Radioactive Pollution of the Environment in the Context of the Energy Problem

The Pugwash Conferences on Science and World Affairs started in 1957, as a result of an appeal by Bertrand Russell, Albert Einstein and nine other world-renowned scientists to the world scientific community to meet together in order to consider the dangers of nuclear war and to reach a common understanding on measures for avoiding nuclear disaster and for helping to arouse world public opinion toward this end. The first Conference, held in Pugwash, Nova Scotia (Canada) in July 1957, demonstrated the possibility of scientists, from many countries with different and conflicting ideologies, meeting together as individuals, unofficially, to apply the spirit and approach of science, and its common language, to the solution of the most vexing and difficult problems facing mankind.

Since 1957 there have been held, under the Pugwash banner, 23 Conferences and 18 Topical Symposia, at which some 700 of the world's most distinguished and influential scientists and scholars from around 50 countries have met privately, as individuals, and discussed a great variety of problems, ranging from the control over nuclear and other weapons of mass destruction, national and international security issues, scientific and technical co-operation in various realms, the responsibilities of scientists and the application of science and technology for the improvement of the lot of the developing world.

At the most recent Pugwash Conference, held in Finland in September 1973 the Working Group considering "Radioactive Pollution of the Environment in the Context of the Energy Problem" prepared a report of which some excerpts follow. Although the Conference as a whole heard and discussed the report, its content are he responsibility of the members of that Working Group. (No votes are taken at Pugwash Conferences, nor is there any attempt at issuing statements from the Conference as a whole ; any public statement in entirely the responsibility of the Conferences' 20-members International Continuing Committee).

The discussions of this Working Group took place in what might be referred to as a "happier time", as far as energy problems are concerned. Certainly, it would be difficult today to maintain the tone of reserved optimism — concerning the possibility of postponing, or at least limiting the widespread adoption of nuclear fission power in the next decade — that characterizes the report. Nevertheless, or perhaps even because of the accelerated motion towards fission power that is a political consequence of this year's "energy crisis", the issues and the problems raised in this report assume, in my view, an even greater importance. The problems and dangers will be with us for a long time to come, and if statements such as this can have any influence in averting the human disasters and suffering that could result from a hasty and careless pursuit of energy abundance, we should all be extremely grateful.

B. T. Feld
Secretary General
Pugwash Conferences
on Science and World Affairs

Preamble

The principal elements of the present energy dilemma are :

1. there is an urgent need to increase energy production in most countries, especially the developing ones ;
2. in the long run this need cannot be met by using the finite and non-renewable fossil fuels, and even in the short run perhaps should not be met in this way, owing both to environmental effects and to the need for reserving some part of these materials for other necessary purposes (e.g. chemical synthesis, proteins, scarce elements) ;
3. however, the dangers of radioactive pollution and of diversion of fissile materials for weaponry increase rapidly with the growing number and size of fission power plants, which are presently the principal alternative to fossil fuels.

Fission Energy Problems and Alternatives

Need for fission energy and assessment of its ultimate potential

A variety of factors influence the degree of the world's need for fission as an energy source and the ultimate potential of this technology. These factors include future growth rates of energy consumption, the forms in which energy will be needed, desires for national self-suffiency in energy, and the characteristics of technological alternatives to fission : potential magnitude, economic and technical feasibility, environmental consequences in comparison to those of fission, and the time horizon on which they can be made available.

In recent years, energy use in both rich countries and poor countries has been growing at an average rate of about 5 per cent per year. Electricity, now accounting for about 25 per cent of all energy consumption, has been growing much faster : 7 to 10 per cent per year in much of the world. Continuation of these rates would give a 4-fold increase in world energy consumption by the year 2000. The actual expansion, however, will depend in part on how energy growth is distributed. Growth of energy use is much more badly needed in poor countries than in rich ones, and a more sensible goal than equally rapid growth in all countries would be distributing growth with the ultimate goal of achieving a roughly uniform level of per capita consumption in all countries. In any case, if it is conceded that the most urgent needs for energy growth are in the poor countries, nuclear fission is at a disadvantage because large nuclear plants are not well suited to the presently small and dispersed needs in these countries.

The potential of nuclear fission as an energy source will not be limited in magnitude in the foreseeable future by shortage of fuel, even in the event that breeder reactors are not deployed. The cost of electricity generated in light-water reactors and gas reactors is already so insensitive to the cost of raw uranium that very abundant low grade ores could be utilized without increasing the price of electricity drastically. If all else were equal, breeder reactors would be preferable because they exploit 30 to 60 times more of the potential energy contained in the uranium. But the impact of the breeder on the safety question and on the issue of plutonium diversion should be carefully assessed before their large-scale

deployment can be supported, and the world uranium supply situation over at least the next 50 years is such that from this point of view haste is unnecessary.

How soon the use of fission energy or others forms will be limited by environmental factors is not clear. Climate on a hemispheric or global scale could conceivably be appreciably influenced by CO_2 and particulate matter from fossil fuel combustion early in the next century, and the heat from energy consumption in all forms could influence climate over regions of 10's to 100's of thousands of square kilometres by the year 2000. Understanding of global meteorological processes is inadequate to permit prediction of the level of energy use at which climatic disruption could become drastic ; although some scientists have suggested that an increase of energy use by a factor of 50 might be too much. Use of solar energy, which already takes part in the global energy balance in its natural form, could alleviate the thermal limit to some degree.

Wide differences of opinion exist on the potential of alternatives to nuclear fission, principally fusion, solar energy, geothermal energy, and cleaner use of fossil fuels. On the one hand, there is no obvious barrier to development of fusion, large-scale solar energy, or geothermal energy on a time scale of 20 to 50 years, and theses sources evidently have many environmental advantages. On the other hand, the full difficulties and environmental liabilities of these approaches may remain to be discovered, while those of fission are already well known. The Working Group was in complete agreement that greatly expanded research programmes on the potential alternatives to fission — and especially the apparently "clean" and thermally advantageous solar and geothermal possibilities — are urgently needed and fully justified.

Current relations and practices governing the release of radioactivity

A distinction must be made between routine releases of radioactivity in the everyday operations related to commercial nuclear power, on the one hand, and the much larger, unplanned and uncontrolled releases that could result from accidents, natural disasters, sabotage, or acts of war, on the other.

First, with respect to routine emissions at nuclear installations other than waste repositories, it was agreed that it is technically feasible and desirable to hold the radiation exposure to members of the public below levels of one per cent or less of the average "natural background" radiation. Two further points must be emphasized : first, better data for comparing the health effects of fission and fossil fuels ought to be obtained, especially on the fossil fuel side - comparisons should be continually updated as new data become available ; second, great technical and regulatory vigilance will be required to see that the theoretical potential for routine emissions far below one per cent of the natural background is actually achieved in practice around the world.

With respect to the management of long-lived radioactive wastes, strong uncertainties still exist. The principal difficulty is that the material remains highly toxic for periods measured in thousands of years ; even over shorter spans, predictions about the stability and continuity of human society are impossible, and over the longer term significant geological change is possible in some circumstances. It is not surprising that even the "experts" cannot yet agree on what methods can guarantee the isolation of wastes over such periods, in spite of the existence of a variety of proposals (ranging from disposal in the earth's core to sending the wastes into space). Disposal in deep salt beds appears attractive, and is already being practiced in the Federal German Republic, but the viability of the method depends on the geological details of the particular salt deposit. Much more money could be spent on nuclear waste management than has yet been contemplated, without greatly increasing the price of nuclear generated electricity, but money alone does not guarantee a solution. It is impossible to be complacent about expansion of the use of nuclear power without having a solution actually in hand.

The possibility of a major release of radioactivity from a reactor or a fuel reprocessing plant, which theoretically could result from an accident, a natural disaster (e.g. earthquake, tsunami), sabotage, or an act of war, has justifiably created deep concern. A major release could conceivably involve thousand of millions of curies of radioactivity, hundreds of thousands to millions of casualties if it occurred near a population centre, and many thousand of millions of dollars in property damage. In theory the probability of such an event is quite small, but perhaps not small enough. This means that reactors should not be

BELGIAN INTERNATIONAL CENTER OF THEORETICAL SOLID STATE PHYSICS
project on ELECTRONIC STRUCTURE IN SOLIDS

University of Antwerp
and University of Liège

Several positions of visiting professors and visiting research associates are available in the framework of the project mentioned above.
In principle the positions are for one year but in exceptional cases they can be extended. Collaboration with existing groups will be required.

Main subjects :

1) Electron-phonon interaction in polar semiconductors (polarons)
2) Bandstructure and lattice dynamics of solids
3) Electron-phonon interaction in metals
4) Electronic structure in amorphous semiconductors
5) Electronic structure of surfaces
6) Electronic structure of defects

Apply to the following addresses :

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sited in earthquake or tsunami zones. Experts have published estimates of the probability of a major reactor accident (excluding sabotage and war, and perhaps some kinds of natural disasters) ranging from 10^{-4} to 10^{-12} per reactor year. Better estimates of accident probability would be desirable. In the absence of agreement or proof, it is only prudent to assume the worst. Siting near large centres of population should be avoided. It is possible, although disputed, that siting reactors 100 metres or more underground in solid rock may provide further insurance against the consequences of major accidents. This possibility should be vigorously researched.

Diversion of fissionable materials

The use of nuclear reactors to generate electricity necessarily involves the production and handling of fissionable materials of a character suitable for the manufacture of nuclear weapons. Light-water and heavy-water reactors yield 200 to 400 grams of plutonium per Mwe-yr, net. Breeder reactors yield between 300 and 700 grams of plutonium per Mwe-yr, net. High-temperature gas-cooled reactors of US design employ fuel fully enriched in the fissile uranium isotope, U-235, and yield in the order of 50 g of fissile U-233 net per Mwe-yr. In each case mentioned, the materials require at most chemical separation to be rendered usable for the production of weapons. It is to be emphasized that the high Pu-240 content of plutonium produced in LWRs does not make bomb manufacture impossible, as is often supposed, but only complicates the design and makes the yield both smaller and less predictable.

There are two principal classes of possibilities for the misuse of the fissionable material from the nuclear fuel cycle ; first, a government without nuclear weapons may divert material from its own non-military nuclear programme in order to produce weapons ; second, material may be stolen from the nuclear power programmes of either weapons or non-weapons nations by individuals or groups with a variety of motives — the production of a weapon for sabotage, terrorism or blackmail, or the sale of the material to another group or even a nation intent on weapons production.

The problem of theft of nuclear material by internal groups or individuals intent on sabotage, terrorism or blackmail was agreed to be a very serious one, although there was some sentiment expressed that the possibility of such activity was much smaller in the socialist states. In any case, the problem cannot be avoided simply by abandoning the breeder reactors, because, as noted above, all other reactor types also involve the use of materials suitable for weapons manufacture. It is difficult to see how the theft of such material can be made impossible in a world characterized by human failings, but measures to make such theft more difficult should be carefully studied and the best ones implemented as soon as possible. For example, relatively, unsophisticated clandestine weapons manufacture might be deterred by maximizing the PU-240 content of reactor plutonium, adulterating material to be shipped with other neutron emitters or neutron poisons, or adulteration with hard gamma emitter to aid detection. Another possibility is to minimize shipments by concentrating enrichment, fuel fabrication and fuel reprocessing facilities at single sites together with several reactors, and guarding the entire area with a degree of elaborateness and thoroughness hitherto reserved for strategic weapons.

The general view of the Working Group regarding radiological terrorism using plutonium stolen from reactor programmes is that this problem is definitely of secondary importance to that of clandestine nuclear weapons, in part because a variety of other extremely toxic substances could be obtained by terrorists with less difficulty.

Breeder reactors

None of the problems described in the foregoing sections are significantly diminished in the case of breeder reactors, most especially the liquid-metal cooled fast breeder now favoured by all countries, and some are significantly aggravated. The relatively low fraction of Pu-240 in plutonium produced by breeder reactors, in contrast to that from light water reactors, worsens the problems of theft and diversion, as does the greater quantity of plutonium produced by the usual breeder cycle. Additionally, some aspects of the reactor safety problem would appear to be compounded in the case of the breeder. On the basis of available data most Group members felt that the breeder is not necessary in the next 50 years on grounds of uranium supply, and, therefore, that there is no need to consider large scale deployment of such reactors unless and until the questions of diversion and safety are fully resolved. Some members, however, disagreed with this view.

Summary of recommendations

1. Owing to potentially grave and as yet unresolved problems related to waste management, diversion of fissionable material, and major radioactivity releases arising from accidents, natural disasters, sabotage, or acts of war, the wisdom of a commitment to nuclear fission as a principal energy source for mankind must be seriously questioned at the present time.
2. Accordingly, research and development on alternative energy sources — particularly solar, geothermal and fusion energy, and cleaner technologies for fossil fuels- should be greatly accelerated.
3. Broadly based studies aimed at the assessment of the relation between genuine and sustainable energy needs, as opposed to projected demands, are required.

4. The hazards of fission should in the meantime be minimized by every means available, specifically:
   a) the greatest technical and regulatory vigilance to achieve the lowest feasible routine emissions at all stages of the fuel cycle, everywhere in the world, including the establishment of a worldwide network of radioactivity monitoring stations ;
   b) accelerated efforts to find technical solutions for the management of long-lived radioactive wastes ;
   c) thorough investigation of the potential of placing underground or clustering nuclear facilities as a means of reducing the probability and/or consequences of disruptions and accidents ;
   d) tightening of surveillance of nuclear facilities ;
   e) exclusion of reactors and reprocessing plants from zones of high seismic activity ;
   f) avoidance of siting reactors and reprocessing plants in densely populated regions ;
   g) the safeguards authorities of the IAEA (International Atomic Energy Agency) should be strenghened and supported, within the context of the present NPT (Non-Proliferation Treaty) ; further studies should include research and development in order to raise the effectiveness of national and international safeguards to the highest possible level, and examination of whether the codification of uniform standards for national control of reactor-related fissile material in the weapons states would be useful ;
   h) research on technical means to render more difficult the use of reactor-related fissile materials for the construction of bombs ;
   i) all nations should sign and ratify the Non-Proliferation Treaty.
5. Taking into account the fact that some problems associated with the breeder reactor are far from clear, large scale deployment of breeder reactors should depend on the results of a thorough re-examination of these problems.
6. Pugwash should examine the need for an International Energy Institute, or, alternatively, the need for changes in the scope and structure of existing international organizations, by reviewing the major efforts now under way in the energy field.

Society News

Energy and Physics

Third General Conference
of the European Physical Society
Bucharest, Romania
9-11 September 1975

The Third General Conference of the European Physical Society will be mainly devoted to the applied and fundamental aspects of energy. This theme will be developped along six main topics :

— Energy production (conversion) on earth (fission, fusion, solar, chemical, geothermal and atmospheric)
— Energy production on a cosmological scale (black holes, elementary particles,...)
— Energy transfer in biological matter
— Energy stragegy and forecasting (including ecology and climatic effects)
— Energy transport and storage
— Energy and information (including statistical mechanics and thermodynamics, and problems of measurements)

These topics will be treated in plenary and parallel sessions. The parallel sessions (four or five) should take various forms :

— Seminars on some of the plenary lectures
— Seminars on problems which may or may not be related to the main six topics
— Symposia with contributed papers on specialized subjects.

One, at least, of the parallel sessions, will be systematically devoted to the development of fundamental physics. It is also planned to include a discussion on teaching of physics in Europe.

Meetings

The meetings in this list are all organized by Divisions and Sections of EPS (boxed) or sponsored by EPS. Europhysics Study Conferences are marked by an Ⓔ before the date.

The order of information is : date, title, venue, and contact for information.

Conferences 1974

2 - 5 April
2nd European Electro-Optics Conference
Montreux, Switzerland
Mack-Brooks Exhibitions Ltd., 62-64 Victoria Street, St. Albans, Herts. AL1 3XT, UK

16 - 19 April
International Conference on Electron Spectroscopy - Progress in Research and Applications
Namur, Belgium
R. Caudano, Laboratoire de Spectroscopie Electronique, Facultés Universitaires, Rue de Bruxelles 61, B-5000 Namur

18 - 24 April
Excited States of Biological Molecules
Lisbon, Portugal
M.D. Lumb, UMIST, P.O. Box 88, Manchester M60 1QD, UK

22-24 April
3rd European Symposium on Polymer Spectroscopy
London, UK
The Meetings Officer, The Institute of Physics, 47, Belgrave Square, London SW1X 8QX

1 - 3 May
State of Order in Amorphous Polymers
Sorrento, Italy
P. Corradini, Istituto Chimico, Università di Napoli, Via Mezzacannone 4, I-80134 Naples

10 - 15 June
Hyperfine Interactions Studied in Nuclear Reactions and Decay
Uppsala, Sweden
R. Wäppling, Institute of Physics, University of Uppsala, Box 530, S-751 21 Uppsala 1

26 - 28 June
The Solid-Vacuum Interface
Utrecht, The Netherlands
G.A. Bootsma, Secretary third NEVAC Symposium on Surface Physics, Van't Hoff Laboratorium, Rijks Universiteit, Utrecht

Individual Ordinary Members

The following have been accepted as Individual Ordinary Members of EPS :

B. Bosco, Florence
J.M.G. Caraça, Sacavém
P. Comte, Lausanne
H.W. de Wijn, Utrecht
M.F. Dos Reis, Brussels
M. Ivascu, Bucharest
Z. Kecki, Warsaw
N. Kroo, Budapest
J. Linderberg, Aarhus
J. Muller, Geneva
L. Papineau, Gif-sur-Yvette
J. Royen, Paris
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N. Szepfalusy, Budapest
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W. Schilling, Jülich
A. Ten Bosch, Berlin
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C.B. Williams, St. Albans
F. Wollner, Lausanne