyptus plantations in the Western Ghats did not discourage India's foresters, however. Far from questioning the wisdom of planting eucalyptus (or other exotics) in India, they switched their efforts to planting eucalyptus in "arid regions with annual rainfall between 700 and 1250 mm."

One of the reasons given for not planting indigenous species was (and still is) that eucalyptus is faster growing, a claim which Shiva and Bandyopadhyay show to be quite unjustified. "Even when biotic and climatic factors are conducive to good growth, eucalyptus cannot compete with a number of indigenous fast growing species." They go on to quote a 1967 report from India's prestigious Forest Research Institute, Dehradun, which states:

"Some indigenous species are as fast growing as, and in some cases even more than, the much coveted eucalyptus."

Indeed, when the Gujarat Forest Department compared the growth rates of ten species of exotic and indigenous species, eucalyptus emerged at "the bottom of the list".

Shiva and Bandyopadhyay list 20 native species with a growth rate exceeding that of eucalyptus. Under the best conditions, eucalyptus grows some 10 cu. metres/hectare/year—the average being 5 cu.m/ha/hr. By contrast, *Duabannga Sonneratioides* is two to four times faster growing (19 cu.m/ha/yr); *Dalbergia sissoo* three to six times faster growing (33.73 cu.m/ha/yr); and *Toona ciliata* at least twice as fast growing (19 cu.m/ha/yr).

Shiva and Bandyopadhyay conclude: "Eucalyptus is a slow producer of woody biomass even under very good soil conditions and water availability."

The above figures only compare the "annual increment in woody biomass"—that is, the yearly growth in the tree's trunk. Other measurements of growth might include the amount of fodder and fertiliser leaves produced; the amount of fruit or nuts; or the volume of oils produced. Such indices of growth are never considered by India's foresters, say Shiva and Bandyopadhyay. If they were, eucalyptus would quickly emerge as a singularly unproductive tree when compared with indigenous species. It produces neither food, nor fodder, nor fertiliser—and its wood is next to useless for firewood, since it burns too intensely.

"The benefits of eucalyptus have often been unduly exaggerated through the myth of its fast growth and high yields", write Shiva and Bandyopadhyay. They go on to accuse India's state forestry departments of "suppressing data that reveals that we have plenty of superior options in the selection of species . . . for satisfying ecological and social criteria."

According to Shiva and Bandyopadhyay, eucalyptus' dominant position in India's reafforestation programme is largely based on the results of a *single* experiment, undertaken by the Uttar Pradesh Forest Department, comparing growth rates in a selection of one year old trees. As such, the experiment is wholly misleading as a guide to the performance of adult trees. Thus, the juvenile eucalyptus come out as the best leaf producers of the seven trees in the experiment. Yet adult eucalyptus are famed for producing very little leaf litter. So too, the experiment suggests that *Pongamia pinnata,* an indigenous species which yields up to 125 tonnes of seeds and fruit per hectare, is only valuable for its roots, since its crown grows little in the first year.

"In the history of forestry science in the world", write Shiva and Bandyopadhyay, "there is no parallel to this unrealistic extrapolation of juvenile single plant data being the justification for large-scale afforestation programmes in all agroclimatic zones of the country". They point out that it is well known that the growth rates of eucalyptus vary with age.

The Uttar Pradesh experiment is just one example of how India's foresters have used selective data to "justify" their decision to plant eucalyptus. They have also systematically ignored evidence that eucalyptus is an ecologically ruinous crop. One problem is that eucalyptus is an extremely thirsty tree. Farmers in many arid areas now blame eucalyptus plantations for lowering the water table and causing streams to run dry. Such is the depth of feeling that villagers in Karnataka have resorted to pulling up eucalyptus saplings from plantations and nurseries.

In its native Australia, eucalyptus occurs in areas with good rainfall. It does not feature naturally in the arid areas of central Australia, except near rivers and other water sources, thus indicating that the species prefers humid and semi-humid environments. "Nowhere in its native habitat is eucalyptus found as a self-sustaining system of vegetation in regions poorly endowed with water." In India, however, the authorities have chosen to plant eucalyptus in the driest areas of the country.

The hydrological impact of eucalyptus has been studied extensively by CSIRO in Australia. One long-term experiment found that eucalyptus caused a fall in the moisture content and in groundwater tables if there was less than one centimetre (cm) of rain a year. "Quite clearly, in the semi-arid regions of India, where the rainfall is about 700 mm, the soil moisture and groundwater deficits created by eucalyptus plantations will act cumulatively, resulting in groundwater depletion, soil aridisation and desertification," comment Shiva and Bandyopadhyay. They go on to point out that the water deficit in the area studied was only made up after a prolonged period of rainfall—some 1477 millimetres being recorded in the year. The arid regions of India *never* enjoy years of such high rainfall. "Eucalyptus, which is ecologically adapted to its native habitat in Australia thus threatens to become a serious ecological hazard in the water deficit regions of India."

Despite the evidence from CSIRO and other research groups, the Indian authorities continue to deny that eucalyptus lowers the groundwater table. In support of that claim, K. M. Tewari, President of the Forest Research Institute, cites a set of *theoretical* calculations which put the evapotranspiration rate for eucalyptus at a mere 345.7 mm. That figure, however, is a third of the observed rate for the tree. Shiva and Bandyopadhyay accuse Tewari of treating eucalyptus plantations like "so many paper cones" when making his calculations. He assumes, for example, that the trees "only transpire through that part of the surface crown which is exposed to direct sunlight." No account is taken of the evapotranspiration losses incurred through exposure to reflected sunlight or through the inner leaves of the tree. Significantly, studies carried out by other scientists put the transpiration rate for eucalyptus at between 1136 mm and 5526 mm—compared with 564 mm for birch, 140 mm for mixed forest and 870 mm for mountain forest.

The Forest Research Institute argues that eucalyptus has the capacity to lower its water intake when water is scarce. This claim, say Shiva and Bandyopadhyay, is utterly baseless. In reality, eucalyptus has no such capacity: even under conditions which would trigger off water conservation mechanisms in many other species, eucalyptus continues to guzzle water. It is able to do so because its shallow root system, radiating out for some distance from the tree, enables eucalyptus to appropriate far more surface water over a far wider area than trees with a deep tap root. The lack of such a tap root, however, means that eucalyptus is far less resistant to drought than such indigenous species as *Dalbergia sisoo, Anzadiracta Indica* or *Accacia nolotica.* Nonetheless, the Economic and Planning Council of Karnataka is encouraging eucalyptus plantations on the grounds that the tree grows well in drought-prone areas.

The shallow root system of eucalyptus has two major ecological impacts if the tree is grown in arid areas. Firstly it prevents the recharge of groundwaters by absorbing rainwater before it can percolate through the ground to the lower soils. This "passive" depletion of groundwaters has been overlooked or willfully ignored by India's foresters, who insist that eucalyptus cannot possibly lower groundwater tables because it lacks a deep tap-root. In reality, the tree's shallow root system, combined with its high water requirements, makes the depletion of groundwaters in arid areas almost inevitable.

Secondly because the tree monopolises the surface water supply over a wide area, it inhibits the growth of other plants. Not surprisingly, eucalyptus plantations are virtually devoid of undergrowth. This leaves farmers with less fodder for their animals.

Finally, Shiva and Bandyopadhyay deal with the effects of eucalyptus on the soil, effects which can only be described as calamitous. Eucalyptus is a "Take, take, take" tree, requiring large inputs of nutrients but returning little to the soil in the form of leaf litter. It is estimated, for example, that *Eucalyptus hybrid*—the most common species of eucalyptus in India—requires some 217 kg of nitrogen, 100 kg of phosphorus, and 1594 kg of calcium per hectare per year. Yet, it returns only 35 kg of nitrogen, 14 kg of phosphorus and 335 kg of calcium per hectare per year in leaf litter. "The huge difference between the nutrient uptake and nutrient return implies that eucalyptus plantations create a massive deficit in soil nutrients," write Shiva and Bandyopadhyay. This nutrient deficit, they argue, is the cause of "second rotation decline" in eucalyptus yields. Indeed, they calculate that after twenty years of growing eucalyptus, the soil beneath eucalyptus plantations suffer a cumulative net loss of 3640 kg of nitrogen, 1720 kg of phosphorus and 25,200 kg of calcium.

Farmers in those areas which have now been invaded by eucalyptus plantations also complain that eucalyptus makes the soil toxic to other plants. "In some areas, the impact has been so severe that small farmers surrounded by eucalyptus plantations have had to dig trenches to protect their food crops," note Shiva and Bandyopadhyay. In areas of high rainfall, the toxins are washed out of the soil, but a study undertaken by the University of Bangalore warns: "It may be said that no crop can be grown successfully near eucalyptus trees in low rainfall areas, where there is every chance of toxic substances remaining in the soil for a long time."

One hopes that this report will be widely circulated among foresters and politicians not only in India but in other Third World countries where the planting of eucalyptus is being encouraged.

If the evils of deforestation are to be reversed, it is not enough simply to plant trees. It is vital that the right trees are planted—trees that are adapted to local soils and local climatic conditions. And that means planting indigenous species, not exotics. Eucalyptus is a fine tree in its native Australia but it is singularly inappropriate for India. The sooner the authorities realise this, the better.

Nicholas Hildyard

Toxic Facts

DIOXIN, AGENT ORANGE: THE FACTS by Michael Gough. Plenum Publishing Co, $17.95, hardcover, 300pp.

There are two standard procedures, toxicology and epidemiology, for evaluating the human hazards of toxic chemicals, particularly the induction of chronic disease, cancer (carcinogenicity) and birth defects (teratogenicity). Toxicology is based on testing such chemicals on experimental animals as human surrogates, and epidemiology is based on the *post hoc* analysis of their effects on exposed humans.

The predictive utility of toxicology reflects a vast body of data on the similar metabolic and biochemical patterns of widely dissimilar mammalian species, including humans, and on their similar responses to toxic chemicals. Illustratively, the human carcinogenicity of a wide range of chemicals was first predicted by toxicological tests, and virtually all recognised human carcinogens are also carcinogenic in experimental animals. A strong scientific consensus, reflected in numerous legislative and regulatory precedents, has thus developed that data derived from valid toxicological studies may be extrapolated to humans with a high degree of confidence. Epidemiology is based on the analysis of morbidity and mortality data over several decades in substantial human population groups with defined past exposures. The inherent limitations of epidemiology are illustrated by the many decades of multi-million dollar research, involving millions of humans with defined smoking histories, which were necessary before casual associations between smoking and lung cancer could be established to all except the tobacco industry.

The position of the pesticide and other chemical industries on hazard evaluation is illuminating. Industry routinely undertakes toxicological tests on its products and submits negative data to regulatory agencies as proof of safety. The major strategy for dealing with awkward positive data, apart from the overwhelmingly documented record on manipulation, distortion, destruction and suppression, is to challenge their human relevance and to insist on unequivocal confirmatory epidemiological evidence. However, as recently documented by Karstadt and Selikoff at Mt Sinai, New York, industries capable of undertaking such epidemiological studies have demonstrated an extreme, catch-22 reluctance to do so for alleged difficulties, including economic ones.

These perspectives are helpful to an appreciation of *Dioxin, Agent Orange: The Facts* by Michael Gough. Gough claims that there is little or no substantial evidence incriminating dioxin, as a contaminant in Agent Orange and in its major ingredient the herbicide 2,4,5-T, as well as in its precursor trichlorophenol, as a cause of systemic disease, cancer or birth defects amongst exposed individuals or populations, including Vietnam veterans, herbicide workers, and communities contaminated by herbicide use or residential proximity to herbicide manufacturing plants or hazardous waste disposal sites.

Gough's exculpatory tactics are superficially plausible, though often strained. These include denigrating and misrepresenting the significance and human relevance of the overwhelming toxicological and carcinogenicity data on dioxin, dismissing positive findings in heterogeneous epidemiological studies for reasons including apparent lack in their internal consistency, and alleging a virtual scientific consensus supporting his position. Such distortion is illustrated by reference to the 1985 EPA Health Assessment Document for Dioxin, probably the most comprehensive and authoritative document on the subject by some 36 national and international qualified scientific experts which Gough fails to cite in his extensive bibliography. The EPA document concludes that dioxin is the most powerful carcinogen ever evaluated, in fact some 50 million times stronger than the recognised highly potent occupational carcinogen vinyl chloride, and that "epidemiology studies . . . have produced positive findings that are suggestive of an elevated risk in humans."

Gough's qualifications, in molecular biology but not in toxicology, teratology, carcinogenesis, epidemiology and medicine, which are the main themes of his book, afford a tenuous basis for his assumed mantle of authority. These comments also seem appropriate for his uncritical support, while previously employed at the Office of Technology, of a contracted report by two British epidemiologists alleging that, contrary to published US data, there has been no recent increase in US cancer rates, and also that exposure to occupational carcinogens is a minor cause of cancer.

While of minimal scientific merit, Gough's book is likely to be useful to dioxin defence attorneys, his current employers at the Risk Science Institute of the International Life Sciences Institute, Washington, a chemical industry think tank, and also his future industrial clients.

Samuel Epstein

Reprinted from *Los Angeles Times*

Cultural Ecology

PACIFIC SHIFT by William Irwin Thompson. 197pp, Sierra Club books, San Francisco 1985. $15.95

William Irwin Thompson's *Pacific Shift* represents an attempt to outline the political and cultural characteristics of what he claims is an emergent "New Age" civilisation centred on the Pacific. This "New Age" culture is the fourth in a series of periods of "cataclysmic cultural change" which he describes in terms of three main "Cultural Ecologies". Although this term is not explicitly defined, each "cultural ecology"—Riverine, Mediterranean and Atlantic —has its own particular economy, polity, form of communication, form of pollution and basic world view. The Atlantic cultural ecology, for instance, has a capitalist economy, an industrial nation-state polity and a communication system based on print. Atmospheric pollution is its typical form of pollution and equations of motion and dynamics its mathematical mode. Luther is this cultural ecology's archetypal religious leader and its characteristic cosmogony is Darwin's *On the Origins of Species*.

Drawing on a broad range of philosophical, religious, anthropological and biological sources, the argument is presented in the sometimes playful, sometimes highly abstruse style reminiscent of French intellectuals. Everything is assigned to its relevant box but the elegance is deceptive and, as is often the case with typologies of this kind, the omissions are more glaring than the inclusions. Why is his field of inquiry limited to the "European" or "Western" civilisations? What merits the exclusion of the countless simpler primitive societies which both preceded and are cotemporal with all four cultural ecologies?

For it is precisely in the description of what Thompson calls the "Pacific Aerospace" cultural ecology that the gaps between typology and actuality become most apparent. This picture Thompson paints of this cultural ecology contains a socialistic economy, an electronic mode of communication and a polity based upon the recognition (and hence transcendence) of the universality of the principle of opposition in the organisation of life/culture. He cites Schumacher: "The pairs of opposites, of which *freedom and order* and *growth and decay* are the most basic, put tension into the world, a tension that sharpens man's sensitivity and increases his self-awareness. No real understanding is possible without awareness of these pairs of opposites which permeate everything man does."

Interesting though this idea is, it nevertheless remains unclear just why it is that Thompson feels that such a culture is emerging in the Pacific. Aside from the possibly adventitious presence of alternatively-minded people on the West Coast of America and of Buddhists in Japan, of important centres of Information Technology in both these places and the crucial role of satellites in communications, there is nothing about what is happening in the Pacific Basin which would justify its being heralded as the crucible in which a "New Age" is being forged. While the increasing importance of this ocean in world affairs is undeniable this is all too familiarly based on its enormous economic potential rather than on its position as the cultural ecology of the "New Age". It is certainly no coincidence that the major American commercial banks are expanding their operations in Los Angeles. Secondly, there is nothing about either information technology or satellite communications that is intrinsically "New Age". Both are intimately bound up with their trade and military uses.

The features Thompson outlines as being characteristic of an emergent cultural ecology are intricately connected rather to the rapaciously extractive activities of man. Like many other books of this kind *Pacific Shift* lacks any consideration of the powerful contradictions to the formation of an ecological society as well as any concrete description of the material and economic basis of such a society.

Alexander Goldsmith

Classified

CALL TO PARTICIPATE

ANTI ATOM INTERNATIONAL CONFERENCE ON NUCLEAR UNSAFETY. Vienna 24/26 September 1986. Supported by: Friends of the Earth Int., Greenpeace Int., Austrian Anti Nuclear groups, German Conference of Anti Nuclear Movements, Lega per L'Ambiente, ECOROPA, END, IFDA and others.

The conference will be held parallel to the International Reactor Safety Conference of the Nuclear States at the International Atomic Energy Agency. Counter research will be presented by outstanding alternative experts in 5 areas: safety after Chernobyl, the civil/military connection and the Third World, scenarios for the way out nuclear energy in the light of constitutional and international law. Conference secretariat: Wolfgang Sachs, Schottengasse 3A, a-1010 Vienna, Austria.

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MISCELLANEOUS

STOP ATOMENERGIE. World Conference of Radiation Survivors in 1987. We need your support. Details from Japan Congress against A- and H-Bomb, 4th Floor, Akimoto Building, 2-19 Tsukasa-Cho, Kanda, Chiyoda-ku, Tokyo, Japan.

CUMBRIANS OPPOSED TO A RADIO-ACTIVE ENVIRONMENT (CORE) need your help, see article in this issue on page 189. Write to Jean Emery, 80 Church Street, Barrow-in-Furness, Cumbria LA14 2HJ.

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DIARY DATES

The University of Sheffield is holding a one day course on DEADLY MAINTENANCE IN THE PROCESS INDUSTRIES on Wednesday 1st October 1986. The course will deal with the hazards of maintenance work and looks at management responsibility and legal aspects of contract and sub-contract maintenance. Further details can be obtained from: Frances Wells, Centre for Continuing Vocational Education, The University of Sheffield, 85 Wilkinson Street, Sheffield S10 2GJ. Tel. (0742) 768555 Ext 4931.

MAKING A NEW ECONOMICS is the title of a conference organised by The Other Economic Summit (TOES) to be held at Leeds University on September 12-14th, 1986. For details write or phone Paul Ekins, 42 Warriner Gardens, London SW11 4DU. Tel 01-627 4760.

OIL INDUSTRY NURSES SYMPOSIUM to be held at Newnham College, Cambridge on September 24, 25 and 26, 1986. For details write to Miss Caroline Little, Conference Officer, Institute of Petroleum, 61 New Cavendish Street, London W1M 8AR.

INTERNATIONAL CONFERENCE ON ENVIRONMENTAL PROTECTION OF THE NORTH SEA will be held in London from 24 to 27 March 1987. The conference is organised by the Water Research Centre (Environment), Henley Road, Medmenham, PO Box 16, Marlow, Bucks SL7 2HD, UK.

IS THE COSMOS REALLY GOD'S BODY? Towards an ecological spirituality. A Day Forum—18th October 1986—Dr James Hemming (Educational Psychologist), Dr Grace Jantzen (Theologian) and Peter Russell (Scientist). Details from The Teilhard Centre, 23 Kensington Square, London W8 5HN.

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Dr A.K. Lawson, Anglophile, 25 Queen Alexandra Road, Salisbury SP2 9LL, Wiltshire. Tel. 0722-26970.

LOCAL EFFORT TO STOP NUKE IS HEATING UP IN N.C.

In the wake of the Soviet nuclear accident, efforts to stop one of the last U.S. nuclear power plants from going on line have heated up here in the Piedmont region of North Carolina.

Under construction for years now the Shearon Harris Nuclear Power Plant's unit one reactor has recently been given the NRC go ahead. Costing more than the total estimate for four units, Carolina Power and Light's (CP&L) Nuclear plant is facing widespread opposition. Recent campaigns to prevent the siting of nuclear waste dumps in both Western and Eastern N.C. have fueled the struggle against opening this plant, which will produce wastes and become a waste dump itself when its productive life is over.

Since the Soviet accident there has been a flurry of activities including local vigils, an anti-nuke waste caravan and telegrams to elected officials.

The plant is located within 20 miles of three major population areas: the university town of Chapel Hill, the state capital of Raleigh, and the city of Durham, as well as many rural communities. Organising this diverse set of folks will be a challenge. Help is needed in the form of organisers/other people, donations, messages of support, and messages of protest to the governor and the public utility staff.

Please contact: Harris Nuclear Plant Opposition, c/o Bill Cummings, 237 McCauley St, Chapel Hill, N.C. 27514, or call me Dan Graham 919-942-1759.

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