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"RECONCILING ENERGY NEEDS AND NON-PROLIFERATION"

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Brasil

(1)

Paulo Nogueira Batista

Mr. Chairman,
Ladies and Gentlemen,

1. Notwithstanding recent events concerning reactor safety, important as that may be, the closing of the backend of the nuclear fuel cycle will very likely remain very much the heart of controversy about the use of nuclear power for peaceful purposes. Opposition to reprocessing of spent fuel expresses itself in essentially two different ways. At the international level, it is said by some that the recovery of residual fissile uranium and of plutonium automatically foster the proliferation of nuclear weapons capability. At the domestic level, it is proposed that reprocessing should not be allowed for it entails the seperation of highly active waste which cannot be safely disposed of.

2. Opposition has become so passionate and vigorous that in some countries, though hard pressed for the solution of their energy needs and where nuclear power could play an important role, decisions have been blocked by the action of militant minority groups. The international flow of nuclear technology and hardware has been, on the other hand, severely restricted in a clearly discriminatory manner. Such developments lead indeed to a highly contradictory situation, one in which the peaceful use of the atom is strongly contested in the framework of an almost implicit acceptance or at least of a silent resignation to an ever-growing nuclear weaponry, in quantitative as well as in qualitative terms.

3. The case for reprocessing - excuse me for being so obvious again - is, however, a very plain one of optimization of energy resources. As it is very well known, though of late not as widely acknowledged, the mere recycling of uranium and plutonium recovered by reprocessing spent fuel in fact increases by some 50% efficiency in uranium utilization. Much more important still, the fueling of Fast Breeders with plutonium can multiply by a factor of 60 to 70 the energy that can be extracted from the fissioning of uranium isotopes.

4. Without closing of the fuel cycles, nuclear power based on fission cannot be used on large scale and for a long time, for uranium as it currently exists in the world - indeed in a geographic concentration even more unfavorable than that of oil - will not be sufficient to support, during the entire lifetime of nuclear power plants, the nuclear electricity generation capability to be required by the world from the year 2.000 onwards.

5. Against such a clear background of advantages and in the context of growing scarcity of traditional energy sources such as oil, it becomes difficult to accept at face value the non-proliferation stand taken by some Governments against reprocessing and against even the mere use of Pu. Can it really be a strict and sole concern about the spread of nuclear weapons capability?

6. The fact that countries enjoying an advantageous position try their best to keep it as exclusive as possible is of course in itself a normal reaction. Such understandable impulse may be considered even more reasonable in the case of advanced technologies which may have, besides commercial ones also political-military implications. There may even

be a legitimate concern which can go beyond the specific more selforiented motivations of one specific country and be of a more general and broad world interest.

7. This is certainly the case of nuclear technology, and non-nuclear weapon countries have always been prepared to cooperate with nuclear weapons countries by accepting their basic notion, that an increase in the number of states possessing nuclear weapons should be avoided for the sake of world peace and stability.

8. This cooperation was firstly given back in the late "50s" when the concept of international safeguards against non-peaceful uses of atomic energy - in itself a severe limitation of Sovereignity - was proposed by the nuclear weapon states and accepted by the non-nuclear weapon states as the only valid way open to such countries to benefit from nuclear energy.

9. Some 10 years afterwards, in the late sixties, another important contribution was asked by the NWS and again agreed to by the NNWS; complete and formal renunciation by the NNWS to the right to fabricate and / or possess nuclear weapons, without receiving any formal security garantees or nuclear disarmament engagements from the NWS. The reciprocity was to be found in full access to nuclear technology provided "full scope safeguards" were accepted.

10. Again some ten years later, NNWS are now told that such full access to nuclear technology for civil application is not any more desirable or possible for it brings about the now unavoidable spread of nuclear weapon capabilities.

11. In this new surprising context, it is maintained that sensitive technologies such as enrichment and reprocessing cannot be made available, <u>even under full scope safeguards.</u> The IAEA statutes and even the more recent NPT are left aside and international binding commitments are broken by unilateral actions.

12. It all looks as if in the defence of priviledged positions some NWS have really gone a bit too far in their appeal to the understanding of the NNWS. In so doing such NWS surely have undermined the climate of confidence which is so basic for the development of international cooperation, particularly in the nuclear field.

13. Banning the civil use of Pu by non-nuclear weapon states under the over-stated risk of nuclear weapons proliferation, while the military production of plutonium continues in nuclear weapons states, at a growing rate, is something difficult for NNWS to swallow. On the contrary, the least they could expect from NWS would be cooperation for the intensive utilization of plutonium to the benefit of our energy-lacking world, with the only restriction of appropriate safeguards of the International Atomic Energy (IAEA) which, in this connection, has already developed an exacting and specific control system.

14. The risk of a country making nuclear weapons in secret by diverting material fabricated under international safeguards is indeed quite remote. The IAEA control system for sensitive facilities such as reprocessing plants, includes permanent surveillance which, by accurate measurements, at strategical points, accounts for any significant amount of nuclear material coming in, remaining, and going out of any such facilities. Any diversion can be readily detected.

15. All cases in the world where nuclear weapons or explosives were fabricated, were beyond the scope of IAEA safeguards system. It is unfair, therefore, to speak of violation or even insufficiency of the IAEA safeguards system with reference to situations in which the Agency's safeguards were not being applied.

16. It should be born in mind that the NPT places no restrictions on the production or use of special fissionable material by non-nuclear weapon states, provided international safeguards are applied. The exercise of that right by non-nuclear weapon states parties to the NPT was never challenged until very recently.

17. The right of every country to reprocess does not mean that each contry will necessarily exercise that right. Most nations are not in need of or in a position to have a nuclear power programme whose size would necessarily justify a national reprocessing facility of its own. Here there is obviously room for international cooperation, specially of a multi-national character. If strong assurances of supply are given to such countries with small nuclear power programmes most of the incentive for national capability in reprocessing may not be felt by them.

18. However, the concept of multinational reprocessing centers as an alternative to national capability has been the object of much talk but never of concrete and formal proposals. There have been so far only informal suggestions about the desirability of multilateral or regional centers. Fundamental political and technical matters, such as access to technology, commercial conditions, assurance of supply, and siting have never been really spelled out. So far, the suggestions imply the preference for siting such multinational plants in the territory of the technology-holding country or at most in countries rich in uranium deposits. The concept of plutonium storage under international custody has recently become the focus of serious attention and of preliminary discussion. It is a more viable concept for not only is it compatible with national reprocessing capabilities, as provided in Art. XII.A.5 of the IAEA statutes, as well as it is in full line with the exercise of the right to use Pu for peaceful purposes. This last question is becoming in itself more important than that of nuclear reprocessing for to some the very use of Pu - and that means the Fast Breeders - should preferably be restricted to a priviledged smaller group of nations. The truth of the matter seems to be that NNWS are not only kept under permanent suspicion of having ill-intentions but are even taken as rather naive and silly, to put it bluntly.

19. In reality, if a country has serious security reasons which inspire military purposes as relates nuclear power, the appropriate route would not be a nuclear electricity generating programme under international safeguards, a by-product of which might be a military programme. At a much lower cost and in a

more direct and expedite manner, nuclear programmes strictly designed to weapon-making purposes, could be started with unsafeguarded research reactors and pilot reprocessing facilities.

20. As we all very well know, neither reprocessing nor enrichment "per se" lead necessarily to nuclear weapon fabrication. There are countries which master one or both technologies but only use them peacefully for obtaining fuel for electricity generation. Enrichment at the isotopic concentration level required for nuclear weapon fabrication can be, however, a process more technically complex than reprocessing, and, at the same time, more suitable for control by the application of safeguards. Reprocessing, besides, is much more vital to the full peaceful use of nuclear energy and is, in addition, a necessary step whichever the reactor technology. Monopoly of that activity has a much broader significance in terms of what it represents for the future of nuclear energy and, therefore, for the world's energy future.

21. In concluding:

a) uranium does not seem available in such great quantities as to allow the world not to make by reprocessing the most efficient and responsible use of it, particularly in a context of growing scarcity of other energy options;

b) the uneven distribution of uranium resources among nations make it imperative for countries with large energy needs not to rely indefinitely on a strategy of external dependence as relates nuclear fuel supply;

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c) so far studies on more proliferation - resistant alternatives to reprocessing have not been found which are safer or more economical;

d) from the nuclear waste view point to burn plutonium and to dispose of extremely small volumes of high active waste in geological deposits seems to be a safer and better solution than to store indefinately large volumes of irradiated spent fuel containing plutonium more easily accessible with the passing of time;

e) reactor safety issues should not be played up and politically used to introduce new elements of discrimination in international relations as concerns the peaceful use of nuclear energy;

f) there has been a clear erosion of confidence in the world as relates nuclear energy, which is affecting the whole fabric of international relations. Policies of denial of the right to reprocess or even to use Pu open the way to serious discriminations among countries and may be a source of tension and conflict in an energyhungry world,

g) confidence building measures of necessity of a non-discriminatory nature are the most urgent task in INFCE, in the NPT review conference and in bilateral discussions and negotiations as well. In these multilateral frameworks LDC should be given, if possible, a special beneficial treatment; as a minimum LDCs should not be discriminated.

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CONFERENCE ON RECONCILING ENERGY
NEEDS AND NON-PROLIFERATION

Contribution to the Panel on
The Debate on Reprocessing

by Charles Van Doren, Assistant
Director, U.S. Arms Control
and Disarmament Agency

In the next 20 years there will be very sizeable accumulations of spent fuel from the present generation of nuclear power reactors. A large portion of it will necessarily have to be stored as spent fuel for an extended period. The debate on reprocessing is over the desirability, timing and extent of reducing that portion by reprocessing, and over our ability to cope with the risks entailed.

For the thermal reactors expected to be in operation by the end of that period, reprocessing is not essential. It seems quite certain that they could be operated for their expected lifetimes without plutonium recycle. Thus we can take an objective look at the cases for and against moving to widespread reprocessing now.

RESOURCES - The most appealing argument adduced for reprocessing is the desire to save fuel resources by making use of the residual energy value in spent fuel. But does this require widespread reprocessing now? No. Extended spent fuel storage leaves this option open for the future, and in fact creates a fuel reserve that could later be drawn upon if serious shortages of fresh fuel seemed likely to occur. In fact, its separation would be easier at a later time, owing to the decay of fission products. (This option has been unfairly labelled the "throw-away" option. It would be more accurate to call it a "stow-away" option.)

To use this plutonium now for recycle in thermal reactors would be many times more wasteful of resources than to save it for possible use in breeder reactors, when and if their feasibility and economic viability become clear. And to separate the plutonium before needed for a specific breeder reactor would be unwise, since

(a) it would be incurring a heavy present cost for a potential future benefit; and

(b) it would needlessly create the proliferation and physical security problems inherent in a stockpile of weapons-usable material, vulnerable to theft, seizure or misuse.

WASTE MANAGEMENT - Another argument adduced for reprocessing is that it contributes to solution of the waste management problems. There is continuing debate as to whether it in fact makes a significant difference in this respect. It does separate out the high level wastes and permit their vitrification. But it creates some new waste disposal problems of its own - including not only the effluents from the reprocessing operation but also the creation of additional contaminated facilities whose decommissioning must eventually be dealt with. (We face this problem in the United States, where the waste disposal and decommissioning costs will greatly exceed the total cost of the plant.) And the fact that high level wastes can be reduced in volume does not mean that the total volume of wastes for which permanent geological disposal must be provided is significantly reduced, if at all. For example, such disposal is still required for spent fuel hulls.

Regardless of where one stands in this debate, one thing is clear: Even if reprocessing is believed to facilitate the waste disposal problem, that benefit does not require reprocessing now. After more extended storage as spent fuel, it would be easier to reprocess and vitrify if that were deemed necessary. In the meantime, further progress can be made in ascertaining the best medium for geological disposition and in testing and preparing suitable sites and gaining public acceptance of their use.

These activities are far more urgent than the actual change in form of the high level waste, which does not reduce the very long period for which it must be isolated from the biosphere. And if reprocessing is not needed for other purposes, the option of geological disposal of encapsulated spent fuel would still be available and would not materially increase the amount of space needed for geologic disposal.

One exception has been cited to the lack of need for prompt reprocessing for waste disposal purposes: That is, Magnox fuel, whose cladding was not designed for long term storage in water, and corrodes rather quickly when so stored.
But -

(1) This is a limited exception, since Magnox reactors are no longer being built; and

(2) A sizeable facility for the dry storage of Magnox fuel has just been completed in the United Kingdom, which should reduce this particular time pressure for reprocessing such fuel.

ECONOMICS OF THERMAL RECYCLE - There has been considerable debate over the economic advantages or disadvantages of reprocessing for recycle in thermal reactors. Basically, it involves the relationship between the cost of fresh fuel, on the one hand, and the following cost elements on the other:

(i) reprocessing costs or charges; plus

(ii) the incremental cost of fabricating Mox fuel; minus

(iii) the saving of spent fuel storage costs otherwise incurred.

Few, if any, of the variables involved can be predicted with much confidence. For example, the cost of processing is profoundly affected by the capital cost of the reprocessing and associated facilities, the cost of money, and the plant availability factor. And I might note that the data base on wich to project the availability factor is very thin. (The actual experience to date with those few facilities that have separated high burn-up fuel shows a startingly low availability factor).

Under current circumstances, most experts both in the United States and in INFCE agree that the economic benefits of recycle in thermal reactors are at best marginal. In the United States, we have concluded that they are not commensurate with the security risks and problems involved, to which we have not yet found adequate solutions.

RISKS AND PROBLEMS. Let me now turn to these security rists and problems. Most of them are attributable to the facts that one of the products of Purex reprocessing is separated plutonium; that, in addition to its radiotoxicity, such plutonium is one of the principal materials needed for a nuclear explosive device; and that less than ten kgs of such material would be needed to make such a device.

These facts make this product-like highly enriched uranium- vulnerable to theft or seizure by subnational groups for the purpose of blackmail, or as agents for a government seeking to acquire the material, or even for terrorist use. And they raise questions as to the sufficiency of existing safeguards.

These risks are not confined to the reprocessing facility itself. They also attach to the subsequent disposition of the plutonium. Thus if we turned to plutonium recycle in the present generation of reactors, there would be a vast increase in the international commerce in separated plutonium and commensurate increase in these risks.

SAFEGUARDABILITY. Reprocessing facilities pose some special challenges for safeguards. The basic problems are -

1. the inherent difficulty of accurately accounting for material in bulk handling facilities, where there is inevitably some hold-up in the plant, and where about 8 kg of Pu constitutes a significant quantity for safeguards purposes; and
2. the special problem of obtaining "timely warning" of diversion when the product is in a form directly usable in weapons.

For these reasons it is especially important to design reprocessing facilities in a way that facilities effective safeguards, and to do all we can to increase in others ways the safeguardability of such facilities. Some useful experiments have been done on this subject at the Tokay facilities in Japan, and several concepts - such as the French Pipex scheme for a fully contained facility - have been suggested. Moreover, INFCE has been examining such concepts as co-conversion to minimize the presence of separated plutonium, and the shipment of fuel materials in mixed oxide form. These technical measures - as well as possible multinational institutional arrangements - all deserve further pursuit in our efforts to meet the safeguard challenge of reprocessing.

Also under study in the IAEA is a possible international plutonium storage regime. But much work remains to be done on this concept, and we do not yet know how effective a regime can be created, or how widely it will be accepted.

<u>CONCLUSION</u>. In my remarks this morning I have tried to show why we believe that the widespread introduction of reprocessing is not currently necessary or desirable; that the security risks and problems it poses are real and serious; and that much remains to be done by the international community to improve our ability to cope with such risks and problems.

(3)

ROLE OF NUCLEAR POWER IN DEVELOPMENT

by

Dr. K. Effat

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Egypt

International Conference

on

Reconciling Energy Needs and Nonproliferation

13 - 16 May 1979

Bonn - Bad Godesberg

ROLE OF NUCLEAR POWER IN DEVELOPMENT

Mr. Chairman, distinguished delegates, ladies and gentlemen,

It is indeed an honour and pleasure for me to participate in this important meeting and to take part in the discussion of the many vital issues and important questions facing us in this crucial period through which nuclear power is passing at present. And before starting my presentation, allow me first to express a deep appreciation and gratitude to the Research Institute of the German Society for Foreign Affairs for their initiative in hosting and organizing this timely meeting at this critical stage where the nuclear community is faced with a situation which needs consolidated efforts and actions to be undertaken and important decisions to be made.

Distinguished delegates.

I have been asked to cover in my presentation today the subject of "the role of nuclear power in development".
In dealing with this rather complex and maybe rather a controversial subject, I shall attempt to put nuclear power in some perspective in the light of the established facts and realities about the two most important aspects which form the basis of the assessment of the future role of the nuclear power on development; namely the energy situation and the available options, and the present economic and technical status of nuclear power as an alternative energy source.

Over the past serveral years, the role of nuclear power in development and its prospects in meeting our growing and pressing energy needs has been the subject of the most wide, intensive and controversial discussions by advocates and oppenents of nuclear power. This debate involves a wide range of questions and complex issues and has particularly intensified over the past six weeks, since the unfortunate event of the accident at the Harrisburg nuclear plant.

The outcome of this debate and the impact of this accident over the future role of nuclear power is difficult to forecast at present, and therefore I shall limit myself here to the intrinsic role of nuclear power in the light of present facts and realities of today. The extent that this intrinsic role will be affected by the growing opposition to nuclear power development, will largely depend on the degree of our success in putting nuclear power in its proper perspective and in providing clear and convincing answers to clarify the wide range of issues and questions being raised over the necessity of using nuclear power and the postulated risks and dangers to the public and the environment by using this source for energy production. In order to give an assessment of the role of nuclear power in providing our needs for economic, industrial and social development, we must first examine the facts and realities of our energy situation today and the available alternatives for meeting our future needs.

The demand for electrical energy has and will continue to grow in both industrially advanced countries and in developing countries. This continuing growth in energy consumption is needed to meet the continued growth to maintain the civilization and industrial development in advanced countries, and to raise the relatively low level of industrial development countries, and to cover the extra needs of the growing world population. Over the past 25 years the world energy consumption has increased threefold from about 3000 MTCE to about 9000 MTCE at present and is expected to double once again by the turn of the century reaching about 20.000 MTCE. The share of electrical energy which is at present about 30 - 35% of the total energy consumption is growing at an average rate of 6-7 % annually and much higher growth rates are expected for the developing countries where the present levels of per capita consumptions are still very low ranging from 300 - 1000 KWh compared to the world average of about 3000 KWh.

The status of development of any country can be gauged by the standard of living of its people with that which can be sustained by production based on our present level of science and technology. Hence one of the key elements in making development plans in any country whether advanced or developing would be the provision of adequate and most economic supply of electrical energy.

To achieve this, exploitation of all available energy resources, hydro, coal, oil, gas, uranium as well as other renewable energy resources such as solar, tidal, wind, geothermal and biomass must be undertaken to the largest possible extent.

The question which is often being asked is why among all sources of energy are we so much interested in nuclear power? There is the energy in the winds, and waves, energy due to temperature differences in the earth and oceans, energy from the rotation of the earth which could be tapped by utilizing the tides and energy from the waters evaporated by the sun. It is true that all these natural phenomena provide us with renewable vast amounts of energy however apart from the fact that all of them are of an intermittant nature, they all have one great drawback, their energies are not in a very concentrated form. The energy per unit volume is rather low hence vast installations and great expenditures are required for there exploitation. Consequently such schemes are as yet not feasible for the provision of the large blocks of electrical energy upon which our modern civilization depends. It is therefore unlikely that such renewable energy resources could have any significant contribution to our electrical energy needs in the foreseable future.

Reserves of fossil fuels oil, coal, gas are known to be limited and estimates of the available resources have always caused concern about there adequacy to meet the growing energy requirements in the future. Furthermore these fossil fuels are needed as raw materials for many industrial products, such as petrochemicals and liquid fuels for transport, and could hence be more efficiently and economically utilized for such uses rather than being used as fuel for electricity production. Some oil producing countries, like Iran for example, with its well known vast oil resources some years ago decided to embark on an extensive program for the construction of nuclear plans to save non-renewable oil and natural gas reserves for better utilization in industrial uses, or for the use of its export revenues to import nuclear technology and equipment and for other development plans and projects.

Then comes nuclear power; which after the sharp increase and the anticipated further increases in oil prices since the end of

1973; occupied a rather prominent position among other alternative energy sources available to us. Nuclear power plants became then fully accepted as a viable competitive alternative energy source to conventional thermal plants. Compared with oil fired plants, there is a clearly established economic advantage. Inspite of the higher capital cost of nuclear plants which may be as much as twice the cost/KW installed of oil plants, the large differential fuel costs savings compensate and exceed the capital costs differential over a rather short period of the operating life of the plant. A calculation made in Egypt for a 600 MW plant at an oil price level of 75 dollars /ton in 1977, showed that the cumulative fuel cost savings would cover the capital costs of the plant in about 10 years. The role of nuclear power can be further assessed in the light of its present status, and its operational record. The facts may be summarized as follows: Nuclear power has been generating electricity over the past 25 years and supplied more than 800 billion KW's of energy by the end of last year from PWR plants alone. Installed capacity of nuclear plants in operation today in 21 countries amounts as of May 1978 to more than 100.000 MWe, with 215 power reactors which has given satisfactory operating record for many reactor years of their life.

More nuclear plants are now under construction and planned in 29 countries, including 11 developing countries, which are expected to be in operation by the mid 1980's. With the completion of these plants, the total would net electrical output from nuclear plants would have reached about 450.000 MWe. Accordingly, it should be recognized that nuclear power is no longer a prospect for the future, but it is a reality of today.

Inspite of these achievements and the clearly established economic feasibility of nuclear plants, and the operational and safety record of nuclear plants over the past 25 years; and even after the unfortunate event at Harrisburg, there has been no significant radiation exposures to the people or to the environment over the whole 25 years history of nuclear plants in operation including Harrisburg. Inspite of all this, the controversial debate and opposition to nuclear power will continue. And the need for the use of nuclear power as a source for energy production will be questioned on grounds other than economic considerations. The clear and glorious prospects for nuclear energy are now being shadowed by clouds of unfounded attacks from opposition groups. They continue to attack nuclear power as an unacceptable dangerous source of energy with associated health hazards, waste disposal problems of highly radioactive materials, and the proliferation of technology which could be used for the production of nuclear weapons. These arguments are however often not sufficiently clear and are not based on technical or scientific grounds but rather on emotional aspirations and exploitation of public opinion. Unfortunately the facts are also presented in a distorted manor by some irresponsible elements in the press and television media. More than ever before it is now the duty and responsibility of the nuclear community to identify and clarify the issues being raised if the role of nuclear power in development is to be maintained and enhanced in the future.

While the controversial debates over nuclear power may continue, the fact remains that the economics, reliability and safety of nuclear plants have been already established by the vast number of nuclear plants under construction providing us with a total electrical output of over half a million KW by the mid 1980's in more than 30 countries. Future developments of fast breeders and the thorium fuel cycle would provide additional vast resources of energy for development and prosperity of humanity.

In conclusion, the role of nuclear power in development depends to a large extent on an ability to find satisfactory solutions to a wide range of problems. Public acceptance, non-proliferation, fuel supply assurances, waste management disposal physical protection, etc.... Problems more political than technical, more international than national, but the need for nuclear power is compelling and I believe we have no choice but to respond accordingly and positively.

FORSCHUNGSINSTITUT DER DEUTSCHEN GESELLSCHAFT FÜR AUSWÄRTIGE POLITIK E.V.

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International Conference on

RECONCILING ENERGY NEEDS AND NONPROLIFERATION:
Perspectives on Nuclear Technology and International Politics

13-16 May 1979, Rheinhotel Dreesen, Bonn-Bad Godesberg

Natural Uranium and Enrichment: Politics of Supply and Access

Justice Russel W. Fox

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NATURAL URANIUM AND ENRICHMENT : POLITICS OF SUPPLY AND ACCESS

Having already explained to the distinguished Director of the Institute, Dr Kaiser, that I felt incapable of handling the topic precisely as it has been set, I have obtained his kind permission to flirt a little with it in a way which brings it more within my sphere of competence.

Some introductory comments are apposite.

International affairs have not yet progressed to the point where any country regards itself as having an assured or inalienable right to a commodity produced in another country. Despite the many developing signs that national boundaries cannot have their former finality and that sovereignty as previously understood is outdated, we do as nations still act on the basis that what is within our national boundaries is ultimately at the absolute disposition, or under the uninhibited control of our respective governments. We have for the present to grapple with our problems on this basis.

We know, or at least are learning, that uranium is not an ordinary commodity. Simply as a source of energy it can fairly be compared with other sources such as coal, oil and gas. It is, of course, unique in its structure because it is neither a carbon or hydrocarbon but it is doubly unique because of the dangers associated with its use. The very processes which produce energy from it involve the production of radio-activity and go far in making it the source of horrendous explosive power. These facts, and their possible consequences, were recognised in the early days, before any nuclear weapon was exploded.

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The fact of life which we have to face is that dependency on uranium as a source of electrical energy exists in many countries and is developing in others. That is to say, the industries of many countries and the individual comfort and convenience of their members are, or are becoming, to a greater or less extent dependent upon it. Many do not have the uranium or enriched uranium necessary for their needs. In Australia this fact has been recognised and is sympathetically understood.

When announcing in August 1977 that Australia would develop its uranium resources, the Prime Minister of Australia in his opening comments said:

> "The Government especially has been conscious that in a world of finite resources there is an obligation on resource-rich nations, such as Australia, to make those resources available to meet the legitimate needs of other nations."

Whether this statement be regarded as flowing from high morals or good sense, or both, does not matter. The fact is that Australia is desirous of selling its uranium to other countries. As a supplier, and in common with other suppliers of nuclear materials, we nevertheless recognise an obligation to ensure that what we sell is not used for military purposes. There are, of course, other problems associated with the use of uranium, - engineering, technical, safety, environmental, financial and otherwise. The one which is probably the greatest impediment to international trade is that of "proliferation", a vague term not well understood amongst the public of our various countries. The perceived dangers of proliferation have now led to restraints and inhibitions not conducive to international trade, giving rise to difficulties for potential suppliers as well as potential consumers.

I emphasise that in my view the danger of proliferation, that is, of horizontal proliferation, is not only one of the actual spread of nuclear weapons, but the suspicion and fear that a country which has the means of producing weapons readily may be planning to do so. History teaches us that such perceptions are often wrong, but they are seriously disruptive, and have in the past been a common cause of war. Another aspect of the same consideration is that a country which does not in fact possess the means may wish to convey the impression that it does, as a means of threatening others and thus obtaining its own way. It is desirable that a regime exist which will minimise the risks of hollow threats or, put the other way, will help to ensure that such threats are recognisable for what they are.

Responsible nations must therefore retain the right to be satisfied beforehand that what they supply will not be used for military purposes. This is a complex and difficult matter, not least of all for a supplier of uranium, because uranium must go through a number of processes, often in different countries, before its derivatives are used as nuclear fuel. It is my view that purchasing countries should acknowledge and accept an obligation to assure suppliers, and hence the rest of the world, both that they do not intend to divert materials for military purposes and that if they have a ready capacity for doing so, it is under firm control in accordance with international standards. It is to be remembered in this connection that nearly all suppliers are also consumers, or potential consumers. It is unlikely that more than a few countries can achieve nuclear independence, that is, self-contained fuel cycles, this century, - even if such a goal were desirable.

We all know of the treaties which have been entered into and the organisations which exist with a view to discouraging, detecting and reporting upon any diversion or possible diversion, for military purposes, and thus giving a substantial measure of comfort and assurance to others. We know also that it has been found necessary to go further and to have exacting safeguards requirements in bilateral agreements. Personally I would like to see stronger international institutions and agreements which would enable bilateral agreements to be superseded in due course, but this is probably some time well in the future. One matter worth observing is that bilateral safeguards agreements necessitate adequate surveillance, by I.A.E.A. personnel or EURATOM personnel, or both, on the territory of subject countries, in order that they be effective. All the arrangements can be very complex and very unsatisfactory from the point of view of a purchaser, but are not less so from the point of view of a conscientious supplier.

In the 1960s and the early 1970s there was a boom, or at least great optimism so far as concerned the development of the nuclear fuel cycle. The NPT was in a way a measure of this optimism. The enthusiasm dulled the perception of a number of difficulties, - difficulties which have since become very apparent. Worse still, in my view, was the assumption on the part of the planners and their advisers that the dangers, and associated difficulties, did not require that the public be taken into their confidence. This doubtless involved as a first step the tedious operation of explaining some processes to the relatively ignorant and this was not done. The repercussions of such an approach in a non-totalitarian state were bound to lead to trouble, and they have done so, and will, I believe, continue to do so. I accept that in relation to some matters, which are of relatively minor importance, the complexity of modern technology and modern politics just do not permit public consultation. It is difficult enough for specialists in the disciplines concerned to explain all the relevant sinuosities to already informed audiences. However, the development of nuclear energy is not a trivial matter, - plainly it has inherent in it a variety of dangers, one or two of which are very great. I cannot for a moment accede to a philosophy which says that in such a case the planners necessarily know best, or should leave the public less than fully informed about the dangers.

The period commencing, say, in 1974, has been said to be one of reassessment so far as concerns matters nuclear. I agree, but there is little point in my addressing remarks to that period, because there has, in general, been time and opportunity for reassessment. This is subject to the re-thinking and improvement in safety measures which within the last few days have been brought to attention by the Three Mile Island accident at Harrisburg, in the United States.

..../6.

Notwithstanding that event, we should now be making such decisions as are possible, or preparing ourselves to make them at an early date. What at present is a major impediment to the development of the nuclear industry, and its associated elements and what contributes largely to the absence of confidence in it, is, quite simply, uncertainty and indecision on the part of the decision-makers. Everyone understands that decisions in the field usually have to some extent to remain flexible, and a decision can simply be one to do nothing for a stated period, but a prolonged and indefinite wait-and-see philosophy can only lead to confusion, and worse.

I should say, immediately, that the Australian Government made its position as clear as it could in August 1977 when declaring that it would develop its uranium mines and sell the resulting yellow cake. The statement of policy then made allowed for some flexibility, and, of course, is open to review as overseas developments may demand. This is not to say that the non-proliferation objective will be relaxed; it will not be. It is now known that uranium will be available from new mines in Australia in 1982 or 1983 and in increasing quantities over the following years. There is, at present, as you know, substantial political opposition within the Australia Labor Party to any uranium mining in Australia. I cannot say whether this will continue; it may do so, and the Labor Party may in the future form the government. But it is not an unreasoned opposition. It centres mainly around three factors of which we have all heard a great deal, namely those of safety, disposal of wastes (or spent fuel) and non-proliferation. Might I suggest that many of our troubles would have been lessened if these or similar arguments, when first advanced, had received more attention, and been dealt with on their merits.

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Partly as a result of INFCE but largely independent of it, much knowledge has now accrued on the subjects mentioned. What I suggest is that the time for firm decision is now upon us. If anyone asks, - "about what?", the simple answer is to say the nuclear future of respective countries over the next 20 or 25 years, or longer, and the international arrangements which should be pursued, with zeal, to meet the difficulties impeding trade, and, in particular, the problem of proliferation. In relation to some matters, the best that can be done is to embark, firmly and clearly, upon particular courses, conscious that events may at some stage show the need for change.

The emphasis in discussion has been on reliability of supply. I do not underestimate the importance of this factor. What should be emphasised, however, is that one of the main difficulties facing everyone at this time is the element of reliability of demand. This is tied up with many factors, not least of which is the assessment of the future energy needs of consumer countries and the ways they are to be fulfilled. For example, I have no doubt that conservation will play a large part in future energy needs, and decisions with regard thereto should be made now, albeit some changes may later be necessary. It must be remembered, too, that expense is enormous and lead times are long, and if care is not taken the latter may prove longer than the occurrence of the requirements to which they relate.

Having said what I wanted to in the Reports on the Ranger Mine in Australia on the subjects of safety and wastes, I have, as a judge, since avoided becoming involved in debate concerning them. But, to take an example, if the disposal of wastes (or spent fuel) has now reached a satisfactory position so that to reasonable men it should no longer be an unacceptable

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hazard, international trade will be enhanced if relevant decisions are made and are made known, accompanied by such proof or demonstration as is possible. So with the structure and nature of reactors and the erection of enrichment plants. If a country proposes to move in the next decade or two to the development of commercial fast breeder reactors, this surely can be made known, and uncertainties of planning thereby reduced. France has partially built what is described as a pre-commercial fast breeder reactor and the U.S.S.R. is said to have three fast breeder reactors. Planning will remain most difficult for suppliers of uranium as well as consumers if clear decisions are not taken. It is in the nature of trade that some things will remain uncertain, such as changes in some political and economic conditions but they are inevitable and governments and businessmen necessarily have to be left to deal with them as best they can. Some countries may, of course, reverse previous plans, and decide against a nuclear future for the time being, and we have seen one or two illustrations of this.

I should return to the matter of my especial interest - non-proliferation. I am, as you probably know, an advocate of the development of international arrangements wherever they can sensibly be made and when I say international I mean to include multinational arrangements made by mutual consent of, say, three or four nations, but according to more widely accepted standards. In this way confidence is given to other nations, which can plan accordingly. Mr Mason Willrich and I have in a paper recently suggested that as a beginning, a scheme for the international control of plutonium stocks should be instituted and that this can be done without damage to the fundamental interests of any country. The I.A.E.A. has in fact for some time been investigating the details of carrying into effect a scheme along these lines, and two international meetings on the subject have taken place at its behest. I think it can safely be assumed that both Mr Willrich and I are reasonably well acquainted with earlier attempts to devise international solutions, but the reasons for their failure have become apparent. We have learnt from them, and should go on, undeterred.

I would hope that decisions at a political level can soon be made which will lead to the acceptance of some scheme, a thorough and proper scheme, such as I have earlier suggested. I am not oblivious to the difficulties and some of the immediate criticisms which will spring to the minds of some. But difficult problems are seldom unravelled simply or superficially. The United Kingdom and France, the countries in which plans for civil reprocessing are furthest developed, have both expressed support in principle for such a scheme, and there is the helpful agreement reached recently between Brazil, the URENCO countries, and URENCO.

If and the extent to which practical arrangements can be made to end the fuel cycle at the spent fuel stage, without reprocessing, this can be an important measure in aid of non-proliferation. Such a course would increase the market for, that is to say the dependence upon, uranium, at least, until the proposed fast breeder reactor becomes well established as a commercial reality. Although we may see one or two such reactors this century, outside the U.S.S.R., it is not likely that they will become a commercial factor of substance until well into the 2000's.

We can usefully remember when we talk of international solutions that the nuclear industry involves a quite phenomenal degree of interdependence between nations, - technically, financially, the production of services, the supply of materials, and otherwise. In the mines of Niger there is participation, in one form or another, of six or seven countries, as well as France. In some countries it is quite practical to purchase nuclear electricity from others, at least in peak periods. National boundaries and sovereignty do not have the significance we have come to accept from prior experience. In relation to the nuclear fuel cycle and particularly the provision of uranium and enriched uranium, we are moving inexorably towards multinational and international arrangements which at the one time secure a supply of necessary technology and materials and at the same time ensure the necessary protection from dangerous results. And it is a unique factor in human history that more than one hundred countries, being parties to the NPT, have agreed to international surveillance on their own territories.

I do not, however, see the proliferation problem being met in its entirety by one simple global scheme. A scheme dealing with plutonium storage is obviously only part of the whole. I have for some time also been an advocate of multinational participation in sensitive processes. I have thought this to be a natural tendency. One may take, as examples, in relation to enrichment, organisations such as URENCO and EURODIF; Eurochemic was an earlier trial of a similar concept, in relation to reprocessing, albeit that the scheme had somewhat different purposes, and, again for slightly different reasons, there is now United Reprocessors GmbH. Within accepted principles there can be scope for

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variation to meet particular circumstances. Schemes such as I have mentioned can and probably should be operated in conjunction with proposals already made concerning multinational fuel centres, but I do not suggest that there need be anything mandatory about this.

The final point I would make on this aspect is rather more stark. It is simply that if due to security fears or otherwise a country (necessarily a non-NPT country) feels that it must retain a nuclear weapons option it may not be too much to expect that it not equivocate and dissemble to conceal its intention, with a view to securing supplies not otherwise available to it.

In the course of my travels I have spoken personally, commonly in their own countries, to senior representatives of nearly all the states concerned and I have a clear view that the reasonable fears and suspicions of all countries can be met if we persevere at the task. I know that the United States, which has so much political and economic power and power derived from its erstwhile supremacy in technology as well as a near monopoly in enrichment, has translated many of its fears into statutory mandate and we know that most of the rest of the world feels that in some respects it has gone too far and in a counter-productive direction. The hope and expectation of many is that its attitude is not immutable. The world will owe much to its leadership and all the more so if what it does is as free as possible from any reasonable accusation of self-serving commercial advantage. It has long since ceased to have a supreme technological position, and it is likely that its position in that regard will be worsened by the Harrisburg incident. So far as concerns enrichment its monopoly is rapidly

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passing from it and we can expect at an early date to have three or four or more countries with a substantial capacity for toll enrichment. In fact, the projections show that for a number of years there will be a glut in the enrichment market.

I have mentioned impediments to trade which are related to international politics. There are, of course, regional and domestic matters. So far as concerns the former, there is the proposal for a nuclear free zone in the Indian sub-continent. There is also the need for an early resolution of the questions affecting supplies to and by and between member states of the European Community. One bears in mind the prospective early increase in the number of members of the Community, one of which already has a substantial nuclear power industry. To look at the matter narrowly, from Australia's point of view, Euratom will need a mandate, as it is called, before proper and lasting arrangements can be made for the supply of uranium to member countries. This is not to say that useful negotiations and discussions cannot take place in the meantime. Failing a mandate it has been suggested that it is necessary to have amendments to the Treaty, or at least Chapter VI thereof. What I would like to stress as vital is the taking of early decisions on what is to be done, and, hopefully, some action. I should record at this point my own view that nothing should be done to undermine the utility and effectiveness of Euratom as an instrument of safeguards policy. The more we can settle nuclear affairs in regions of the world the better, and the Euratom area, with its vast industrial and technological resources is obviously one of the most important.

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Part of the title of this lecture to which I must at least pay passing respect refers to access to sources of supply of uranium and enriched uranium. The Indian nuclear explosion of 1974 provoked international concern that an additional state had taken a large step towards acquiring a nuclear weapon capability and that this could have unpredictable repercussions for the stability of that country's immediate neighbourhood and possibly for international stability. There were many who thought that the Indian action called into question the future of the non-proliferation regime. International attention was compelled at the same time to focus on the sources of raw materials for energy arising from the oil embargo of 1973. The proliferation issues were addressed multilaterally in a number of bodies such as the Nuclear Suppliers Group. But in relation to assurances of supply of uranium much attention has been focussed on the actions of two countries. The United States closed its enrichment order books and Canada subsequently announced that it was withholding supplies from a number of countries from the beginning of 1977. These actions were regarded by consumer countries to be a disruption of promised supplies and aroused fears concerning the future. They have led to what I believe to be a too general and at times excessive emphasis on assurances of supply. Confidence has to be restored and this should be possible on a sound basis of non-proliferation objectives shared mutually by both suppliers and consumers.

I sympathise with the need of consumer countries for energy security. For the nuclear industry, the acceptance and strengthening of non-proliferation policies can only serve to produce that result.

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It is, I hope, evident from what I have already said that in my view, a matter of major importance in the matter of access to supplies is to free the market from its present impediments, and this by overcoming them rather than scoffing at them. It is, of course, the fact that the major purchasers for many years will be highly industrialised countries: the Western European countries, Japan and the United States. The United States has resources of its own and very large stocks. But, as I understand, it is thought that towards the end of the century, if its program proceeds, it will have to import uranium for its own purposes. The needs of most of the European countries and certainly Japan for uranium are more pressing. None of the countries mentioned will expect to be given guarantees of supply by foreign governments. The utilities can be relied upon to secure long-term contracts with mining companies, whether privately or government owned. There is every reason to suppose that these will be fulfilled on a commercial basis unless governments specially intervene, and government intervention is not likely to be capricious; it is more likely to be based on perceived dangers of the nature already mentioned. Governments, for their part, have to be warned against the danger of retaining in bilateral agreements wide discretions for themselves, when these can possibly be avoided.

Particular courses open to prospective purchasers have been seen in operation: the purchase of equities in the share capital of mining companies, within the limits permitted by governments, and the making of large loans subject to relevant conditions which also will have to pass the scrutiny of governments. Another course being followed is that of

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encouraging and financing exploration in other countries, in the expectation of favoured treatment; perhaps also in reliance on a right to favoured treatment. There has also been some bargaining of technology or equipment for raw products. I have given passing thought to the possibility of adopting in the nuclear field, at least in part, something similar to the many commodity agreements which now exist, and the Telstar agreement currently in operation, but the possibilities are for others to explore. Commercial men can devise many ways, once they know the guidelines, of achieving the results they desire. What it is necessary to emphasise is that non-proliferation protection must not become the victim of any such arrangements. There can be no bargaining of safeguards against supplies of uranium or enriched uranium.

The creation of an international fuel bank has been proposed by the United States as an aid to assuring supply and diminishing tendencies towards reprocessing. This proposal is, as it were, still sub judice and we should await the outcome of INFCE before further action on it. What can be said now is that we should at all times bear in mind the position of the less developed countries, not merely as a matter of words but as a matter of reality. This is in the interests of the developed countries when considering world trade generally; it is much more so when considering nuclear energy, and the dangers attendant upon it. We must see the position from the point of view of such countries, although they differ greatly in their respective situations. Some are quite highly industrialised. Very few have any present involvement at all in the production of nuclear power, and as far as I know none has currently a need which is not being fulfilled. The initial requirement of most will probably be for reactors of a size smaller than any commercial reactor produced in manufacturing countries. I might express the hope here that not all will regard indigenous industry as a sine qua non of their own welfare and happiness. Surely many will settle for reliance on agricultural pursuits. If they are themselves deficient in natural resources yet judge themselves to have a real need for a nuclear program, a number of questions will arise. I envisage that several suppliers of uranium and enriched uranium will be prepared, in proper circumstances, to ensure that they are not left without the necessary assurance of materials. Although I speak quite unofficially I think I can say that my country, acting alone, or in conjunction with others, would like to take every reasonable step to ensure that such countries receive fuel supplies as and when they need them and that they are not left in any needless state of uncertainty about that matter. The maintenance of small stockpiles may be an aid to this end, and INFCE may give us more direction in this regard. The problem of the less developed countries, or some of them (they differ considerably in this respect) may well be more in the direction of obtaining finance and skilled personnel than of obtaining the material. Here the industrialised nuclear nations are inevitably in a dominant position. One can only hope that they use it wisely.

You do not need me to tell you the impact which domestic politics are apt to have on international affairs; indeed the latter frequently cannot be appraised properly without an understanding of the former. I judge that the matter of supplies of uranium and enriched uranium are not less likely to be affected by local politics than are other commodities. I do suggest, however, that international arrangements, once made, will be apt to reduce considerably any uncertainties or difficulties within the domestic arena. Discretions reserved to supplier countries under bilateral arrangements for non-proliferation reasons will be much less likely to cause difficulty to supplier and consumer if international agreement, to which both are party, exists on important aspects. Indeed, the ambit of the discretions may be greatly reduced, if not wholly displaced by such an agreement. I am sure we all have a distaste for situations which give one country power, capable of exercise from time to time, over the operation or development of the nuclear fuel cycle of another country. It is my hope that the scope of, if not the necessity for, such discretions will soon be limited or abrogated by international arrangements. I want to make it clear that in the meantime I see no answer to their retention, and this in appropriate measure is the policy of my country.

I have already referred to enrichment; it is predicted that the market will be oversupplied until at least the 1990s, although predictions in this area are notoriously hazardous. The lead times for the construction of an enrichment plant of any size are considerable and the likely effect of laser beam enrichment on the commercial market is unknown at this point. Australia has been approached by a number of countries and by URENCO to enrich in that country. Plainly we will be dependent upon overseas technology and finance. It may be that Australia can in due course provide toll enrichment for countries in the Pacific area, and beyond, but I imagine that what is primarily contemplated is that we sell enriched uranium and little, if any, which is not enriched. There is time to consider this matter and that is what we are doing, assiduously and with a view to reaching a decision as soon as this can practically be done.

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Plainly, there are non-proliferation dangers associated with enrichment. Pakistan is currently causing quite a stir, because it is making or acquiring a centrifuge enrichment plant, which it cannot use for its CANDU reactor, or any other reactor which can be built before the enrichment plant is ready. What a difference it would make to its position if it had already, or even now, were to submit to international control of that plant. Otherwise the world, and particularly its near neighbours will rightly or wrongly, conclude that it wants to have a nuclear weapons option. This is not the occasion to embark upon an examination of means of detecting and deterring the production of highly enriched uranium, beyond saying that to create confidence that high enrichment is not taking place, and that preparations are not being made for it to take place may well require a more detailed and individual examination of the particular situation than is the case with the plutonium avenue of production. It is my understanding that some enrichment plants, even of the centrifuge type, are not at all readily convertible to weapon purposes; confidence may exist without more.

This leads me to a final observation. I do not see a world, now or in the near or mid-future, where there will be many enrichment plants or many re-processing plants. I believe that natural forces, such as technological, financial and environmertal considerations, will restrict the number of them, provided that we do not so act as to drive countries to an unnecessary independence in possessing them. There may also be factors, such as the disposal of spent fuel and of wastes which will in the long run tend to limit reliance upon nuclear energy, so far, at least, as it is derived from thermal reactors.

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My crystal ball is quite unrevealing on this subject when it comes to fast breeder reactors, or fusion.

In conclusion, might I say that my principal points are two: we must work energetically towards international solutions where these are possible, and we must now, or in the near future, without waiting endlessly for further information, come to decisions which will substantially reduce the uncertainties which now abound, and which are so unsettling.

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RECONCILING ENERGY NEEDS AND NONPROLIFERATION:
Perspectives on Nuclear Technology and International Politics

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Contribution to the Panel on the Debate on Reprocessing

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CONFERENCE ON RECONCILING ENERGY
NEEDS AND NON-PROLIFERATION

CONTRIBUTION TO THE PANEL ON
THE DEBATE ON REPROCESSING

by Bertrand L.Goldschmidt,
Advisor to the C.E.A., Paris

1st Part : The Historical Background up to the Carter Policy of 1977

1942 The Americans accept the participation of a representative of the British atomic project (myself) in the early work on plutonium extraction pursued in Chicago by Glenn Seaborg's team. The transfer of know-how in this field in between the United States and the United Kingdom is thus complete until the end of 1942.

1943 Breakdown of relations in the nuclear field in between the American and Anglo-Canadian projects.

1944 The collaboration resumes after the Quebec Agreement of September 1943. United States, Britain and Canada decide "not to communicate any information to third parties without mutual consent". It is the first non-proliferation agreement.

Furthermore the three anglo-saxon partners, having agreed to limit their cooperation to the pursuit of the war, the United States decides that, owing to the Hanford reprocessing plant being already entirely designed, the United Kingdom and Canada cannot bring any contribution to its conception, they therefore are refused access to the American plutonium technology. Such a denial was more inspired by competition for postwar industrial and commercial advantages than by non-proliferation reasons.

This denial of reprocessing technology brings about the launching in the Anglo-Canadian project of an independant research program which leads to the successful discovery of a new method, based on solvent extraction, similar in principle to the one universally adopted today. Such action early demonstrated the difficulty of monopolizing technology.

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1945 The Smyth report does not describe the method of separation of plutonium.

1946 The Lilienthal-Acheson report defines "the production in suitable quality and quantity of plutonium", and more specifically "the operation of the various types of reactors for making plutonium, and of separation plants for extracting the plutonium" as some of the activities "dangerous" for national exploitation and which should be under international management.

However this report suggests that plutonium can be denatured into a form that does not readily lends itself to making atomic explosives and therefore considers as non dangerous a power reactor using up denatured plutonium in an installation where no new plutonium can be produced by the presence of additional uranium.

This notion of denatured plutonium will soon be abandonned as progress in weapon technology enables explosion to be made with plutonium rich in Pu 240.

1952 The European Defense Community Treaty fixes 500 gr. per year as a limit to the amount of fissionable material "designed for, or primarily useful in, atomic weapons" that any participating country could produce yearly without a permission of the Council of the Organization. This limitation of a yearly production of 500gr. of plutonium was one of the reasons of the French requests for modification of the draft treaty which led ultimately in 1954 to the rejection of the Treaty by the French Parliament.

1954 The amendment of the MacMahon Act which allows the conclusion of agreements of cooperation in between the United States and other countries permits the transfer of declassified information relevant to the production of special fissionable materials i.e. plutonium.

1955 France publishes in detail the chemical steps of the PUREX process at the first Geneva Conference organized by the United Nations, this disclosure was followed later by a similar declassification by the United States and the United Kingdom.

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1956 1/ The amount of special fissionable material produced in an installation submitted to the safeguards of the future International Atomic Energy Agency (IAEA) causes a major row at the Statute Conference in New-York. The draft statute gave the IAEA the right to decide what amounts of produced plutonium a country could keep under safeguards for specified non-military uses. This was considered by many countries as giving the Agency a too great a right of intervention in the future civilian nuclear power program of its concerned members.

The Franco-Swiss compromise which saved the conference from a deadlock is the basis of Article XII A 5 which specifies that in order to prevent stockpiling the Agency shall have the right to require the deposit under its juridiction of any plutonium recovered or produced over what is needed to be used for peaceful purposes, under its safeguards, for research or in reactors existing or under construction specified by the member country concerned.

2/ The Euratom Treaty gives the right of ownership to the Commission of any plutonium present in the Community and not being used for military purposes.

Reprocessing is considered as a transformation operation and does not fall under the supply Agency exclusive right to conclude supply contracts.

1957 1/ The Report of Armand, Etzel and Giordani "An objective for Euratom" gives as an argument against an early building of an European enrichment plant, not only the future development of the breeder reactors but also the probability that plutonium produced in the first European reactors will be able to be recycled economically thus reducing the need of enriched uranium.

2/ In the official U.S.A.E.C. semi-annual report (July-December 1957) it is stated :

"Work is proceeding in an effort to demonstrate the feasibility of recycling plutonium as fuel in thermal heterogeneous reactor systems. If successful, a system recycling plutonium generated in its own operation will be able to produce three to four times

...

as much power from a given quantity of natural uranium, or even of a somewhat depleted uranium, as would be possible without recycling. By this method, thermal reactors with auxiliary chemical separations and fuel fabrication facilities could be designed to operate continuously without dependance on a virgin supply of enriched uranium. A reactor system of this type might be useful also for nations with raw uranium resources but without gaseous diffusion plants."

3/ Creation of the OECD backed Eurochemic, first joint industrial european nuclear enterprise. Its aim is the construction and the running of a laboratory and a plant devoted to irradiated fuel reprocessing, the improvement of the technology and the formation of specialists.

The result was the spreading of the reprocessing technology to 13 Western European countries. France had a leading role as it made available to the joint enterprise its Marcoule technology resulting of the C.E.A. research work and Saint-Gobain's engineering know-how. The U.S.A. cooperated with this European endeavour at least partly in the belief that it was preferable to steer such a sensitive activity into a multinational channel.

This pooling of plutonium extraction technology, considered today as one of the most sensitive operations from the standpoint of proliferation, seemed at the time to be highly desirable within the context of European cooperation and did not give rise to any political difficulties.

Built at Mol in Belgium, thanks to a good understanding between the principal European chemical industries concerned, the plant operated from 1966 to 1974 when it closed down for financial reasons, because of the American British and French competition which, profiting of larger installations were offering reprocessing costs at 20 U.S. $/ the kilogram. It is now brought up by the Belgian Government, an action that runs counter, paradoxically, to the present political trend in favour of internationalizing the administration of such plants.

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4/ The earliest U.S. bilateral agreements indicate that the reprocessing of U.S. supplied fuel would occur only in U.S. facilities or in other facilities acceptable to the United States.

It is clear that reprocessing is thus contemplated, that it is expected to take place in the United States and that while reprocessing outside the U.S.A. is not ruled out the U.S retained a veto power over it. In later arrangements it was clearly specified that this right of approval over reprocessing in a non U.S. facility was related to the "safeguardability" of the reprocessing plant in the philosophy of the Agency statute which gives the Agency the right of approval" solely to ensure that this chemical processing will not lend itself to diversion of materials for military purposes and will comply with applicable health and safety standards".

1958 The U.S.-Euratom agreement, as a special benefit to the Community, omits the usual right of approval of reprocessing, and furthermore the U.S. agrees to reprocess material for Euratom if requested to do so, if the U.S. were then providing reprocessing services to its own domestic licences.

1965 Start of the first Indian reprocessing plant built without significant outside help.

1968 Article IV of the N.P.T. treaty assumes clearly that reprocessing for peaceful purposes cannot be denied to parties to the treaty.

1970 Completion of a first German small reprocessing plant. Smaller or pilot facilities are also built in Italy, Spain and Argentina. Conclusion of a contract in between Japan and French industry for a sizeable plant at Tokaï-Mura against British competition and some American industrial interest.

1971 The surplus of reprocessing capacities in United Kingdom, France and United States, responsible for some of the Eurochemic difficulties leads France, United Kingdom

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already in possession of large plants and Germany which is about to built one, to join forces under an agreement firstly commercial, and later technological, "United Reprocessors" with a view to avoiding the risks entailed in an uncontrolled development of reprocessing capacities prior to saturation of existing plants.

1973 Amendment to the U.S. regulations which make any assistance in the field of reprocessing technology or for the construction of a reprocessing facility dependant of the membership to N.P.T. of the country concerned as well as the possible multinational statute of the plant considered.

1975 The London Suppliers meeting singles out enrichment and reprocessing activities as specially sensitive and for which exports should be dealt with restraint even if under IAEA safeguards. Following France's suggestion, it was agreed to condition the transfer of reprocessing (and other sensitive) technologies to the acceptance of the non-explosive clause and IAEA safeguards not only for the initial corresponding plant but for any other one the country concerned could build,in a reasonable future, using the same process.

1976 During the London meetings three negociations in the sensitive field of reprocessing were near completion, one concerning German industrial help to Brazil, the other two related to French industrial assistance to South Korea and Pakistan.

Three corresponding trilateral agreements were modified so as to be in strict conformity with the London guidelines and were presented and approved by the Board of Governors of the IAEA in late 1975 and 1976. There were the first trilateral agreements with the IAEA to include the concept of control of technology.

Korea cancelled its contract under external pressure and the carrying out of the Pakistan one is at a standstill since 1978.

The difficulties encountered by these contacts led the French Government to create a Council for external nuclear policy which decided in December 1976 not to authorize any new bilateral contracts on the sale of industrial reprocessing plants to foreign countries, for the time being. The German Government decided later to adopt the same policy.

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By end of 1976 only two large commercial reprocessing plants were available in the Western world the French one at La Hague and the British one at Windscale, the extension of this later being subject to a future inquiry.

No commercial plant was in operation in the States : N.F.S. having been closed down, the Morris plant having been abandonned without really starting and the Barnwell plant being still three years from completion.

2nd Part : Comments on the present situation

In the present oil and energy situation in the world, it seems to me quite inconceivable that many of the main industrialized western countries could consider abandonning, for reasons of non-proliferation, the utilization of plutonium as additional source of energy. The savings on uranium which will be provided by such utilization of plutonium will be considerable. Thus a policy of irradiated fuel storage should essentially be considered as temporary only because of the lack of capacity of reprocessing plants and of the schedule of breeders.

Therefore the issue of the non-proliferation problem in relation to reprocessing and plutonium utilization lies in the search of 'reasonable' solutions avoiding over-penalties on energy production.

A first problem is the physical protection of isolated plutonium : it seems desirable that for plutonium stocks for future industrial uses the protection should be as safe as in the case of weapons stored under the control of weapons states in or out of their territory.

To minimize the proliferation risks arising from plutonium utilization, the first step is the continued use of IAEA safeguards which are generally considered as efficient and have ensured up to now a satisfactory protection for plutonium devoted to peaceful uses.

...

The IAEA utilizes only in a limited manner confinement and surveillance measures which are able to play an increasing role in the industrial facilities. These measures are thought to offer a particularly promising way to facilitate the implementation of safeguards in reprocessing plants, providing at the same time means to improve national actions taken against theft.

This concept is based on the confinement existing in the reprocessing plants, on account of the strong activity of the materials. This confinement should be extended to the entire facility.

Such a facility described in the French "PIPEX" proposal at INFCE, can be seen as a tight pipe with a small number of controlled inlets and outlets : the less their number, the easier to control. Emphasis is put more on physical impossibility of undetected diversion than on material accountability, the accuracy of such an accountability being necessarily limited in large industrial plants.

The multiplication of small reprocessing plants spread over many countries constitutes an avoidable proliferation risk. Some countries could attempt to justify the necessity of such small plants by their energy independance policy ; but they are obviously of small economic value and they could be made less attractive if countries possessing large reprocessing plants were able to offer reprocessing services.

As far as existing plant capacity will not meet the demand, creation of multinational facilities would offer better insurances against proliferation since such organization would render safeguards denounciation more difficult than in the case of national plants and moreover would limit the spread of small plants.

Joint location of reprocessing and fuel fabrication offer advantages only for the prevention of diversion by sub-national groups and limitation and transportation risks of plutonium. The advisability of such arrangements must be appreciated from this point of view, keeping in mind that the economic incentives are weak and the industrial involvements are intricate.

Utilization of mixed oxides, the modern form of "denaturing" plutonium, seems to be acceptable to fuel manufacturers under

...

certain conditions. On the other hand, any solution involving mixing plutonium with highly radioactive materials should be avoided. As a matter of fact remote fuel fabrication technology is not presently available, and furthermore the development of such a technology would pose serious problems the solution of which is not yet known. Even if these problems were to be solved, such fabrications would be penalized by increased costs and health hazards risks.

Separated plutonium storages are naturally the most sensitive point inside the fuel cycle, since it may be feared that they could constitute an available stock for seizure in case of denounciation of safeguards agreements. Article XII A 5 of the Statute allows the Agency to exercise the responsability of storing plutonium before its utilization.

In the mind of the authors of this article XII A 5 (Ambassador Lindt from Switzerland and myself) it was then considered that the reprocessing would generally take place in the country to whom belongs the irradiated fuel and therefore that this country could keep the amounts of plutonium necessary for its research program and its reactors existing or under construction, the Agency having the right to require for storage under its supervision all plutonium in excess of those above amounts.

Today the situation is rather different, the reprocessing generally takes place in a different country than the one where the irradiated fuel is produced. Therefore it seems reasonable from a non-proliferation point of view that, in order to minimize plutonium transportation, the plutonium storages should be located close to the reprocessing plants. Their management could be in charge of either the IAEA itself or preferably of the host country provided the essential condition that plutonium movements be authorized only by the IAEA Officer responsable of the storage.

The plutonium should be only released when needed either for the research program or for the fueling of reactors in operation or nearing completion.

The conditions for the return of plutonium should be determined precisely by the reprocessing countries in terms of criteria which would have been widely acknowledged internationally and agreed upon by the customer States before reprocessing.

...

These conditions could, for example, make provision for automatic restitution for energy production utilizations and for research uses agreed by the concerned States. The release of plutonium would be made only for immediate use, excluding national storages, according to a specified fuel fabrication schedule. Reexportation of plutonium by the customer country could also be subject to a previous agreement from the reprocessing State. In these conditions, the IAEA would authorize the restitution of plutonium only after verification of conformity of uses to the conditions defined bilaterally between the reprocessing State and the customer country.

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International Conference on

RECONCILING ENERGY NEEDS AND NONPROLIFERATION:

Perspectives on Nuclear Technology and International Politics

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The Driving Forces of Proliferation

Sir John H i l l

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THE DRIVING FORCES OF PROLIFERATION

by Sir John Hill

A paper presented to the Conference on
Reconciling Energy Needs and Non-Proliferation
At Bonn, May 1979

Non-proliferation, it has been said, is like motherhood. Everybody is for it. But, unlike motherhood, not everybody agrees on how to achieve it. In this address, I hope to explore in some detail the nature and causes of the phenomenon of nuclear weapons proliferation: in particular I shall consider the question of what role, if any, nuclear power development could have in stimulating or abetting the spread of nuclear weapons. This will lead me on to the main theme of this talk: the balance between technical and political factors in the fight against proliferation.

The birth of nuclear energy can be said to have occurred in the closing years of the 1930s at which time the possibility of nuclear reactions, though known for some time by a small elite of theoretical physicists, first came under the active scrutiny of the scientific community at large. From that time on, the theoretical possibility existed for any nation desirous of so doing to harness the energy of the atomic nucleus either for controlled use in power production or for purposes of destruction. What has been termed the greatest atomic secret, the question of whether a weapon based on a nuclear reaction could be made to detonate with a significant yield, was revealed to the world at large in August 1945 with the use of the atomic bomb on Hiroshima and on Nagasaki. As from this time, the existence of a nuclear weapons technology has been an incontrovertible and irreversible fact. Any nation henceforth, if firstly it had access to the technology of nuclear weapons fabrication (by no means an easy matter), and secondly to an adequate supply of one of the fissile materials U-235, Pu-239 or U-233, to a sufficient degree of purity, was now in a position to join the nuclear arms race if it so desired. My subject this morning will not be the question of access to weapons fabrication technology, important though this is; my remarks will be confined to a consideration of the routes available to a nation seeking to secure a supply of fissile material sufficient for a weapons programme, that is to say a quantity of some tens of kilograms a year or more (a smaller quantity than this would be of negligible significance). In particular, as I have said, I shall want to consider the extent to which a nuclear power programme could or could not facilitate this task.

In public discussions of the proliferation problem, the attention of the world has largely been focussed on just one of the fissile materials I have mentioned, namely plutonium. There are indeed undeniable hazards associated with the unsafeguarded production of plutonium and it is right that all due weight should be given to these. At the same time this should not serve to blind us to the equal or even greater importance in this respect of isotopic enrichment methods, as a means for the production of U-235: this route to the production of fissile material might, in my view, in some cases offer a potential advantage to the would-be proliferator, simply in view of the smaller scale of operations involved.

Coming on now however to the question of plutonium production methods, it is clear that a considerable range of techniques is available to the state seeking a supply of Pu-239. High on the list would of course be dedicated production reactors: so also would be certain types of research reactor. Lower on the list, in my view, would come accelerators and power reactors. Accelerators, because no such machine has yet been built of sufficient power to be able to produce fissile material in the kind of annual quantities we are discussing. Power reactors, simply because this is a disproportionately expensive way of obtaining the quantities of fissile material one would need. I shall shortly attempt to enlarge on the difficulties associated with this latter route.

The point that cannot be let slip in all of this is that the possibility of producing nuclear materials of this kind does not of itself act as one of the driving forces of proliferation. The theoretical possibility of any number of nations attempting to construct nuclear weapons has, as I said at the beginning of this talk, been with us for the last thirty years or more. During this time fissile materials have been isolated and processed in abundance, without more than a handful of nations having gone down the road towards a nuclear weapons capability. The Non-Proliferation Treaty of 1968 has provided over a hundred number of states around the globe with the means of registering in a clear and unambiguous manner their intention to abstain from nuclear weapons development. One area of the world, South America, is well on the way to the establishment of the militarily denuclearised zone, provided for by the Treaty of Tlatelolco. There are further treaties setting constraints on the deployment of nuclear weapons in outer space and the emplacement of nuclear missiles on the sea-bed. It is thus clear that the mere existence of a technology of this potential has not of itself been sufficient to drive the greater part of the world into the arms of the nuclear deterrent. The element of political will, witnessed by this reluctance by most countries to encourage the spread of nuclear weapons is, I submit, of the first importance in assessing the causes of and remedies for proliferation.

What then is the position of civil nuclear technology in the proliferation mechanism? That nuclear power is a sufficient condition of proliferation, unfailingly resulting in a spreading of the bomb, as has been alleged by some, is, I think, clearly a suggestion lacking plausibility. That nuclear power is not furthermore a necessary condition of nuclear weapons fabrication by a nation so minded to do is clear if we consider the many alternative routes to fissile material that I have outlined. But, though neither a sufficient nor a necessary condition of nuclear weapons, is nuclear power at the least one possible method whereby the proliferation could secure access to the fissile material needed for a bomb? The answer to this question is of course yes. The potential of nuclear materials in civil use, if diverted to military applications has been recognised by the civil nuclear industry from its inception, hence, in large measure, the cover of secrecy under which some of the early development of the civil technology had to be carried out. What has also been known is that technical means could be devised to render the diversion of nuclear material from civil to military use extremely difficult, indeed effectively impossible without alerting the attention of the world at large. It is my belief that this technology, coupled with the inherent unsuitability of the civil nuclear fuel cycle for military use, will conspire to make this perceptibly a far less suitable route for the would-be proliferator than any dedicated facility.

Can reactor-grade plutonium be used to form the fissile core of a nuclear weapon? That some kind of explosive assembly can be put together in this way has been confirmed by the release of a report from the United States Energy Research and Development Administration (ERDA) on 5th September 1977: this announced the successful detonation, in the course of experiments understood to have been carried out in the late 1940s or early 1950s, of a nuclear explosive made with the use of plutonium of relatively low Pu-239 content, recovered by the reprocessing of nuclear fuel. But what does this really prove? That reactor-grade plutonium can be used without further purification to make an explosive of some kind? So indeed it would appear. That this is the most efficient route for constructing a nuclear weapon? Almost certainly not. That it is a course easily available to most Non-Nuclear-Weapons-States in the world today, if possessed of a civil nuclear fuel cycle? Most emphatically not.

The conditions under which the ERDA explosive was assembled, in particular the cloak of secrecy which could legitimately be thrown around the proceedings, made this a situation in no way resembling that which obtains in a country whose nuclear facilities are under international safeguards.

International safeguards are the cornerstone of measures to demonstrate that civil facilities are not being used for weapons purposes. We can and should seek to ensure is the enforcement in nations whose facilities are under safeguards of measures which would make it as difficult and as time-consuming to divert fissile material from its legitimate use to weapons production as to build a completely separate weapons capability.

What would this involve? The criteria one could sensibly adopt in evaluating the proliferation-resistance of fuel-cycles have been looked at in the context of the NASAP programme in the United States and are currently being examined as part of the International Nuclear Fuel Cycle Evaluation programme (INFCE). On the basis of studies of this kind, it is possible to identify a number of criteria of relevance to the comparative evaluation of fuel-cycles in this respect. Among these one might single out the following as being of undisputed importance:

- Quantities and distribution of Special Nuclear Material : one would need to consider the number of sites over which SNM was distributed and the transport requirements which this entailed
- Form of Material : the accessibility of the material, its chemical form, its isotopic composition
- The nature of the nuclear facilities : in particular, the time and the resources needed to divert SNM to use in a weapons programme
- Protectability : the safeguardability of the material, and the time in which and ease with which diversion and misuse can be detected.

The last two criteria are to my mind of particular importance and the elements of delay and timely warning must rank high among the objectives of the technical means adopted for non-proliferation purposes.

The kind of technical means with which we shall be concerned can broadly be divided into those we can describe as safeguards tasks proper and those in a sense more intrusive measures aimed at affecting not only the operation but the very nature of the nuclear fuel cycle. Time does not permit that I should speak in detail of the safeguards task, which will in any case be a familiar subject to most of you here today. As you will know, the IAEA was charged under its Statute with the safeguarding of nuclear materials in civil use and the Non-Proliferation Treaty and the Treaty of Tlatelolco later referred to this function. The principles of materials accountancy, containment and surveillance employed by the Agency in discharging its functions will be familiar to most of you. The United Kingdom has also been active in seeking ways in which the concept of full fuel-cycle safeguards administered by the IAEA, could be made acceptable even to countries who do not feel able to accede to the NPT.

The British Government has always given maximum support to the IAEA and to safeguards arrangements concluded under the NPT. In particular, in common with the United States, the UK has made a Voluntary Offer to the IAEA whereby all of our civil nuclear facilities are open to scrutiny by the Agency's Inspectors. We are aware that the world at large welcomes this action by the United States and Britain and indeed I feel it right that the Nuclear-Weapons-States should be seen to enjoy no specific privileges in respect of their civil activities.

Nobody could say that safeguards arrangements, whether they are administered by the IAEA or whether by EURATOM, admit of no further improvements. Beyond question there is scope for improvement in the technical means adopted for the verification of nuclear materials. There will almost certainly be scope in the design of industrial-scale fuel plants for the incorporation of new design concepts aimed at facilitating the application of safeguards. And there is an unquestionable case for an increase in the number of the Agency's Inspectors.

But while there is room for improvement here, as in all other walks of human endeavour, I feel nevertheless no hesitation in asserting that the safeguards task with which the Agency is charged is and will continue to be carried out to a very high degree of effectiveness.

Coming on now to my second main sub-division of technical non-proliferation matters, namely the technical choices to be made between alternative fuel cycles, a great deal of work is of course in progress around the globe in the context of the INFCE programme launched by President Carter in 1977. There is of course a staggeringly large range of choices that could be made with respect to the nuclear fuel cycle, any of which might appear to bear in some degree on the question of non-proliferation. The subject is an enormous one and I could not hope to cover it even superficially in a talk of this length. It is easy enough however to identify some of the areas with which one would have to be concerned if one were to attempt to treat this subject properly. In the first place one would have to look at the various fuel cycles currently under discussion as alternatives to the uranium/plutonium cycle: the once-through fuel cycle, the various types of thorium fuel cycle and others. All of these are rightly receiving careful scrutiny within INFCE and elsewhere; it seems however likely to me that on detailed consideration there will appear to be little to choose between these and the more conventional plutonium-based cycles, given an equivalent system of safeguards. Of course on this last point it will be important to ensure that future nuclear installations are designed so as to make the application of safeguards as easy as possible. Secondly, within the context of the uranium/plutonium cycle, one would need to consider the extent to which the separation of pure fissile material is necessary at the reprocessing stage, and whether some system of co-conversion or, perhaps at a later stage, co-processing would not be equally feasible. Here one might wish to look inter alia at the so-called CIVEX system suggested by my colleague Dr. Walter Marshall and by Dr. Chauncey Starr of EPRI. While not likely to be of immediate application, the CIVEX concept could, it is thought, eventually be adopted in a mature fast reactor programme, assuming that out-of-pile times can be sufficiently reduced below their present level. This concept, as you will know, involves the incorporation of a certain amount of short-lived fission-product activity into the blended product being fed to a fast reactor, providing a radiation shield which lessens the likelihood of diversion by lengthening the process time and increasing the probability of detection in a safeguards system. Such a concept would however in all likelihood entail economic and possibly environmental penalties and these would need to be taken into account in determining upon the desirability or otherwise of its adoption. Again, though here more in the context of the fight against terrorism than under the heading of non-proliferation proper, one would wish to look at the whole question of transport, and the ways in which the transport of fuels of a high fissile content can be made a safe and secure operation. One would wish to ask whether this can best be achieved by the use of special vehicles, and if necessary of armed guards, or whether it would be preferable to reduce this potential hazard by some degree of co-location. One would want to look at ways in which the improved physical protection of sites could be of value in facilitating the safeguards task. And finally, and perhaps most importantly of all, one would wish to look at the various enrichment technologies and at their relative degrees of proloferation-resistance.

All of these technical choices are of great importance. But equally such technical questions cannot be considered in isolation from the institutional features that are assumed to obtain. In the last analysis, I believe, it is these institutional features that will come to be seen as the main determinants of the proliferation resistance of fuel cycles. To take one familiar example, it is often asked whether a fuel cycle involving reprocessing is a better or a worse thing from the proliferation standpoint than one simply involving the storage of spent fuel. But this, I submit, is the wrong way to ask the question. For there is in my view nothing in the nature either of reprocessing or of spent fuel storage that is of itself conducive to weapons proliferation. The situation that we find in the world at present is a growing number of countries who each have at present only a small nuclear component in their generating systems. For countries in this category there is little or no attraction economically speaking in installing their own highly capital-intensive reprocessing capacity. The natural and most attractive solution for countries in this position is to purchase reprocessing services from an existing plant such as Windscale. As an alternative, such countries could participate perhaps together with suppliers, in the establishment of some kind of multinational institution which would provide fuel-cycle services on a non-discriminatory basis to countries with a legitimate end-use for the fissile materials. The development of an internationally acceptable framework for fuel-cycle centres of this kind is likely to take some years. In addition, there is a strong case for seeking international agreement on a regime for handling separated plutonium. A system for the international storage of plutonium is already under discussion within the IAEA. Where countries have a requirement to separate plutonium for energy or research purposes, a system of this kind could make a valuable contribution to providing increased confidence that the movement and use of plutonium are internationally known and carefully monitored. An IPS regime could moreover be applicable not only to material separated in the future, but also to stocks of plutonium already separated. Alternatively, where a country had no use for plutonium, complementary multi-national or international arrangements could exist for the storage of spent fuel, which would again prove economically more attractive to such countries than a national storage facility. There is no doubt in my mind that arrangements of this kind, where plutonium would be returned to customer states only under safeguards, would minimise any proliferation risk from spent fuel storage or reprocessing.

Were on the other hand arrangements of this kind not to be available for one reason or another, then countries in this position would be obliged in the short term to extend their spent fuel storage capacity: in the longer term, they might, for reasons of security of energy supply, find it increasingly attractive to provide themselves with an indigenous reprocessing capability, even despite the economic drawbacks of this course of action. Such developments, while they of course would by no means necessarily lead to the decision to separate fissile materials for military purposes, nevertheless put fewer barriers in the way of weapons proliferation than the kinds of multilateral arrangement I have just spoke of.

What all of this shows is that what appear to be purely technical questions turn out on closer analysis to have a large political dimension, and while we can and should submit these technical issues to searching scrutiny, we should not forget that this is only half the story. Indeed at the end of the day it is the political measures which will in my view turn out to be the really important issue.

On the basis of what we have said so far, what should then be our strategy with respect to the future of nuclear power? Should we in fact be permitting further civil nuclear developments at all, or should we follow the advice of those who tell us that any civil nuclear activity is a potential proliferation risk and that the world should cut loose totally from the nuclear option? From what I have said, it is, I hope, clear that I do not believe that the limitation of nuclear weapons in any way calls for the curtailment of nuclear power programmes. Stopping nuclear power programmes will not make the proliferation problem go away: the problem is primarily a political one, and the least that could be said of the proposed strategy of cutting back on nuclear power is that it would prove totally irrelevant to the task at hand. Indeed I might go further, and say that such a cut-back would if anything jeopardise our non-proliferation objectives, for the simple reason that it would prove unacceptable to those nations on whose co-operation we rely in our attempt to ensure that non-proliferation remains possible.

For the remainder of this century, there is no doubt that the world's nuclear power capacity will continue to be made up in the main of thermal reactors operating on a once-through cycle, and that the extensive commercial use of plutonium as a nuclear fuel in any part of the world is still some ten to twenty years off. This provides us with a breathing-space, which we should use to explore ways in which we can help to maximise the proliferation-resistance of plutonium-based fuel cycles, in preparation for the time that their commercial development becomes desirable. It is, I think, now generally accepted that the reprocessing of nuclear fuel and the use of plutonium will in the fullness of time become a necessity for many of the countries who have a nuclear power programme. How soon this necessity will arise will depend on features which will vary considerably from country to country, such as the availability and cost of indigenous uranium resources and the size of the expected nuclear power installation programme, which may in its turn depend on the availability and cost of other fuels. It may depend on other non-economic criteria also. One important objective of the INFCE will be to set out criteria for the introduction of plutonium-fuelled thermal reactors and fast reactors, which will enable countries to identify their optimal course of action given their own position in respect of energy supply and demand and other factors. Eventually however the need for the use of plutonium as a nuclear fuel will come even to those countries at present best endowed with indigenous resources. Thermal recycle will probably be seen by only a small minority of countries as being of major economic benefit, and for most countries the economic case for this fuel cycle will at most be marginal. The fast reactor fuel cycle by contrast will, I feel certain, come eventually to be seen by all countries with a major nuclear component in their generating systems as offering a significant economic advantage over the uranium-based once-through cycle, and will eventually supersede the thermal reactor cycle as the mainstay of the world's nuclear generating capacity. And so long as we have the right institutional features, there is in my opinion no reason why the use of plutonium as a fuel should render impracticable the task of protecting fissile materials.

Again it might be asked, would our best strategy be to retain all of our civil nuclear technology including fast reactors, but do all we can to limit the access of any further nations to this technology? Would this help to reduce the risk of the technology being put to military use? My conviction is that this would be a profound mistake. It was clear to the nations which negotiated the Non-Proliferation Treaty that if the vast majority of the countries of the world were to be persuaded to give up a defence option of great significance, then this could not be done without at the very least an adequate quid pro quo being offered. The incentive that was offered to the Non-Nuclear-Weapons-States in the NPT, and it was in my opinion the correct incentive, was assistance from the nations with the greatest nuclear expertise to the non-nuclear weapons states in developing all those applications of nuclear energy which could be developed without the risk of nuclear weapons proliferation. Important elements in the NPT are of course Articles I and II which outlaw the transfer of nuclear weapons technology: but an equally important article in my view is Article IV.2 whereby parties to the Treaty "undertake to facilitate and have the right to participate in the fullest possible exchange of equipment and materials and scientific and technological information for the peaceful uses of nuclear energy". The idea that the safeguarding of the nuclear fuel cycle should go hand in hand with the promotion of the peaceful uses of atomic energy was already implicit in the Statute of the IAEA, which from its inception was given the dual task of promoting civil nuclear power and of setting up and administering the safeguards regime.

What I have said should not be taken as endorsing the unrestricted spread of nuclear facilities to countries that can make no real use of them. This would clearly be foolish. What I do however most strongly believe is that, where nations are in a position to benefit from nuclear power, then the world is not only entitled but even in a sense duty-bound to assist them in the development of the peaceful uses of nuclear energy, always provided that adequate safeguards arrangements can be agreed. If the developed world is not prepared to share its use of nuclear technology in this way, this can have only one consequence. Almost inevitably, if a country is refused access to the use of this technology on reasonable terms, then it will feel itself impelled to obtain what has been refused by means of indigenous development. We have seen this after the war, where the exclusion of Canada from the UK/US accords on the protection of nuclear information led to the decision by the Canadians to develop their own reactor system, the reactor which we now know as Candu. We have seen this in other fields as well. As I have said, I feel certain that if the western world were to persist in a refusal to provide reprocessing services to the less developed countries, then this could have only one effect: that these countries would perforce attempt to develop their own reprocessing technology. The international community would hardly then be in as good a position to regulate the uses to which reprocessing technology was put as it would have been if it had provided adequate services in the first place.

To what extent then is non-proliferation a technical question? And how far is it a problem which can be addressed purely by political means? In a sense of course these two aspects of non-proliferation cannot really be separated. However, to the extent that we can answer this question at all, our conclusion must I believe be that it is political factors to which we must primarily look in seeking the remedies for proliferation. More than anything else, what guides the choices of nations faced with the question of whether or not to develop nuclear weapons, is their perception of their national security and of the extent to which they can rely upon the international community to protect them in the event of a nuclear attack, without the need for their own nuclear weapons arsenal. The British Foreign Secretary gave us I think a penetrating account of this matter when, speaking in May 1977, he said: "There is a direct link between removing the incentive to acquire nuclear weapons and the creation of conditions of stability and security. The reverse of the case is a recipe for nuclear conflict. The quantitative threat of proliferating nuclear weapons can only be contained by a qualitative improvement in the management of international relations". In illustration of this, one finds in the statements made by a number of nations at the time that they signed the NPT in 1968, references to the importance that these nations attach to the promise of intervention by the United Nations Security Council in the event of their being threatened with nuclear attack. If we are to be successful in the struggle against nuclear weapons proliferation, one important objective must be to ensure that the non-nuclear weapons states do not regard their military security as being endangered by the non-proliferation regime. This may involve the international community in concerted political action if the occasion so demands. It also involves the protection of other vital interests including, I believe assurance adequate energy supplies to all nations around the world, and it is from this point of view that the development of civil nuclear technology may be of especial importance in assisting us to fight against proliferation.

Again, while technical choices in the nuclear fuel cycle are important, they are important only in the context of institutional safeguards arrangements. Political choices of this kind are an indispensable correlate of the various technical choices that I have earlier outlined. Such an exercise as INFCE will succeed in its objectives only if it manages to keep in view these aspects of the proliferation problem.

The possibility of nuclear power and possibility of nuclear weapons have both been with us now for many years. To a very considerable extent the development of these two technologies has been separate. But in the last analysis there is no such thing as the civil atom or the military atom. An atom is a neutral thing and technology is a neutral thing. It belongs to the most important moral and political duties incumbent upon mankind as custodians of this earth to ensure that the technology of nuclear energy is one that is turned not to evil but to good.

7

REPROCESSING AND ENRICHMENT: THEIR PROLIFERATION RESISTANCE

by

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Let me begin by expressing my pleasure and gratitude for the opportunity to be here today to give my views on proliferation resistance of methods of enriching uranium and of reprocessing spent nuclear fuel. It is especially a pleasure to join in this discussion with Professor Beckurts, with whom I have had a close and intellectually rewarding experience for many years.

I must add that the remarks I shall make are entirely my own personal views. I am not here as an employee or a representative of the Government of the United States, but because of the personal invitation you have made me.

You should find a substantial degree of agreement between my views and those of Professor Beckurts. After all, we are both technical people. We start from a common data base, and to a large extent our understanding and appreciation of the role of nuclear power have evolved in a similar context. No doubt there is some divergence of views, and both the similarities and differences will appear as we go on. Some of the topics I shall take up are recent developments in the United States. These will certainly ensure that we do not say the same things throughout.

At the start, we discuss proliferation resistance of fuel cycles in a larger context. We can begin with agreement that there is no proliferation resistant nuclear fuel cycle or nuclear power process in the absolute sense. There is no way to design or choose such systems which completely avoids the possibility that they could be used as the starting point in a program to produce nuclear weapons.

This is a truth which technical people realized at the outset of the re-examination of nuclear fuel cycles that has been taking place during the past two or three years, and a realization that the interested political analysts have reached more recently. We have all therefore rephrased the questions being asked in this examination of fuel cycles, to the more cogent ones of - what are the differences among our options as regards sensitivity to proliferation, economics, and other characteristics; and, is there something that should be done to strike a better balance among the imperatives? I belong to the group that believes we can profit from analyzing our possible courses of action in light of these questions, and that in fact we may possibly find that some redirection can lead to choices regarding nuclear power that are more socially acceptable than would be developed following current trends.

We must avoid pressures to conduct such analysis in a quantitative mode. Proliferation resistance itself is not quantifiable. It is usually hard enough to calculate things correctly when they can be quantified. Attaching numbers to qualitative values serves usually to mislead or confuse. It is most often done only to make the answers come out the way we want them to be, in a manner that hides the completely subjective character of the analysis.

There are differences in the characteristics of nuclear fuel cycles and of technical options for nuclear processes, that affect the ease with which the fuel cycle or the technical process may be used as a springboard to developing a nuclear weapons capability. This is independent of the question of whether a determined choice of some nation to "join the nuclear club" would in fact use the commercial fuel cycle as the starting point. There are reasons why a country on the way to developing a nuclear weapons capability might find use of existing commercial capability to be attractive, and there are reasons to believe that plans to take such a course have in fact been seriously entertained. Therefore we must not reject the possibility. But in the last analysis, the option would always exist to adopt a fully clandestine path, using facilities built and operated entirely for nuclear weapons purposes. If steps are to be taken either in a technical or an institutional way to preclude use of commercial nuclear facilities in nuclear weapons development, there is no reason to do more than would lead the country in question to choose the clandestine course. Beyond that point no additional proliferation resistance of commercial cycles would have any value.

Let us now turn to the subject at hand: the implications of isotopic separation and spent fuel reprocessing for proliferation of nuclear weapons capability. We discuss first, enrichment.

There is a growing realization that of the methods that have been successfully developed so far for isotope separation, the gas centrifuge is the one that is most closely tied to possible scenarios for proliferation of nuclear weapons capability. Of the several reasons for this linkage, the most important is the relatively low level of technology needed to design, build, and operate centrifuges for isotopically separating uranium. This does not mean that the technology is really simple. After all, it has taken considerable time and financial investment for the Tripartite centrifuge partners to achieve technical success and to build an industrial capacity of some size. But it is true that the technical competence required for design, construction, and operation, at levels of efficiency and competence needed for a modest weapons program, is widespread and is not simply the property of a few countries. After all, the well-known work done by Zippe in the United States after his return from the USSR was accomplished using the relatively unsophisticated machine shop at the University of Virginia. The centrifuges developed there had characteristics that would make them quite acceptable in cascades producing enriched uranium for weapons use by a country developing a new capability of this kind.

There are philosophical differences between the technical approaches that have been pursued in different countries in developing gas centrifuges. Without developing this point further, I would only like to say that centrifuges embodying a lower level of technology would be more readily subject to misuse than those of a higher level. For this reason, it appears to me that there are even more important reasons for protecting the lower level technology from spreading to potential new weapons states than for protecting high technology.

The gaseous diffusion process is certainly less suited to misuse through producing separated uranium for nuclear weapons than is the centrifuge. In fact, a gaseous diffusion cascade designed to produce slightly enriched uranium for LWR's could only be used to produce uranium of weapons quality through operation of the cascade far from any condition of good efficiency. Throughput would be very low, and equilibrium times would be very long.

The same is true in some respects for the nozzle process developed in Germany. However, I think that it is in principle more easily possible to change the number of stages of a nozzle cascade than a gaseous diffusion cascade. But this point really depends on specific designs of diffusers for both processes, and good design could negate or even reverse the conclusion.

There is, of course, a French concept for producing slightly enriched uranium by a process which has not been revealed. I cannot comment on the proliferation resistance of this process, except to repeat the view of French authorities that the process could not readily be used to produce highly enriched uranium.

Finally, there are more advanced methods of separation being worked on in a number of places. These include use of lasers and of electromagnetic principles. Recent reviews have indicated that it should be possible to design and operate at least some types of laser isotope separation system in ways which would make it very difficult to produce highly enriched uranium through use of the same equipment. This is only one input to the question of whether laser isotope separation might be used toward nuclear weapons purposes. It might help to answer the question of whether the Exxon Corporation could surreptitiously use its proposed isotope separation plant at Richland, in the State of Washington, USA, to produce weapons grade uranium. That, however, I regard as an unimportant question. We really would like to know whether some non-weapons country might use the technology to get material for nuclear weapons. I doubt this very much, particularly for the next few years. Powerful lasers with the right characteristics will not be ordinary items of commerce, and the ability to construct them will not be widespread. At any foreseeable time in the future, and in the absence of discovery of any simple and cheap alternatives for isotope separation, the simple gas centrifuge would always be the choice of any nation seeking to develop a nuclear weapons capability based on enriched uranium.

We now take up the subject of reprocessing. A number of processes have been successfully used for separating uranium, plutonium, and fission products. The most interesting question to be asked at this point is - how do other processes compare in proliferation resistance with the Purex process, which is the commonly acceptable commercial means?

There is certainly no advantage to be found in the older batch methods based on standard procedures for chemical analysis. The particular aspect of chemical reprocessing that has drawn attention in all reviews of the relation to nuclear weapons proliferation is the generation of separated plutonium in a form that can be handled with relative freedom. Ordinarily, the product of the spent fuel reprocessing is separated plutonium, valuable because of its potential use in recycle fuel for LWR's or new fuel for plutonium cycle breeding.

In my view, there is not much advantage to be gained from coprocessing, which is a concept according to which the product stream would contain the plutonium and the uranium mixed. It is easy to obtain separated plutonium from a coprocessing plant either by drawing directly from a pure plutonium stream within the process where it exists before remixing, or through straightforward chemical treatment of the coprocessed product. A high throughput chemical separation process could be operated in a small line of high-alpha-activity dryboxes, or in a small hermetically sealed room.

The Civex process that has been proposed by Walter Marshall and Chauncey Starr adds to coprocessing a new dimension of activity spiking. This is to be achieved in a reprocessing plant which has been designed so that no internal stream and no product stream contains plutonium separated from active fission products. Furthermore, the plant is to be so designed that converting it to be capable of producing pure plutonium would be difficult and time-consuming.

There is little doubt that a plant designed according to the Civex prescription would itself be substantially more resistant to misuse in producing pure plutonium for weapons than a more conventional reprocessing plant, though careful review indicates that turning Civex from a concept into reality has a long way to go. The principal improvement in proliferation resistance would be found in reducing the subnational threat, since a terrorist group could not take over a Civex plant and readily extract plutonium.

I also believe that the advantage against proliferation by a nation that might use Civex in its commercial fuel cycle is only marginal. It is not necessary to modify the Civex plant to produce plutonium. It is really only necessary to extract the plutonium from the product of the Civex plant in a separate process elsewhere, using equipment similar to that used to separate plutonium from coprocessed fuel. The principal difference would consist of shielding against the high radiation level. The separation of Civex product would still be simpler than chemical processing starting from hot, clad, spent fuel.

Civex would also possess one other feature in common with other systems of reprocessing or enrichment, that would lower barriers against proliferation capability. The designers, constructors, and operators of the plant would constitute a trained and experienced cadre of scientists and engineers who could more easily and successfully be used for clandestine plants.

The fuel cycle that is commonly used in American analysis as a basis for comparison on proliferation-resistance is the LWR, once-through. It must be granted that this is more proliferation resistant than processing the fuel. After all, getting plutonium for nuclear weapons would then require developing the chemical processing capability on a clandestine basis, and would preclude starting from a previously existing commercial capability. There remain questions as to how important are the differences, and what can be achieved taking into account the need for nuclear power? These questions are reserved for the end of my comments.

There is one chemical processing scheme that comes close to no processing at all, and which would still permit recycling plutonium. This is the Airox process, developed a number of years ago by Atomics International. It works in the following way. A spent fuel rod has holes drilled in the cladding in a line from one end to the other. The rod is then exposed in a furnace to oxygen at about 400°C. Formation of U_3O_8 occurs, accompanied by volume expansion which breaks open the cladding along the line of holes, like a zipper.

The fuel falls out in the form of a powder, since the sinter bonds are broken by the volume expansion. The fuel is then reduced again to UO_2 through exposure to hydrogen at about 650°C, and reformed into pellets. In the course of the process, the cesium, noble gases, and halogens are completely removed. Ruthenium and tellurium are partly removed. The process has been tested out and demonstrated on a bench scale.

Use would be made of Airox in the fuel cycle through adding fresh partly enriched uranium before reforming and sintering, to produce a mixture whose fissile content is suitable for return to a LWR. This accomplishes plutonium recycle without chemistry - at least without wet chemistry.

The process could be repeated a number of times after successive exposures in the reactor. At each stage the fission product content would be greater than in the previous stage, but the principal effect on neutronics would only be through requiring higher fuel enrichment in successive stages. In time the conversion ratio would be depressed, too, and this should determine when the process stops.

The system has several advantages. It would stretch the value of fuel about as much as would recycle based on wet chemical reprocessing. It would avoid the loss of actinides during reprocessing, which is the cause of the long term problems of nuclear waste. It would dramatically reduce the volume of nuclear waste, which is associated mostly with high-and low-level waste water streams from reprocessing. It would lead to a small but interesting rate of burnup of fission products, because these would spend a major fraction of their active lives in the flux of a nuclear reactor. It would have two disadvantages. Airox is probably not a suitable experience base for reprocessing for a fission breeder economy. And the storage of fission products in the nuclear reactors would increase the level of land contamination that could result from a serious accident.

Of course, the long term future of nuclear power rests in the plutonium breeder. There is little doubt in my mind as to this point, and I believe there is a growing acceptance of it as fact in the Government of the United States. There is, however, a question as to when the breeder will be needed. It appears from recent analysis that the need for the breeder in the United States can be deferred somewhat beyond dates that were accepted a few years ago, though this view is by no means unanimous in the United States. Individuals who believe the need is farther away are optimistic concerning the amount of uranium in mineral deposits in the United States. Individuals who believe in an early need for breeding are pessimistic concerning the ability to remove that uranium from the ground fast enough to supply needs that will exist around the end of the century. The opinion as to whether the breeder is needed sooner or later is also affected by other beliefs: how much energy can be saved through conservation, how much energy can be supplied as a function of time from such so-called soft technologies as solar and wind, and from exotic technology such as fusion.

In Europe, Japan, and other areas, the analysis leads to very different results. Most countries do not have the extent of uranium resource within their own boundaries that is possessed by the United States. In most cases, it will be necessary to buy uranium from such well-endowed suppliers as Australia and Canada. Foreign exchange considerations then become important; purchase of uranium to supply 40,000 MW(e) of water reactors would require foreign exchange of a billion dollars a year at the present futures price of uranium. These facts form the driving force for early development of the LMFBR in many countries. Breeders require reprocessing, and in the face of this need the concern about reprocessing as a force toward proliferation weakens as an absolute.

But perhaps reprocessing is not so important for the breeder after all, at least in the longer run. I would like to give a short description of a new concept we are working on in the United States, called the Fast Mixed Spectrum Reactor, or sometimes the "once-through breeder". This is a fast reactor which in the steady state would receive fresh fuel as natural or depleted uranium with no added plutonium, would generate plutonium in the fuel through breeding, and burn the plutonium in-situ without chemical reprocessing. Metal fuel would ensure high breeding gain in a hard spectrum region at the center of the reactor. A moderated (but actually highly undermoderated) surrounding region would expose fuel to neutrons during early residence in the reactor, generating the plutonium required for fuel when it is later moved into the hard spectrum region.

Residence time of fuel in the reactor would be very long - about 10 years in the hard spectrum, and about 17 years altogether. Radiation damage would be very high (fluence about 8×10^{23} n/cm^2, E > 0.1 MeV), and burnup would approach 20% at the highest flux points in fuel. This would be severe treatment of fuel, but there is optimism that the necessary performance can be achieved.

Depending on the strategy used, the FMSR would stretch the amount of energy derivable from uranium by a factor from 3 to 20 before reprocessing is needed. The project is now being conducted cooperatively by Brookhaven, Argonne, HEDL, General Atomics, Oak Ridge, and MIT, at a low but growing level. It appears that in the long run there may be some technical things that can be done to affect the vulnerability of the nuclear fuel cycle. This may be one of them.

Another technical option that has received much attention in the United States is the use of the thorium cycle. Of course, the thorium cycle by itself offers little or no advantage in non-proliferation, because the U-233 produced can be used to construct nuclear weapons. Versions of the thorium cycle based on denaturing have been proposed, according to which the U-233 would occur only mixed in with U-238. This would avoid accessibility of the U-233 in a weapons-usable form, except by some isotope separation process. On the other hand, separation of U-233 from the U-238 would be easier than isotopic separation of U-235 from natural uranium. Furthermore, all schemes based on denatured fuel call for reprocessing the spent fuel, and the chemical streams from reprocessing contain large amounts of plutonium. This must be burned (hence plutonium recycle), or it must be put into the high level waste, causing waste storage problems far exceeding those of conventional waste from reprocessing.

Concepts based on the thorium cycle are only possible over the long term, because no thorium-based industry exists, and much of the technology is undeveloped. It is doubtful that this option will be adopted.

I earlier promised a few remarks on the value of proliferation-resistance of fuel cycles and processes, and the practicality of such measures when faced with the need for nuclear-generated electricity.

It is very doubtful in my mind whether any technical measures would ever be adopted on grounds that they enhance proliferation resistance, if they cost a lot more. The impact of economics of power on financial health of a country will always be kept in mind, and will dominate if a belief develops that this health is being threatened.

I also believe that the most important measures that can reduce the possibility of proliferation of nuclear weapons capability over the next few years are institutional in character. These include such measures as strengthening safeguards administered by the IAEA, the adoption of international management in some cases, and multinational enterprises in others.

But I also believe that some benefit to the cause of non-proliferation can be found in technical measures. These are most easily adopted at a time when other methods less desirable from a proliferation standpoint have not already been put widely into use.

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13-16 May 1979, Rheinhotel Dreesen, Bonn-Bad Godesberg

Reprocessing and Enrichment: Are there Alternatives Which are More Proliferation-Proof?

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REPROCESSING AND ENRICHMENT: ARE THERE ALTERNATIVES WHICH ARE MORE PROLIFERATION-PROOF?

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1. Introduction

As is well-known, there are many ways for a nation to obtain nuclear weapons-usable material if its government so decides. Only a few of them are directly connected with the nuclear fuel cycle and none of the present nuclear weapon states has actually used this route. Limiting nuclear weapons proliferation or even achieving nuclear disarmament is primarily a political problem and implies removing the incentives for possession of nuclear weapons. The assertion that the world-wide spread of nuclear power and its fuel cycle must necessarily lead to weapons proliferation is not justified. Nevertheless, any responsible approach to nuclear energy must ensure that nuclear power programs, as they evolve, do not present a route that is more attractive than other routes to proliferation or make significant contribution to the independent paths.

This paper will deal with the very limited objective of assessing several nuclear technologies as to their risk of proliferation. We shall disregard questions of protecting fuel cycle facilities against abuse by subnational groups, and shall rather define proliferation to be the overt or covert diversion of weapons-usable material by a national government with the objective of constructing crude nuclear weapons. Different technology vary in the degree of a resistance to misuse, but there is none which is absolutely safe. To minimize proliferation risks, a combination of institutional arrangements, "technical fixes" and safeguarding schemes must be chosen. In this context, the available technologies must be judged according to their safeguardibility, i.e. the ability to detect, through international safeguards, the intention for nonpeaceful utilization. Such detection must occur early enough to initiate political counteraction ("timely warning") and with a probability high enough to deter a national government from such utilization. We thus tacitely assume the existence of an internationally accepted system of full-scope safeguards.

Proliferation can occur at various stages of the fuel cycle. We shall distinguish, somewhat arbitrarily, the front end of the fuel cycle, including enrichment technology (chapter 2), and various options for the back-end, i.e. once-through cycle in a throw-away or stow-away mode (chapter 3), the various reprocessing/recycle technologies in the uranium-plutonium fuel cycle (chapter 4) and the thorium-uranium fuel cycle (chapter 5).

The proliferation resistance of a nuclear technology cannot be considered in an isolated manner. It rather has to be seen in the context of existing or slowly evolving realities. Other criteria which must be considered in assessing nuclear technology are:

- Economics: How does the technology compete with others on the short and on the long run, and how does it contribute to the effective utilization of nuclear fuel recources?

- Environmental effects: Is the technology connected with specific emissions or with other risks including dose committments, which are significantly different from the alternatives?

- Commercialization Lead-Time: Is development of the technology sufficiently advanced to justify early commercialization. If not, what is the cost and time required for further development?

Only those technologies which generally satisfy the above criteria are likely to come into wide use. We, therefore, will limit our consideration to the most promising enrichment and reprocessing technologies and will also restrict our consideration to the following reactor strategies:

- once through U/Pu- and Th/U-fuel cycle for thermal reactors
- closed U/Pu fuel cycle for thermal and fast reactors
- closed Th/U fuel cycle for thermal reactors.

2. Assessment and Comparison of Enrichment Technology

At the present time, enriched uranium fueled LWRs are the world's primary sources of nuclear power. Most of the reactors under construction, and on order, are LWRs. As a consequence, the assured supply of enrichment services under equitable terms and conditions is an important and necessary component of the supply of nuclear power. Only two technologies are currently applied to the commercial production of low enriched uranium. Others, now under development may have potential for relatively increased proliferation resistance or for extension of the uranium resource base via tails stripping. The current status and distribution of enrichment technology may be summarized as follows:

- Commercially applied technologies

. Gaseous Diffusion: The gaseous diffusion process which is based on preferential flow through micropores of the lighter molecules contained in an isotopic mixture is applied for the commercial supply of enrichment services by the US-DOE, EURODIF and the USSR. The enrichment factor is rather low. Thus a plant for production of low enriched uranium (3 % U-235) consists of one large cascade with some 1200 stages in series. Due to the necessity to compress the process gas after each stage the energy consumption of this process is relatively high. The energy costs count for 50 % in a cost break down of the specific separative work costs. This is one of the main reasons why the US-administration in 1977 has decided to use for future plants the centrifuge technology.

- Gas centrifuge: Centrifuge technology which is based on the separation effect in a mixture of isotopes by a strong centrifugal field in a rotating cylinder is at present applied for the supply of commercial enrichment services by the United Kingdom, the Netherlands and Germany within the tripartite organisation Urenco. Development of this process is carried out in several other countries. Besides the decision of the US to use this process there are plans to build centrifuge enrichment plants in Japan. The enrichment factor of a single separation element is high in comparison to the diffusion, nozzle and chemical process. In an enrichment plant for low enriched uranium (3 % U-235) there are many parallel cascades of which each consists of about 12 stages only. Thus the build up of capacity can follow closely the demand. The specific energy consumption is about 6 % of that of the diffusion process.

- Technologies approaching industrial demonstration

- Separation Nozzle: The separation nozzle is an aerodynamic process and can be described as a gas jet deflection process. The process gas is a mixture of H_2/UF_6 containing around 5 % UF_6. The separation factor is low. Thus it is necessary to have some 500 stages in series in order to reach an enrichment of about 3 %. Up to now the energy consumption is higher than for the diffusion process. The process has been developed at the Karlsruhe Nuclear Research Center in Germany. Besides the construction of a demonstration plant in Brazil within the scope of the German-Brazilian nuclear agreement no commercial plants are envisaged up to now.

- Chemical Separation: The chemical enrichment process is based on exchange reactions occuring due to a phase equilibrium difference in uranium isotopic composition in two different phases. One phase may be stationary or the two phases may be moving in a countercurrent flow. While the principles of this technology have been investigated in several countries the French CEA announced, in 1977 at the Salzburg IAEA conference, that France has developed this technology close to industrial demonstration. The main advantage claimed by CEA is that this process could be proliferation proof due to the long equilibrium time and criticality limitations. However, for a further evaluation sufficient data have not been published.

- Advanced technologies

Besides several other technologies which had been proposed and investigated to some extent there are two processes which are of major interest and which are presently in the research and development stage.

. Laser: The technology is based on the difference in the light absorption spectra of U-235 and U-238. There are two approaches, one using atomic uranium vapor and the other using a molecular uranium compound e.g. UF_6. The separation is reached by exciting selectively the desired uranium isotope which is subsequently separated either by ionisation, dissociation or chemical reaction. The separation factor in theory is very large, thus the laser process may be a one step separation process. In practice, however, the number of stages required for a given enrichment will depend on the degree to which the separation factor will be reduced due to transfer of excitation by molecular collision between the two isotopes. This process, however, may allow for an economic tails stripping and thus help to save uranium. The process is under investigation in several countries. Commercial application however is not envisaged before 1990.

. Plasma Enrichment: The plasma enrichment process which is under investigation in the US is based upon the fact that in a uniform magnetic field the ion cyclotron frequencies of U-238 and U-235 ions of a plasma differ by about 1 %. There are indications that this process also may be particularly useful for tails stripping. Details have not been published. Commercial application if at all is not envisaged before 1990.

Most uranium enrichment facilities based on proven technologies, (i.e. diffusion and gas centrifuge) and facilities under construction, based on technologies which are not yet in the stage of commercial application (e.g. nozzle, chemical) are designed and constructed to produce low enriched uranium, containing approximately 3 % U-235, which cannot be used for nuclear weapons. From the point of proliferation risks, it is necessary to recognize the potential for production and/or transfer of high enriched uranium (HEU) in enrichment facilities.

An important way to acquire weapons - grade material would therefore be to use an enrichment facility, designed and operated for production of low enriched uranium, to produce high enriched uranium by modifying the plant.

There are, however, the following barriers to proliferation:

- the application of international safeguards to materials and facilities
- institutional arrangements with supervision by governments involved in controlling plant, technology and nuclear material produced,
- inherent technical features in enrichment technology making the construction, operation and concealment of undeclared facilities difficult.

The central safeguards approach to ensure that the facility is operated as declared and no diversion of nuclear material will occur can be met by applying the following basic safeguards procedures:

- Verification of design information
- Material accountancy
- Containment and surveillance.

In enrichment facilities highly accurate measuring techniques are applied facilitating the application of material accountancy. Facility modifications (such as rearrangement of cascades or utilization of batch recycle modes) to required to produce HEU depend on the enrichment process used. However, by application of the above safeguards procedures, these modifications would be easily detected because such basic changes would require major manufacturing activities and/or significant changes of the operating data.

Institutional measures, like classification and export control of sensitive equipment and enrichment know how as well as the establishment of facilities under multinational auspices may also serve to reduce those risks which would not be covered by international safeguards.

All enrichment technologies are highly sophisticated and the technical difficulties in developing the specialized components and mastering their manufacturing problems can be seen as an additional barrier to proliferation. An attempt to compare the proliferation aspects of various enrichment techniques and to quantify the proliferation potential in absolute terms is very difficult. Making such a comparison would require careful selection of assessment criteria. Without showing such a comparison in this paper it can be said that the difference in the proliferation potential between the different enrichment technologies is not quite as significant as one may assume. A closer analysis would show economic or technical differences which favor one technique or the other at any one time.

3. Once-Through Fuel Cycles (Throw-away/stow-away)

The once-through fuel scheme can be used in all thermal reactor systems. Table 1 gives a survey of resource requirements, economy, availability, environmental compatibility and proliferation resistance of these reactors when operated in a once-through mode.[1] For the LWR and HWR systems, no thorium bearing fuels are listed because they are less attractive than their uranium fueled counterparts. Only the HTR with high fuel burnup (100 - 130 thousend MWd/t) would lend itself, also in a once-through mode, to Th-bearing fuels.

LWR and HWR are currently economically and technically feasible, while the HTR still requires some development to bring it to commercial status. HWR and HTR have lower natural U-requirements than the LWR and would, therefore, extend available U-resources. The range of annual U-requirements of a 1 GWe-station operating at 75 % load factor assuming a 0.2 % tails assay is shown to be between 95 t Unat for the best HWR and HTR systems and about 160 t Unat for present day LWRs. At best, each million tons of natural uranium could supply 250 - 350 reactor stations of 1 GWe for a 30 year lifetime. Once-through operation can thus only be considered as a near term solution to perceived proliferation problems.

(1) P. Engelmann, G.W.Cunningham: Alternative Fuel Cycles-Technical Possibilities and Limitations; ENC '79

Another problem with once through schemes can be pinpointed by surveying the cumulative amount of spent fuel arising from thermal reactors during the next 50 years. A forecast predicts about 55.000 tons in storage by 1985, 120.000 tons by 1990 and 350.000 tons by the year 2000. The cumulative Pu content in the spent fuel is about 300 tons, 600 tons and 1800 tons respectively for the aforementioned years. Taking into consideration the long half-life of Pu-239 and the relatively short half-lifes of the fission products, it is obvious that Pu will become increasingly available from spent fuel as time passes. Thus the Pu content of spent fuel repositories could be an important proliferation risk in the future, particularly if such stores are distributed widely.

With respect to the economics of power generation, it remains an open question whether the once-through systems are superior or inferior to the closed cycles at present uranium ore prices. In addition to the ore prices, other economic factors such as the costs for conditioning and storage must be considered and these costs are presently known only with a large degree of uncertainty. With regard to the environmental compatibility of once through schemes, it is likely that the lack of effluents from reprocessing plants will be largely balanced by the effects of larger mining activities.

There appear to be major problems with the safe final disposal of unreprocessed spent fuel. Gas pressurization within the cladding of the fuel elements presents a potential problem for long term fuel storage. As was discussed during the Windscale inquiry, due to the larger effective surface of irradiated pellets the danger of leaching may be higher for direct final storage of fuel elements than for storage of vitrified waste. Direct final storage would require extensive operations for conditioning and packaging of fuel elements to introduce a barrier against release of radioactive materials. Even if satisfactory technical solutions can be found, the stored spent fuel will contain much greater quantities of uranium, plutonium and other actinides than are contained in the high level waste from reprocessing and fuel recovery. Consequently, the long-term heat load and plutonium toxicity hazard from stored materials will be much higher for the once-through cycles.

With respect to proliferation resistance the once-through fuel cycle offers advantages for the near term. In the long term, however, once-through schemes have no advantages in comparison to a closed fuel cycle.

4. Closed U/Pu-Fuel Cycle

The U/Pu-fuel cycle is suitable for use in both thermal and fast breeder reactor systems. Closure of the fuel cycle in either case requires reprocessing of spent fuel to recover usable uranium and plutonium. The reprocessed U and Pu are then fabricated into new fuel rods for recycle to the appropriate reactor type. Both types of reactor systems can be operated using mixed U/Pu oxide (MOX) fuels.

An optimistic estimate of the worlds future reprocessing capability, based on the cumulative nominal capacities of current and planned plants,is about 20.000 t by 1990 and about 100.000 t by the year 2000. When compared to the figures for cumulative spent fuel mentioned in chapter 3, this shows that only 20 % of the spent fuel produced by 1990 will have been reprocessed. The unreprocessed fuel must remain in intermediate storage. Such storage should present no new technical problems as facilities are already in existence, and the technology is well demonstrated. In view of the somewhat controversial possibilities of "Quick and Dirty Reprocessing" storage of large amounts of fuel does present some proliferation risk as the storage sites are likely to be widespread. Only an immediate and large scale investment in new reprocessing capacity, beyond that currently planned, could significantly reduce the amount of spent fuel in storage before 2000.

At present reprocessing capability is known to be established in the US, Russia, U.K., Japan, France, India and Germany. There is a large measure of agreement about the specifications for the plants in these countries. They all are exclusively designed for the U/Pu-fuel cycle, and the basic chemical processing flow-sheet follows the PUREX process.

The major proliferation concerns associated with fuel reprocessing are:

- A country with fuel reprocessing capability possesses the technology to obtain plutonium from fuel cycle materials.

- Fuel reprocessing produces plutonium-containing materials that are more easily converted for weapons use than either fresh or spent fuel materials.
- Widespread reprocessing will involve large scale storage and transport of Pu-containing materials, thus making effective safeguarding and international Pu-management more difficult.
- National reprocessing and storage of Pu-containing materials may significantly reduce the "timely warning" necessary for discouraging national proliferation by means of political actions.

These concerns are best addressed through political actions such as establishing treaties and agreements for minimizing access to Pu, establishing effective institutions for safeguarding and monitoring of reprocessing plants, and perhaps even establishing an international organization for Pu-management.

In addition, several different technical schemes have been suggested recently to alleviate these problems. They include:

- Co-location
- Co-conversion
- Co-processing
- Partial processing
- Spiking.

Co-location involves placing as many fuel cycle steps as possible within a single control area. This reduces the diversion risks associated with plutonium transportation. Co-location is primarily a means of deterring diversion of Pu by sub-national groups, however it has a technological impact on national abuse of the fuel cycle, since it makes it simpler and more convenient, for the safeguarding authority to maintain accountability and containment surveillance.

Co-conversion requires blending of the U and Pu nitrate streams prior to conversion to the oxide form. This scheme eliminates the production and storage of pure plutonium oxide and thus increases the difficulty of possible diversion by sub-national groups. Since a national government would have to modify such a plant or perform additional chemical processing to obtain pure plutonium oxide, this scheme also aids in providing "timely warning" of fuel cycle abuse.

Co-processing requires that the solvent extraction system be designed to produce only mixed plutonium/uranium nitrate so that there is never a reprocessing stream containing pure Pu. The extent to which this option increases proliferation resistance depends primarily upon the ease with which it would be possible to modify the plant to produce a pure plutonium stream. As with co-conversion, this scheme also would increase the margin of "timely warning".

Partial processing consists of designing the reprocessing plant in such a way that a portion of the fission products always remains associated with the Pu stream.

The concepts of co-processing and partial processing have been combined in a proposed "civilian fuel reprocessing" scheme which has been named "Civex". In the Civex process, the uranium and plutonium are never separated from one another, or completely decontaminated of fission products. Since the recycle plutonium is always mixed with uranium and radioactive fission products it is very safe against theft or diversion by sub-national groups. In addition, since further remote purification steps are always required before pure plutonium can be obtained, the Civex system also aids in providing "timely warning" of national abuse of the fuel cycle.

The Civex scheme has certain drawbacks however. Among them:

- All fuel refabrication operations must be carried out remotely. This greatly increases the difficulty and expense of fuel analysis, quality control, machine maintenance, fuel handling, inspection, etc.
- Civex processing imposes economic and operational penalties when used with LWR's. The fission products in refabricated Civex fuel impair fuel efficiency in the thermal spectrum of LWR's.
- The remote, precision fabrication technology required by Civex might be applicable to weapons production.

Spiking involves incorporating some highly radioactive material into fresh MOX fuel. The spikant may be added at any desired point in the reprocessing, conversion or fabrication processes. Pre-irradiation of refabricated fuel may also be used to introduce a radiation hazard. Both spiking and pre-irradiation are primarily of use for deterring terrorists or sub-national groups from diverting fuel in transit. These methods can only be considered effective as a means of reducing proliferation risk, as opposed to risk of theft, under circumstances where the realization of the fuel cycle in the country concerned does not include the reprocessing plant.

With the exception of co-location, the aforementioned schemes do only gradually enhance the ability of an international safeguarding authority to detect national proliferation abuse of the fuel cycle. National abuse will be deterred only if there is a high probability that it will be promptly detected in time for appropriate political sanctions to be applied. Therefore there can be no purely technological "fixes" to avoid proliferation abuse of the fuel cycle by a national government. Instead, technological development should concentrate on providing plant designs and equipment which will enhance the effectiveness of the safeguarding authority in providing adequate material accountancy and containment surveillance. This philosophy has been incorporated into the so called "PIPEX" concept which would be designed according to the following general principles, as presented by the German delegation to INFCE Working Group 4:

- In present reprocessing plants, the fissile material is contained inside a primary barrier provided by the equipment all along the plant: e.g. pipes and tanks at the first steps, apparatus in glove boxes at the end of the process. A secondary barrier exists also at the first steps of the process, essentially made of heavy concrete, where the gamma activity of the materials is strong. At the moment, there is no such barrier at the tail end.

  In the PIPEX concept, the biological shielding is completed and extended to the whole process in order to ensure the continuity of the secondary barrier protecting the fissile material throughout the plant. It goes without saying that this barrier must be adapted to each step of the process, the heavy concrete being replaced for example by ordinary concrete when gamma shielding is not necessary.

- The continuity and the tightness of the external containment (secondary barrier) must be controlled at any time by the inspectors in charge of the surveillance of the plant.

- The containment is provided with an inlet for irradiated fuel and an outlet for plutonium. At these points a quantitative control is exercised enabling the total balance of the plant to be drawn up. In addition, the containment is provided with other inlets and outlets the number of which is minimized. At these points, qualitative controls are exercised by the inspectors, if necessary, by automatic continuous measuring devices in order to ensure that no fissile material is crossing the containment.

- In an ideal plant using the PIPEX concept, it is thus possible for the inspectors to verify at any moment that the plutonium which has been brought inside in the form of irradiated fuel elements remains effectively inside and leaves the containment only through a controlled outlet. Of course, this concept is an ideal one which must be followed as closely as possible in industrial realizations. In order to be successful such realizations should be made by steps, starting from existing plants to achieve complete containment through sucessive improvements.

In this manner the PIPEX concept makes diversion more difficult and safeguards easier to apply. The PIPEX concepts of containment and surveillance are especially appropriate for reprocessing and fuel fabrication because they fit in naturally with the necessity to provide a shield between radioactive materials and the human operators in these plants.

It is our general view then, that steady evolution of present day technology for reprocessing and fuel fabrication is the most promising route for the future. Such evolution should be directed toward co-location of facilities having reprocessing plants that are designed, according to PIPEX principles, to include e.g. co-conversion within the containment. The technological changes required by partial processing or spiking do not appear to be the most promising cost effective methods for the future because they involve considerable additional expense and may lead to additional technical problems. They are primarily oriented towards the prevention of theft by terrorist or subnational groups rather than at national proliferation.

5. Closed Th/U-Fuel Cycle

The principal difference of the thorium cycle is that it produces U-233 rather than plutonium. Since the η-value of U-233 in typical thermal reactor spectra is considerably greater than that of the other fissile isotopes U-235, Pu-239 and Pu-241, the superior nuclear properties in thermal reactor spectra can result in higher conversion ratios and, consequently, smaller fissile makeup requirements. The high thermal absorption in Th-232 and the accompanying high fissile inventory required for criticality tends to discourage consideration of once-through fuelling, unless very high burnup values can be reached. Since natural thorium contains no fissile component comparable to U-235 in natural uranium, the use of the thorium fuel cycle does not preclude a need for uranium. Uranium-235 or plutonium from uranium-fueled reactors is required to start and to replace the fissile material consumed. The choice of the enriched material is also influenced by economics.

The thorium cycles can be utilized in all present reactor types, although these reactors, with the exception of the HTR have been developed for operating with the U/Pu-fuel cycle. The utilization of thorium has drawn increasing attention within the INFCE-activities. Here the main objectives were the reduction of the uranium ore consumption in a closed fuel cycle of thermal reactors and tentative increase in the proliferation resistance, particularly when utilizing medium enriched uranium (MEU) with enrichment of about 20 % U-235 or 12 % U-233 instead of highly enriched uranium (HEU).

The natural uranium savings established for the closed HEU/thorium cycle in various reactor types when compared to the closed U/Pu-cycle amount in typical cases to

- approximately 20 % for PWR
- approximately 35 % for HWR
- between 50 % and 70 % for HTR.

All these systems possess a potential for achieving self-sustaining or even breeding fuel cycles when operated with the Th/U-fuel cycle, which would lead to even greater uranium savings than mentioned above.
With respect to their proliferation resistance, the thorium/HEU and the U/Pu cycles are, in principle, comparable. In the Th-HEU-cycle the weapons usable fissile material (U-235, U-233) is present in the fresh fuel. The problems, therefore, are similar to those of fresh Pu-containing fuel.

In the spent thorium fuel, the U-232 content makes misuse more difficult. In the case of the HTR, the U-232 content amounts up to 500 ppm of bulk uranium. Due to the decay of U-232 and its daugther products with γ-energies up to 2,6 MeV the reprocessed uranium exhibits γ-activity of about 50 mCi per kg uranium after 20 days and increases further with the time. This radiation makes it necessary to develop remotely operated refabrication facilities. It does not disable states or sub-national groups from misuse of weapon usable material, but it makes access to it more difficult. Moreover, the hard γ-radiation improves the detectability of diverted material.

The concept of the denatured MEU/thorium fuel cycle requires uranium enrichment of less than 20 % for U-235, 12 % for U-233 or to a linear combination of these values when both of these isotopes are present. This means, that the weapons usable material can be eliminated from the front end of the fuel cycle. In the spent fuel the uranium enrichment is below 10 %. The amounts of fissile plutonium present are smaller by a factor of 10 to 20 compared to the U/Pu-cycle. When recycling the uranium, either highly enriched material must be added or some enrichment must be performed in order to achieve the initial enrichment. The relatively high activity caused by the U-232 and its daugther products makes the latter route very improbable, as todays requirements of enrichment facilities for the maximum acceptable U-232 content are below 0.5 ppm.

If the enrichment of the added material is restricted to 20 %, the closing of the fuel cycle would be more difficult because of increasing U-238 content. Introduction of a feed/breed fuel concept would allow removal of U-238 and perhaps simplify closing of the MEU/Th-cycle. The reasons are first in the possibility of denaturing the fertile material by such an amount of U-238 that at discharge its U-233 enrichment just approaches the proliferation safe 12 % limit. The spent fissile material can be disposed of after the feed/breed separation. And second, the reprocessing can be performed by the "conventional" means of THOREX and PUREX-technologies. In this manner it is possible to avoid development of reprocessing technology in which four main components would have to be separated and which would require probably extensive efforts.

The technology for the thorium fuel cycle for LWRs and HWRs is principally available, but not yet established on industrial scale. At the end of the sixties, R&D was performed for fabrication of thorium fuelled HWR rods in Germany.

The feasibility was proven and the processes tested are ready for use. For the HTR there exists an established technology for production of thorium containing fuels of which more than 13 tons have been produced in Germany to date. The production of LWR/HWR fuels can be done partly on the basis of this technology. These processes which are suitable for continuous and remote operation are frequently mentioned when discussing advanced reprocessing schemes. They are nearly fully developed for the HTR. For the LWR and HWR requirements they must still be qualified, but no principal problems are to be expected.

The technology for the closing of the thorium fuel cycle by reprocessing and refabrication is at present not yet commerically available. Some 870 tons of thorium fuel mostly on the thorium oxide basis have been reprocessed since 1952 in the US. In Germany, the R&D efforts began in 1965 and have continued to where currently a pilot scale plant for highly burned up fuel is under construction. Based on these facts, it is possible to consider the technology for the thorium cycle as being feasible.

The closed Th/U-fuel cycle may be considered as a medium term alternative to the U/Pu-cycle. The use of denatured uranium/thorium fuel yields the potential of increased proliferation resistance both at the front end and at the back end of the fuel cycle. On the other hand it is inferior to highly enriched uranium/thorium cycles, which offer the potential of near-breeding or even-breeding in thermal reactor systems. In the long term the interaction between both of the fuel cycles under discussion, with corresponding utilization of specific properties of various reactor types, seem to present a very attractive alternative for the future.

6. Concluding Remarks

The past few years have shown a drastic reduction of the speed of development in nuclear power programs and correspondingly, of the introduction of fuel cycle technology. One might argue that this slow-down has given us a lot of time to develop new technology. However this is not probable since due to the general reduction in growth potential, the willingness and capability of nuclear industry for introducing new technology is decreasing. Also, the same reasons which have led to the large delays in nuclear power programs based on present technology have led to a great increase in the lead and development times of prototypes for new technology.

We must therefore expect that the rate of technology changes will be slow. For the time being and for quite a long time to come, the once-through fuel cycle, mainly with the Light-Water-Reactor, will be the main option of nuclear power. Even if reprocessing starts soon in some countries, only a small fraction of the total fuel will be reprocessed well into the next century, which means our main energy source will in practise remain the once-through-cycle. This shows that methods to improve its fuel utilization will be very important! As far as proliferation resistance is concerned, the cycle is relatively safe and easily safeguardable. However in view of the increasing amount of fuel in store, the question of Plutonium accessibility becomes more serious as time proceeds. Reliable methods to safeguard spent fuel must be employed. Direct final storage of spent fuel creates a long term safeguarding problem which is a waste of resources and should not be encouraged.

The other proliferation risk of the once-through cycle occurs at the front end; that is in the enrichment plant. As we have discussed in chapter 2, the various enrichmend technologies may differ in their proliferation resistance but all can be safeguarded effectively. The spread of further enrichment plants throughout the world will probably be slow.

In the medium and long term, reprocessing of spent fuel from reactors in the uranium/plutonium cycle is an absolute need mainly for economical reasons. It is unlikely that a process completely different from the PUREX process will be used in view of long standing experience with this process. Basically different alternatives are barely visible and would take too much time to develop. From the point of view of safeguarding, modifications of the original process along the line of the PIPEX concept, involving some modifications like co-conversion, are promissing and lead to high detection probability and sufficient warning time. Additional modifications like CIVEX, spiking or use of pre-irradiated fresh fuel will increase resistance against subnational abuse but do not significantly contribute to the proliferation resistance. They may introduce, on the other hand, other problems, especially in the inspection and handling of fresh fuel. Recycle of plutonium from reprocessing plants may either be in thermal or, preferably, in fast reactors. There are, however, considerable incentives for thermal recycling. Reprocessing plant development and introduction on a large commercial scale will take a long lead-time. This and the request for economy-of-scale will limit the number of reprocessing plants in the world.

The thorium-cycle adds a very interesting alternative solution to the fuel cycle problems. Basically the proliferation problems of a closed thorium/uranium-fuel cycle are similar to those of the uranium/plutonium-cycle. However the thorium-cycle may offer some advantages due to the better detectability of U-233 and due to the possibility of using denatured fuel. The real advantage of the thorium-cycle compared to the uranium-cycle is the fact that it is more efficient in thermal reactor systems and that it extends the raw material basis for nuclear power. Its main disadvantage is the fact that the technology is less developed. In the long run, it is quite likely that both fuel cycles, U/Pu and Th/U, may co-exist, each one having particular advantages. If the concept of "safe fuel cycle centers" is accepted, we might even have "hybrid" systems, with plutonium burning breeder reactors, generating denatured uranium to be used in an outside, less safeguarded world. But this is a very long term option.

In any case technical fixes are only of limited value. They must be part of a non-proliferation strategy which comprises institutional and safeguarding measures correspondingly, and which can only be established if there is a widely accepted non-proliferation regime in the world.

REACTOR SYSTEM and FUEL	Resource Requirements t Unat/a-GWe at 75 % Load Factor, Once-Through Operation	Economy, Development Needs, Expected Availability Date	Environmental Compatibility, Safety Aspects	Proliferation Resistance; Critial Points
LWR, U present design	158	now economical and available	acceptable; problems of spent fuel storage	good; enrichment facility spent fuel storage
LWR, U improved design	134-142	economical after fuel development around 1990	like present LWR; lattice changes require accident analysis	similar to present LWR
LWR, U ultimately improved	110	possible after extensive R, D + D past 2000	similar to LWR, improved	similar to present LWR
HWR, Unat	130	now economical in some countries and available	acceptable, but 10 % more waste heat than LWR, tritium release in normal operation; problems of spent fuel storage	good; spent fuel storage (more Pu than LWR) D_2O plant, safeguarding at reactor
HWR, slightly enriched U	95	similar to HWR, Unat		like HWR, Unat but enrichment facility necessary
HTR, LEU	125	expected to be similar to LWR and HWR after demonstration phase of technology, may be available 1990/2000	good; 20 % less waste than LWR, high degree of inherent safety; problems of spent fuel storage	good; enrichment facility spent fuel storage
HTR, den U/Th	115	like HTR, LEU		like HTR, LEU less Pu in spent fuel but enrichment higher
HTR, HEU/Th	95	like HTR, LEU		poor; because weapons usable material (HEU) present at several stages of cycle

TABLE 1: Comparison of LWR, HWR, and HTR Once-Through Systems

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Perspectives on Nuclear Technology and International Politics

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The Multinationalization of Reprocessing and Enrichment: How and Where?

Horst Mendershausen

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THE MULTINATIONALIZATION OF REPROCESSING AND ENRICHMENT: HOW AND WHERE?

Horst Mendershausen

TWO MOTIVATIONS

Nations may combine for two reasons in managing uranium enrichment and spent-fuel reprocessing: (1) in order to supply these nuclear fuel services and thus assist electric power generation from nuclear fission; and (2) in order to prevent a diversion of nuclear fuels to weapons production. Both of these functions can of course also be fulfilled by purely national enterprises and national governmental measures. In fact, multinational enterprise and arrangements are only likely to come about, and to live, if they surpass and reenforce national arrangements in the joint performance of supplying and safeguarding the fuel services. If participants and cost bearers are not confident that this is the case, the unavoidable complications that multinationalization adds to enterprise management and decision making are likely to abort it.

So multinational fuel service arrangements must help supply and help safeguard. They may well offer different mixes of the two kinds of performance, one combination being more supply oriented, another one being more safeguard oriented. But if orientation toward supply is accompanied by blindness toward safeguarding, or by paralyzing disagreements about how to safeguard, multinationalization will perish by its political unacceptability. And if zealous safeguarding stifles production and availability of the fuel services, multinationalization will founder on economic unacceptability. These extremes are not viable. To be viable, multinational arrangements must offer something on both scores, and in comparison with uni-national ventures they must not take away too much on one score while adding something on the other.

Let me stress in passing that economies of scale do not give a prima facie advantage to ventures under multinational auspices. Multinational plants are not necessarily (and have not always been) larger than national plants. National plants can be (and have been) scaled to a multinational market. One must not forget the international trade in enrichment and fuel reprocessing services and the possibilities of national governmental safeguards attached to such trade. The advantages of multinationalism must be proven and cannot be taken for granted.

These general ideas will serve as a guide through, and I think they will also be confirmed by, the brief review in this paper of multinational enrichment and reprocessing arrangements, existing and proposed. The question of "multinationalization, how and where" does not only await an answer for proposed new ventures. It has already found some practical answers, and it would be foolish to disregard the answers provided by the experiences of Urenco and Eurodif, Eurochemic and United Reprocessors. In a nutshell, the answer to the "how" question, provided by these experiences, has been: "Composition, mission, and organization of the multinational venture depend on the specific project, the specific partners, and other circumstances, including the state of international confidence. The supply function is primary." Projects, partners, and circumstances are not interchangeable ad libitum. And their answer to the "where" question has been: "In Europe." This is not because I happened to pick European examples. There are as of now no multinational enrichment and reprocessing enterprises elsewhere, and those few non-European countries that are at least marginally involved in multinational activities of this kind at all, are so by way of bilateral links to the European group enterprises, or to individual European partners, e.g., Japan with France, Brazil with Germany and Urenco.

Whether examination of proposed new ventures will lead to very different answers, particularly on the geographic point, remains to be seen. It also remains to be seen whether the existing ventures will remain viable in changing circumstances.

EXPERIENCE WITH MULTINATIONAL FUEL SERVICE VENTURES

The idea of multinational enrichment and reprocessing ventures originated in the United States, where the practical utilization of nuclear fission also originated, first for weapons production and then for electric power generation. From the start, American proposals for multinational arrangements were predominantly safeguard oriented. Supply requirements for American needs were well enough satisfied by national nuclear fuel enterprises. But American concerns with the spillover of nuclear fuel industry abroad into weapons manufacture by other states always made American policy makers look for ways of barring, or at least impeding, the exercise of control over the weapons-prone phases of the nuclear fuel industry by national political authority--at least in states that had not yet been accepted as possessors of nuclear weapons.

The principal ways by which this could be accomplished were (1) reliable fuel supply from the United States, which might obviate the need for fuel service industries elsewhere, (2) multinationalization or denationalization of developing fuel service industries elsewhere, and (3) broad international agreements to forego certain fuel operations altogether, such as uranium enrichment by centrifugation and the reprocessing of spent reactor fuel that yields plutonium. During the Atoms-for-Peace period post-1954, the emphasis was on the first way, ample American fuel supply. The third way, in the form of U.S. efforts to bring about abstention, was always in the picture,* but these efforts became prominent, even dominant, only under the Carter Administration, particularly with regard to reprocessing and reliance on reprocessed fuel. The second way, multinationalization, was always contemplated as an alternative and, in the course of time, was proposed with variable degrees of enthusiasm and critical doubt. Except for the Acheson-Lilienthal and Kissinger episodes of 1946 and 1975, respectively, however, it never became a prominent line of American policy, at least not for enrichment and reprocessing. (This paper does not deal with multinational fuel banks and storage arrangements for spent reactor fuel, and recent American endeavors to bring them about.)

Ironically, the recurrent safeguard-motivated American suggestions of enrichment and reprocessing ventures under multinational auspices were taken up in Europe without American participation, and for the purpose of fuel production and supply, not primarily for the purpose of safeguarding. The multinational enrichment projects of Urenco and Eurodif and the reprocessing arrangements of Eurochemic and Unirep came into being largely in the pursuit of four considerations:

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*See Lawrence Scheinman on U.S. efforts to prevent construction of enrichment plants and developments of related technology. "Security and a Transnational System: The Case of Nuclear Energy," in Transnational Relations and World Politics, R. O. Keohane and J. S. Nye, eds., Harvard University, 1971, pp. 290ff.

(1) Technological and commercial opportunity. In these regards, Europeans sought to profit from American leads and their own research efforts, to establish enterprises capable of competing with the Americans, and to achieve through these capabilities general gains in economic and political positions ranging from reliable fuel services for European power reactors to the sales of such services and of equipment elsewhere in the world.

(2) Reliability (independence) of nuclear fuel supply. In this regard, Europeans sought to protect themselves against the economic and political risks of dependence on imported energy materials in general, which had become so high during the great conversion to oil; and against the risks of dependence on American nuclear fuel services in particular, which, as experience came to show, were subject to variable constraints, changes in terms, and threats of interruption, and therefore not reliable.

(3) Resource pooling and risk sharing. This consideration militated strongly in favor of giving nuclear-industrial enterprise, whose development was seen everywhere as primarily a national task, a multinational turn. Nuclear fuel enterprises and related technological development required amounts of capital and human resources, and carried economic risks, that tended to exceed the capabilities of individual nations. This invited combination with other national efforts in enrichment and reprocessing while nuclear equipment industries and marketing, as well as reactor operations, remained largely national.

(4) International organization interests. The organizational interests of OECD and the Common Market favored joint enterprises among

their respective members; but these interests did not prove to be very effective in generating multinational fuel enterprises in these frameworks. With the exception of OECD's Eurochemic, whose reprocessing venture did not live very long, European fuel enterprises were organized by ad hoc groupings of countries that cut across, or were narrow selections from, the membership rolls of the broad-purpose international organizations. The European Community, so far at least, has failed in its efforts to develop a framework for such enterprises.

Different mixtures of these four considerations were responsible for several European countries, in groups of three, five, or thirteen, combining in the 1960s and early 1970s in order to supply:

(1) Eurochemic's fuel reprocessing services from a jointly owned plant at Mol, Belgium;

(2) Urenco's enrichment services by centrifuge from its members' plants at Almelo, Holland; Capenhurst, Britain; and in the future also Gronau, West Germany;

(3) Eurodif's enrichment services by gaseous diffusion from its plant at Tricastin, France; and

(4) Unirep's marketing, and to a degree technological, cooperation among the national fuel reprocessing enterprises of France (Cogema), Britain (BNFL) and Germany (DWK).

The ways in which the four aforementioned considerations have contributed to each of these four ventures makes an interesting story that cannot be told here. Nor can I analyze here in detail the very different organizational structures of the four ventures.* Suffice it to say that Eurochemic's single enterprise was governed by a committee of its thirteen participants with equal rights; that the several enterprises in the Urenco-Centec "troika" form a complex of national, bilateral, and trilateral undertakings of the three members with much technology exchange and joint marketing; and that the (for the time being) single center of activity of Eurodif is under the political, managerial, and technological control of a principal partner, France, while four minor--or should we say, limited--partners (Italy, Spain, Belgium, and--so far at least--Iran) participate only as capital contributors, committed customers, and participants in general policy decisions. The cartel-like organization of Unirep finally provides policy coordination, and some other cooperation, for three distinctly national enterprises, two fully active or almost so, and one largely incipient each capitalized, managed, and contracting on its own. Parenthetically, the two presently producing national partners, Cogema and BNFL, have created subsidiary and limited multinational arrangements of their own by letting foreign customers for their services, e.g., Japanese and German electric utilities, participate in the capitalization of the new Cap La Hague and Windscale oxide fuel reprocessing plants.

We can see here four different forms of multinationality in effect, each responding to a particular set of partners and their special conditions,

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*See my <u>International Cooperation in Nuclear Fuel Services, European and American Approaches</u>, The Rand Corporation, P-6308, December 1978.

and none of them necessarily a better model than the next for future ventures that may come along.

Supply of enrichment and reprocessing services is the principal purpose of these multinational ventures, supply to partners and also to nonpartners, in Europe or elsewhere. Before I ask now: What about safeguarding? let me say that supply or production having been the dominant purpose has not meant in practice that all of the partners have been satisfied, all of the time, that those ventures served that purpose well enough. There have been frictions in all of them, particularly of late, but three of the four organizations have survived to this day. The one casualty was Eurochemic. This early European--and incidentally U.S.-favored--multinational fuel reprocessing venture came to an end when--and I simplify a long story--some members felt that they had learned enough to go into the business on their own. Then the Mol plant was turned over to Belgium and appears to be now on its way to becoming a national Belgian fuel reprocessor. The lesson? Fuel service production may not only be multinationalized; it may also be renationalized.

What about safeguarding? The prevention of weapons spillover has been an objective, albeit a secondary one, in the formation and operation of the four multinational ventures. In the formation of both Eurochemic and Eurodif, the idea that sharing in a multinational production operation might obviate the need for participating nonnuclear weapon states to set up enrichment and reprocessing plants of their own was a contributing factor. But in neither case, nor in the other two ventures discussed, were participating countries asked to commit themselves not to build plants under national jurisdiction. The European ventures thus shunned the idea of exclusive, or obligatory, multinationality which came to the fore in American discussions of multinational nuclear fuel enterprise in the mid-1970s. Urenco provides an exception; its members are treaty bound to commercialize enrichment by gas centrifuge only within the tripartite framework.

With regard to the communication of technology to participants and nonparticipants, Eurochemic had no restrictions--the technology of reprocessing, at least in small plants, and of lightly irradiated natural uranium, has been in the public domain since the late 1950s--but in Eurodif it was otherwise. While France under presidents De Gaulle and Pompidou was hardly a preacher of the nonproliferation gospel, the French, who have control of Eurodif, have pointed with satisfaction to the relative unsuitability of the gaseous diffusion enrichment process to easy duplication, and they have kept technological details of the process under wraps anyway. The low-enriched uranium which Eurodif is to supply to customers is not explosive material.

Urenco and Unirep have paid much attention to technology safeguarding by making relevant technology transfers by one of their members to nonmembers subject to approval by all of their members (e.g., in Art. II, sec. 5 of the Treaty of Almelo). "Relevant technology" means in Urenco everything related to the gas centrifuge process. The Treaty of Almelo does not keep member countries from exporting other enrichment technologies unilaterally; Germany's exportation of jet nozzle enrichment technology to Brazil did not fall under Urenco rules. In Unirep, "relevant technology" is said to signify information on reprocessing in larger than laboratory size (10 te/year throughput) plants. In both organizations, these restrictions on technology transfers undoubtedly bespeak the desire to prevent weapons spillover from the covered processes, and the Treaty of Almelo at least presents this desire as a formal commitment of the partners (Art. VI). It is fairly evident that these restrictions have been also, and even primarily, motivated by a desire to prevent the rise of commercial competitors of the group or grouped enterprises, but the commercial motive, restraint of competition, does not contradict the antiproliferation motive here; it rather reinforces it. Both Urenco and the national reprocessors combined in Unirep have much more to gain financially from the exportation of their services than from the exportation of their technology.

Nevertheless, the provisions against weapons spillover built into these multinational ventures are no more than patchwork when one looks at them from a comprehensive safeguarding point of view. To some extent, they are inherently incomplete. These ventures cover only specific sectors of the enrichment and reprocessing industries of the member nations. Their anti-spillover provisions do not affect other than the covered sectors, such as enrichment by jet nozzle or laser processes, or small-scale reprocessing plants. To some extent, the provisions are also what one might call functionally weak. They do not bar weapons spillovers which customers--member or nonmember countries--might undertake with materials furnished to them by the multinationals. Urenco may some day deliver highly enriched uranium for the purpose of feeding somebody's research reactor, and Unirep partners will deliver reprocessed plutonium in one form or another for the purpose of feeding somebody's power reactor. But if the customer's real purpose turned out to be, or shifted along the way to, weapons manufacture he would have been supplied, in effect, with nuclear explosives, because the two materials in question are fuels as well as explosives. To be sure, not an entirely unfamiliar situation if one thinks of various chemical substances--including the household article, gasoline, which can serve in Molotov cocktails--but on a very different political scale, of course. One functional weakness of these supply-oriented multinational ventures, from the point of view of weapons spillover prevention, is that they furnish in the course of their normal business more or less weapons-suitable products, just as purely national ventures do or would.* Another, rather minor weakness may be noted in passing. Proprietory interests, which as I have noted militate against technology transfers, also militate against the inspection of internal processes by outsiders, e.g., against the admission of IAEA inspectors to Urenco plants.

Thus, in the existing multinational ventures of reprocessing and enrichment, safeguarding definitely takes second place to supply. It has been a subsidiary motive in their formation, and their capabilities to perform it with their own means are incomplete and weak. But the built-in means are not the only means.

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*Carl Walske makes interesting observations on the weapons suitability of materials in "Nuclear Electric Power and the Proliferation of Nuclear Weapons States," International Security, Winter 1977, pp. 98ff.

BUILDUP AND EROSION OF CONFIDENCE

This weakness of the fuel service ventures could be compensated by broad confidence creating measures, and up to a point has been so compensated. The most important confidence creating measure was the NPT, which went into effect in 1968. Next in importance were the verification and inspection systems by officials from outside the host country under the aegis of IAEA and Euratom. These systems evolved gradually in the 1960s and early 1970s, and as they evolved, they began to cover the operations of the multinational ventures as well as national activities. If one visualizes, as quite a few people hopefully did at the time, that the largely supply-oriented fuel service ventures would be operating in a political environment of a universally subscribed to and universally adhered to NPT, buttressed by universally applied verification and inspection systems, the gaps in their built-in safeguarding armor could appear quite tolerable. One might even say that such an environment might have obviated the need for the built-in armor altogether.

But the political environment did not reach this level of universal confidence. In fact, it retrogressed.* Even before the three surviving multinational ventures became operational, the Indian explosion of 1974 tore a hole into the fabric of confidence that had been woven. It was not the only hole to be sure, but a big new one. The spectre of sudden weapons spillover from explosion-capable fuels raised its head and became

*See Bertrand Goldschmidt and Myron B. Kratzer, Peaceful Nuclear Relations: A Study of the Creation and the Erosion of Confidence, Rockefeller Foundation and Royal Institute of International Affairs, New York and London, November 1978.

quite frightening in what was then recognized as an environment of only partial adherence to the NPT, spreading and often uninspected nuclear industrial facilities, unstable regional and world political relations, and projects of transferring fuel cycle technology to further countries--a real environment so different from the one previously hoped for. In the few years that followed, the newly formed Nuclear Suppliers Group, and correlated actions taken by some of its members individually, succeeded in arresting the spread of certain "sensitive" technologies to further countries, thus patching up at least one of the holes in the confidence fabric. But the seriousness of the remaining holes for the future prospects of multinational fuel service ventures was revealed in three developments: (1) the hardening of American opposition to any closure of the nuclear-industrial fuel cycle in our time, (2) American disenchantment with the remedial notion of multinational fuel centers, and (3) the Holland-Brazil crisis in Urenco. In each of these developments, safeguarding or spillover prevention was pitted against fuel service supply, one necessary function against the other.

The determined American assault after 1976 on the commercialization of reprocessing and plutonium recycling under known and previously encouraged technologies created difficulties for the development of nuclear industry and commerce. It also led to policy differences with the principal other industrial democracies and adherents to the NPT, which need not be analyzed in this paper. With regard to multinational fuel service ventures, the new American policy unwittingly tended to vindicate the supply orientation of the existing European organizations and perhaps to stimulate some new ones elsewhere with a similar bend; for it put a premium on independent fuel supply capabilities. But the temptation doctrine on which much of the new policy was based also made it more difficult to maintain and develop appropriate measures of spillover prevention. If the only acceptable safety from weapons spillover were the unattainability of explosion-capability fuels, if the temptation to use such fuels for weapons had to be regarded as too powerful to be resisted with NPT pledges, IAEA inspections, intergovernmental contracts, and other commitments of governments, then an internationally workable political safety regime for nuclear energy would be exceedingly hard to come by. Reprocessors and reprocessed fuel users would have to be regarded as virtual bomb producers, shippers and handlers, as indeed they were in the minds of some teachers of the temptation doctrine. Multinational reprocessors would hardly be safer than national ones.

Indeed, the idea of multinational fuel centers in American policy-thinking appears to have fallen victim to the temptation doctrine and the campaign against "plutonium economy." In 1975, Secretary of State Kissinger, speaking at the U.N., still formally proposed "as a major step to reinforce all other measures, the establishment of regional nuclear fuel cycle centers." Such centers, he said, would serve energy needs on a commercially sound basis, reduce the incentive for national reprocessing facilities, limit possibilities of weapons spillover, and create a better framework for applying international safeguards.* But

*"Building International Order," Address by Secretary Henry Kissinger on September 22, 1975. Department of State Bulletin, October 13, 1975, p. 551.

disenchantment followed quickly. The abandonment of national facilities could not be vouchsafed. However well safeguarded internally, the multinational centers would also distribute plutonium to customers. What would guarantee that these would not succumb to the temptation to divert their ration of plutonium to weaponry?* Despite general feasibility studies by the IAEA, the nations of no region showed much interest in forming multinational ventures that seemed primarily safeguard oriented. And primarily production oriented ones might not be regional, because regions harbor not only potential cooperators but also often the sharpest antagonists. The Carter administration treated the Kissinger proposal with skepticism and for all practical purposes dropped it. Eroded confidence appeared to leave no room for championing regional reprocessing centers.

The Holland-Brazil crisis in Urenco, finally, showed that common production interests of partners in an enrichment enterprise could be jeopardized by divergent views about safeguard requirements. The bilateral and multilateral safeguards on which Germany and Brazil had agreed for the purpose of their joint undertakings in reactor construction and pilot fuel cycle plants did not satisfy certain parties in Holland. Dutch opposition threatened to annul Urenco plant construction projects in Europe and Urenco supply commitments to the reactors under construction in Brazil

*Several publications by prominent American thinkers on nuclear policy illustrate the disenchantment. See, e.g., the contributions of Lawrence Scheinmann, Constance B. Smith, and Abram Chayes in International Arrangements for Nuclear Fuel Reprocessing, A. Chayes and W. B. Lewis, eds., Ballinger, Cambridge, Mass., pp. 76, 157ff. Albert Wohlstetter, et al., Moving Toward Life in a Nuclear Armed Crowd, Pan Heuristics, Los Angeles, California, 1976, pp. 92ff.

unless Brazil subscribed to the NPT and accepted "full scope" safeguards, something that Brazil had long refused to do. Thus the big German-Brazilian nuclear industry deal, which had already provoked lively conflicts with the United States and a tug of war in the London Suppliers Group, came close to breaking up the Urenco "troika." The British and Germans differed with the Dutch over what arrangements with a customer deserved sufficient confidence that the customer would not ultimately derive weapons material from purchases of low-enriched uranium. For the time being, at least, the breakup was avoided.

Thus, the erosion of confidence in provisions for the prevention of weapons spillover did not only stifle new initiatives for multinational reprocessing ventures, it also threatened the continuity of one of the existing multinational enrichment ventures, and that despite the fact that safeguarding provisions had undergone substantial evolution since the 1960s and early 1970s.

DO MULTINATIONAL ENRICHMENT AND REPROCESSING HAVE A FUTURE?

At the present time the outlook for such ventures is generally unfavorable, and no paeans on their economic and political virtues, no wistful hopes that a bigger shot of multinationalization administered to this or that venture will blow the troubles away, will change the facts.

All of the existing supply-oriented European ventures are facing greater difficulties than were anticipated at their beginnings. For the larger part, these difficulties result from the troubled state of the nuclear fission energy in general. Delays and blockage of the construction of nuclear facilities in many countries, increasingly complex regulation, widespread antinuclear Luddism, political vacillation, and cost escalation are depressing the prospects of demand for nuclear fuel services--at least causing much uncertainty--on the one hand, and impeding the programs for supplying these services on the other hand. The whole nuclear industry complex, from the raw material base to electricity demand and waste disposal, is out of joint, with bottlenecks threatening here and excess capacities there. How different from the high hopes that had been placed in the rise of this important new energy industry only ten or five years ago! For the smaller part, the difficulties are specific to the fuel cycle ventures and reflect technological problems of reprocessing, uncertainties about fuel cycle choices in various countries and the executability of big contracts--also uncertainties about future offers of enrichment and other fuel services from the United States.

No wonder then that there are tensions within the organizations. I have referred to one in Urenco. Eurodif, close to beginning large enrichment operations, has at least one member, perhaps several, who now have no use for their quota of output--and who have other complaints besides. In Unirep, at least two of the three partners appear to question the usefulness of existing cooperation, and that for different reasons. The adversities may not be fatal, but they are not healthy. Some members may exit (Iran from Eurodif?), but then others may join (Belgium in Unirep?), perhaps even non-Europeans. Some speculative developments may not materialize, such as mutual capital participation among the Unirep partners, but a joint overseas transportation enterprise for spent fuel appears to be on the way now.

For new supply-oriented multinational ventures, one may have to look outside Europe. A Japanese-Australian enrichment venture is being talked about, with facilities in one or both countries. It would be an interesting combination of a technologically advanced large new uranium consumer and what is expected to be a large new uranium producer, different from the European combinations of industrially developed but uranium poor countries. But as of now this appears to be the only strong candidate. In Southern Asia, the Middle East, Africa, Latin America, the political and economic prerequisites for multinational fuel service ventures are generally lacking, unless one thinks of some country there attaching itself to a European or a future Far Eastern venture. That is not impossible. Multinationalism in the Soviet Bloc is a separate story.

But the question uppermost in people's minds, in this fifth year of eroding confidence and the second year of INFCE, is whether there is a future for primarily safeguard-oriented multinational ventures, whether such ventures might now come about. The operational question is really narrower: it is the question of a binational, trinational, or multinational management of certain segments of nationally conducted fuel reprocessing activities, for short, multinational plutonium management. I say for short, because the segments under consideration reach from plutonium separation to plutonium storage, plutonium fuel or MOX fabrication, and release of fuels to customers.

The question is being batted around in INFCE, and perhaps in diplomatic consultations, too. The urgency of this as yet inconclusive search stems from the hope that such partial multinationalization of fuel reprocessing, installation of multinational enclaves in national enterprises, would help significantly in restoring mutual confidence in the international community with regard to fuel cycle closure for the LWR technology, and perhaps others as well. This could be a forlorn hope because the conflicting priorities of those who want to produce and supply plutonium-type fuel, those who want to obtain and use such fuel, and those who want to see no production, trade, and use of such fuel at all, or as little as possible, remain unreconciled, as far as I can tell. To be sure, nobody wants to broadcast this kind of fuel, but can multinational management create confidential acceptance by producer, consumer, and antiweapon proliferation interests that functioning supply is not tantamount to reckless broadcasting? This is doubtful, but perhaps possible, at least to some degree.

Let me use as an illustration the scheme that has been advanced by Ambassador Russell Fox of Australia and Mason Willrich of the Rockefeller Foundation.* It has the virtues of having been put in the public domain and of being a rather sensible, sober-minded, and readable document. Fox and Willrich propose that "stocks of plutonium in excess of immediate needs" be stored at the sites of commercial reprocessing plants in the "physical custody, direct and complete" of some "multinational or international agency." The controlling agencies, the authors say, should preferably be established "on a case by case basis through negotiations

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*Russell W. Fox and Mason Willrich, International Custody of Plutonium Stocks: A First Step Toward an International Regime for Sensitive Nuclear Activities, The Rockefeller Foundation and Royal Institute of International Affairs, New York and London, 1978. The following citations are from the document.

among groups of countries, including one or more reprocessors, suppliers of spent fuel and/or suppliers of uranium, enrichment, and/or nuclear equipment," in conformance with some general IAEA standards. (Other schemes that I have seen make the IAEA itself the managing agency.) The participants should agree on and apply "quite precise criteria" governing releases of stored material "for immediate use in a defined civil purpose . . . under continuing safeguardability," criteria which no state could alter unilaterally. The costs of operating the international custody of civil plutonium stocks are believed not to be large, and the authors suggest that most of the costs should be allocated among the participants through user charges.

I shall not attempt to give a critical appraisal of the Fox-Willrich scheme and of its alleged benefits to the several interests involved. Despite its tentativeness and the problems that one may easily see, this scheme might have a better chance of being tried out in Western Europe and Japan than some others, certainly better than such far-out notions as an IAEA reprocessing plant on a UN island. Perhaps the United States government might acquiesce in it. But who would bet on that?* The questions of how and where, even whether, safeguard-oriented multinational enterprise in this field will see the light of day--enterprise rather than IAEA monitoring--are unanswerable today.

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*For a skeptical view, see Victor Gilinsky, "Plutonium Proliferation and the Price of Reprocessing," Foreign Affairs, Winter 1978/79, pp. 379-381.

CONCLUSION

• Primarily supply-oriented multinational enrichment and reprocessing ventures exist in Western Europe, if somewhat precariously today, and some similar new ones may be created in the Far East. Their contributions to confidence in the prevention of weapons spillover are minor, but that would be no serious problem if such confidence were maintained under broad unilateral and intergovernmental commitments on the conditions of peaceful uses of nuclear energy. Attempts to reverse the erosion of confidence, which has occurred in recent years, by creating novel and primarily safeguard-oriented multinational economic ventures, face great political difficulties, even among the industrial democracies let alone elsewhere. If such an institution should be born, which seems less unlikely in Western Europe than anywhere else, its effects will have to be awaited, its viability proven. If none is born, nations will have to look for other means to limit the damage done by their mutual distrust.

FORSCHUNGSINSTITUT DER DEUTSCHEN GESELLSCHAFT FÜR AUSWÄRTIGE POLITIK E.V.

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International Conference on

RECONCILING ENERGY NEEDS AND NONPROLIFERATION:
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D R A F T

The Politics of Supply and Access Viewed from the Standpoint of a Consumer Country

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To start with, let me explain briefly the energy situation in Japan. As you all know, Japan is the extreme example of an industrially advanced country with a relatively large population who has almost no energy resources of her own.

Japan's total indigenous energy resources, inclusive of hydroelectric power and coal, are barely enough to meet 10% or so of her total energy requirements. Therefore, Japan's dependence on imported energy resources is very high as compared with other industrially advanced countries.

Today, Japan depends on imported crude oil for about 75% of her total energy need. The supply of oil which is the major source of energy has become most unstable, subject as it is to developments in oil-producing countries. This became clear from what happended recently in Iran. Thus, it is imperative that Japan make utmost efforts to secure alternative energy sources at the earliest possible time. In this context, nuclear energy is believed to be most promising for us. However, even in this field, we are facing the difficulty of obtaining the raw material. With no domestic uranium resources, Japan has to depend virtually 100% on foreign countsies for the supply of uranium. The big question is how to secure a stable supply of uranium over the long range and how to reduce the extremely high dependence on uranium imports. This question has a direct bearing on Japan's energy security.

At present,Japan depends totally on other countries not only for the supply of natural uranium but also for enrichment services. We cannot achieve further development and utilization of nuclear energy without importing nuclear materials and enrichment services from abroad. In other words, Japan is compelled to rely entirely on world market for nuclear fuel supplies.

In this connection, we do appreciate the statement of Mr. John Douglas Anthony, Deputy Prime Minister for Trade and Resources of Australia in June 1978:" Australia's poliy is based squarely on our recognition of Australia's obligation as a country well endowed with energy resources to make those resources available to other countries many of whom have no real alternative in the wake of the world energy crisis, than to turn to nuclear energy as a means of supplying electricity to their peoples."

Indeed, for a country like Japan who is resourceless but heavily relies on nuclear power generation, it is most difficult to have the nuclear option without securing uranium supplies. However, the confidence in nuclear energy as a reliable alternative energy source is still far from being established. This is, at least partly, a reflection of uncertainties regarding the availability of nuclear materials. we are unfortunatly not convinced that uranium supplies will be forthcoming on the scale assumed in our nuclear programme.

The Ford-Mitre Report published in April 1977 says, in effect: " There is no problem over uranium supply. Once the demand is there, the supply will grow as needed, as has been the case for most commodities." This theory is, in my thinking, too optimistic, at least from the standpoint of consumer countries because they can not take figures of global uranium and simply assume that uranium will be available at any time.

The uranium problem is not merely whether there exist enough resources in the world, but whether consumer countries will be able to get access to the quantities they need at prices they can afford.

Needless to say, energy policy is of long-term nature. And planning is concerned with reducing risks and uncertainties. Therefore, energy planning should be done on the basis of conservative and not optimistic estimates.

This is particularly true with the development of nuclear energy, because it needs long lead-times in preparing toward plans.

In any case, we cannot feel confident about security of supply unless the fuels and services needed for comprehensive nuclear programme are guaranteed. The development of nuclear energy requires that consumer countries are fairly convinced of the possibility to have access to the necessary amount of nuclear materials under acceptable conditions. Any costraints which raise uncertainties about the continuous flow of supplies could endanger the implementation of their nuclear power programmes to provide an uninterrupted supply of electricity.

Thre is certainly a long-term issue of the adequacy of uranium resources. However, the present concern of consumer countries is not so much that the uranium will run out or become too expensive in the long run, but that it might become unavailable for one reason or another. In other words, we are not much worried about the physical existence of uranium resources, that is to say, the total volume of uranium which exists geologically. This is rather of academic interest. What really matters for practical purposes is the actual quantity which can be made available to consumers. Reliable access is our predominant concern.

The most desirable situation from a purely economic point of view is the free uranium market as the case of any other resources. The supply and demand of nuclear materials is essentially a commercial problem. In the past the supply and demand of uranium was met on a private contract basis between producers and consumers. Bilateral negotiations of long-term contracts between individual mines and electrical utilities were nomally the principal approach in the uranium market.

The reason why long-term contracts prevail in the uranium market is the long incubation time required for the nuclear industry. In particular, the consumer finds it nessary to have a firm commitment of long term deliveries of uranium more than any other commodity. Electrical unilities cannot risk by depending only on spot or short-term supplies. Thus, in most cases, the supply contracts are made on a long-term basis. Leaving aside stokpiling which could be costly, we expect to assure security of supply mainly by relying on binding long-term arrangments. In view of the special nature of the uranium market, such long-term contracts will continue to be the mainstay in commercial deals.

However, there are a number of significant factors which have affected the long-term commecial contracts. Among others, the political avilability of uranium has begun to concern recently the world nuclear industry.

The 1973 oil crisis gave a lesson to the energy users that disruption of supply could be caused for political reasons. Now, the non-proliferation requirements have raised the commercial deal of uranium to a political level. The future availability of nuclear materials has become one of the crucical issues in the nuclear policy debate. This is something which has never been experienced in the history of trade of any natural resources. Sir Herman Bondi is right in pointing out that uranium is the "most politicised commodity in the world."

The political conditions of access to nuclear materials have become very stringent and complex in recent years. Such conditions were not part of international regime of nuclear energy before. Thus, the problem of vulnerability to unpredictable politically-oriented disruption of supply has become important energy security issue. Consumer countries are very concerned about the disruption of supply caused by political decisions in foreign countries over which they have no influence.

Some supplier goverments tried to upgrade the non-proliferation requirements of their bilateral supply arrangments to the extent that are not required by other supplier countries. And in the absence of consumer goverment's timely response, they threatened or actnally imposed embargoes on deliveries of uranium under existing arrangments. These actions have forced some emergency changes in the implementation of nuclear power programmes of the affected countries, causing damaging uncertainties, inconveniences and, in some cases, fianacial losses. Therefore, we are worried about non-proliferation policies of some supplier countries which involve sudden interruptions of nuclear fuel supply. In this connection, it is to be reminded that the consumer countries have more cause to be worried, because present arrangments do not provide them with adequate assurance of supply. The existing bilateral agreements are concerned in principle with non-proliferation conditions and not give any commitment to guarantee that deliveries under commercial contracts are duely made.

In the absence of such legal obligation, some supplier countries might be misled into thinking that they are free to limit or stop the deliveries under exsting supply arrangments in the name of non-proliferation. Consequently, there is always a certain risk that the supply of nuclear materials might be interrupted as a result of supplier government's unilateral action seeking to achieve expansion or amendment of non-proliferations conditions in the bilateral agreements.

Further, supply sources are currently limited to a few countries. This means that consumer countries will have few alternative sources of supply in the event of dispute with a supplier country over terms and conditions of supply. This fact has heightened our concern that supplier countries might exploit their advantageous position to enforce new non-proliferation requirments.

Moreover, the behavior of some supplier countries gives us impression that they might eventually seek to obtain commercial gain using non-proliferation as an excuse.

No doubt, embargoes or any interruption could lead to uncertainty relating to the timely availability of nuclear materials, thereby causing planning difficulties.

For a country like Japan who is heavily dependent on imports of nuclear materials, uncertainties caused by such changes of nuclear policies of foreign governments go to the root of the problem of security of energy.

We are all committed to the principle of non-proliferation of nuclear weapons. However, non-proliferation conditions can become effective only if they fit in with the actual circumstances. For this purpose we should try to reduce or mitigate disincentives derived from possible unilateral actions of supplier countries in the interest of increasing the credibility of non-proliferation objectives. We do not want, by no means, to avoid the updating of the non-proliferation conditions, if they really deem to be necessary. But we are concerned about the possibility that changes so introduced into the market might inhibit fair trade in nuclear materials and damage the energy security.

I believe that the following principles should govern the future relationship between suppliers and consumers.

Firstly, the supplier countries should honor existing commercial contracts on the supply of nuclear materials, as long as a comsumer country has not breached non-proliferation norms. Should, however, the misuse of nuclear materials for purposes other than peaceful be proven, then embargoes or even stricter measures should be applied as a sanction. If a country is not in breach, supplier countries should not use or threaten to use export powers to achieve changes in the terms of the bilateral agreements. There should be a clear presumption that once conluded commercial contracts will be fulfilled unless the recipient country of nuclear materials violate the agreed non-proliferaton rules.

Secondly, all changes in non-proliferation conditons be prospective and not retrospective in application. In other words, the supplier countries should refrain from applying any changes reflecting their new policies to existing supply contracts, in particular, to materials committed prior to the change of conditions. It is essential that the supplier countries guarantee that the requirements for new non-proliferation conditions will not affect the export licences for deliveries of nuclear materials under already established arrangements.

Thirdly, broad agreement should be sought before new terms and conditions are implemented on a bilateral basis. This means, any proposal for additional non-proliferation requirements which are beyond generally recognized levels among countries concerned, would be put forward for multilateral consideration prior to bilateral negotiations. Otherwise, resource-poor countries who have embarked on major nuclear power programmes must continue to live with the escalating requirements of supplier countries. Therefore, the rules for framing non-proliferation objectives should be rationalized and standardized based on a broad international consensus. Only after such procedure, the rules are to be incorporated in the bilateral ageements between supplier and consumer countries. Thus, the new rules could be applied in an unambiguous and non-discriminatory way. In any case, unilateral action to achieve changes in non-proliferation conditions should be discouraged. Although supplier governments have the right to intervene in the nuclear trade, export controls should not result in excessive uncertainties in the supply of nuclear materials. The manner in which the governments concerned operate their cotrols should not be unilatral or arbitrary.

For above resons, it is sincerely hoped that the countries concerned make joint efforts to establish an international mechanism of nuclear supply. The acceptance of a set of internationally agreed non-proliferation conditions, identified as necessary by consensus, would provide the cosumers with the assuranse of fuel supply and at the same time satisty the non-proliferation requirements of the suppliers. This would certainly provide incentives to the consumers in order to make easier to support non-proliferation objectives and reduce disincentives which would derive from arbitrary actions of supplier countries. Thus, a balanced climate of mutual confidence will be created between suppliers and consumers, avoiding political conflicts over the export conditions of nuclear materials and mitigating impediment to nuclear trade as a whole.

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Multinationalization of Reprocessing and Enrichment:
How and Where ?

Some remarks by M Osredkar
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There are many reasons for believing that multinational undertakings for either of the two processes, reprocessing and enrichment, as the needs will grow, will have advantages from the point of view of economies of scale, nonproliferation, economics and financing. It is not clear, however, how in general in a multinational undertaking some other requirements besides the three mentioned can be met, such as availability of technology, mutual confidence of partners, expedience in shared decision-making and responsibility, operational capability and efficiency, etc. The problems involved in establishment and operation of multinational indertakings, as known, are considerable. I believe that solutions to these problems depend very much, among others, on the homogeneity of the countries involved in respect to their development and interests. Therefore, it seems to me worthwhile reflecting how some DCs could join in such a multinational undertaking.

Examples from which to learn on multinational undertakings in the very specific nuclear field are very few. We could, in fact, use ~~only~~ two: Eurodif and Troika (Urenco/Centec). For the sake of this discussion one might characterize them as follows:

Eurodif: diffusion process basically requires big size plants and investments; it can, therefore, only be materialized by the technology - holder attracting other shareholders - - clients; essentially undertaking is based on joining financial means to pay for technology, engineering services and investments for putting up one plant.

Troika: centrifuge process being developed separately by three partners who realised the advantage of exchanging and joining their knowledge to accelerate the development of the process and, on basis of common knowledge, to build several plants and create other jointly owned companies to further the process.

Obviously, partners in the two undertakings besides knowing their needs for enrichment, had to have either financial means and accept the plant to be built in the technology-holders' country as in case of Eurodif or had to have financial means and knowledge to join in Troika and have enrichment plants nearby.

In either case one could not imagine how an average DC could enter it since DCs in general, have neither financial means nor specific knowledge, even when they know what they need. They are or will be, in fact, left to satisfy their needs mostly by buying enrichment services from individual enrichment suplying countries under uncertain conditions subject to changes in their policies, as was the case in the past not only in relation to the DCs. The industrial countries could, in such situation, remain unconcerned about the interest of DCs and take care of their own needs for enrichment and reprocessing by joining their efforts (following the described examples) or, perhaps, even providing for other customers some extra capacity to be made available more or less on a market basis, the market being fully monopolized. Such a set up would, in eyes of many developed countries, even have the advantage of being, in a large extent, "proliferation proof". Such views have been expressed repeatedly and are, in fact, governing at present the nuclear field.

It is not unknown that the developing world is certainly not willing to accept such position and does interpret it as discriminatory particularly when nonproliferation aims are being used as the argument. The inevitable consequence is a strong tendency to become independent even for high price and sacrifice, causing thereby additional suspicions about the real goals of self-sufficiency and nuclear power. At the same time, many developed countries will find that, in addition to domestic difficulties, their export market will also be impaired. They, therefore, might realize the need for opening the possibilities for DCs to enter multinational arrangements on equal footing in spite of their full lack of assets traditionally required for equality. Unless such possibilities are found the traditional "North-South impasse" cannot be solved and interests of both kinds of countries, developed and developing, will remain unsatisfied or even damaged. It should be noted in addition that the problem of transfer of nuclear technology is an integral part of the general North - South problem (and of the New economic order) and that it can not remain isolated much longer if the North - South impasse is ever to be overcome.

The capability to create equal possibilities for DCs, however, lies much beyond the reach of industrial companies unless the governments come in, since it really means creating a kind of artificially made equality by providing developing countries with necessary financial means, out of national income of richer countries, needed by DCs to become, for instance, shareholders in multinational undertakings. Such contributions to DCs can only be made with governmental action which would not be unusual as, in nuclear matters, industrial companies and governments mostly work in tandem. As much as such a suggestion might seem unrealistic or even utopian one should recall only that the history of last 35 years shows several cases of similar governmental actions or that many countries having less developed areas (South) are following essentially such policies (in relation to them).

In case of Yugoslavia, which has been paying particular attention to developing its underdeveloped regions (such as Kosovo), the results have been extremely beneficial and have essentially contributed to stability and mutual good confidence in the federation.

One can see no reason why Yugoslav and other such experience could not be used to estabilsh confidence internationally, among developed and developing countries, lack of mutual confidence being the most important and acknowledged international problem. And it is not only the question of confidence in nuclear matters involving on one side nonproliferation commitments weighed, on the other side, against willingness to share nuclear technology and to assure supplies; it is ~~more~~ rather the question of confidence between those who have and those who have not which can be established only with great difficulty and efforts. This confidence can not be based only on implementation (which hardly exists) of the promises of transfer of technology since the crucial condition for technological transfer is the transfer and creation of economical and buying power enabling acceptance of technology and cooperation in multinational undertakings. The modes of how to implement such approach would have yet to be invented and created.

ADDRESS BY
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"IMPLEMENTING THE NUCLEAR
NON-PROLIFERATION ACT OF 1978"

MAY 14, 1979

BONN, GERMANY

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I HAVE BEEN ASKED TO DISCUSS THE IMPLEMENTATION OF THE U.S. NUCLEAR NON-PROLIFERATION ACT OF 1978. I WELCOME THE OPPORTUNITY, BECAUSE I BELIEVE THAT EVEN A YEAR AFTER ITS ENACTMENT THERE REMAIN MISCONCEPTIONS ABOUT THE PROVISIONS OF THIS LAW AND THE MANNER IN WHICH WE INTEND TO IMPLEMENT IT.

IT IS UNDERSTANDABLE THAT THESE MISCONCEPTIONS EXIST. THE LAW IS COMPLEX, AND IT CONTAINS PROVISIONS WHOSE INTENT IS UNCLEAR.

I WOULD LIKE FIRST TO TRY TO CLARIFY THE LAW AND THE MANNER IN WHICH WE ARE IMPLEMENTING IT. I WOULD THEN LIKE TO DISCUSS OUR PRELIMINARY VIEWS ON HOW THE NUCLEAR FUEL CYCLE MIGHT BE MANAGED AFTER INFCE AND HOW WE MIGHT IMPLEMENT OUR LAW IN A MANNER CONSISTENT WITH SUCH A REGIME.

I. NUCLEAR NON-PROLIFERATION ACT OF 1978

IN DISCUSSING THE NON-PROLIFERATION ACT I WILL FOCUS ON FOUR ASPECTS OF THE LAW. --NUCLEAR EXPORT CRITERIA; CONDITIONS

RESULTING IN TERMINATION OF US NUCLEAR COOPERATION; REPROCESSING APPROVALS; AND THE REQUIREMENTS TO RENEGOTIATE OUR AGREEMENTS FOR COOPERATION. I WILL NOT DISCUSS IN ANY DETAIL OTHER ASPECTS OF THE ACT, INCLUDING US INITIATIVES TO PROVIDE ADEQUATE NUCLEAR FUEL SUPPLY, STRENGTHEN THE INTERNATIONAL SAFEGUARDS SYSTEM, AND TO ASSIST DEVELOPING COUNTRIES WITH THEIR ENERGY PROBLEMS. I DO NOT WANT MY LACK OF ATTENTION TO THESE PROGRAMS IN THIS ADDRESS TO BE CONSTRUED AS AN INDICATION THAT WE DO NOT ATTACH IMPORTANCE TO THEM. IMPLEMENTATION OF THESE PARTS OF THE LAW AND POLICY ARE ESSENTIAL TO ACHIEVING OUR NON-PROLIFERATION OBJECTIVES, AND WE ARE DEVOTING SIGNIFICANT RESOURCES TO THESE AREAS. HOWEVER, IN THE BRIEF PERIOD I HAVE TONIGHT I WOULD LIKE TO ADDRESS PRIMARILY THE SECTIONS OF THE ACT THAT HAVE PROVOKED CONTROVERSY AND ARE OFTEN MISUNDERSTOOD.

A. NUCLEAR EXPORT CRITERIA

THE LAW SETS FORTH CRITERIA FOR US EXPORTS OF SOURCE MATERIAL, SPECIAL NUCLEAR MATERIAL, AND PRODUCTION AND UTILIZATION FACILITIES AS WELL AS SENSITIVE NUCLEAR TECHNOLOGY. MUCH ATTENTION HAS NATURALLY FOCUSED ON THESE CRITERIA BECAUSE THEY HAVE THE MOST IMMEDIATE IMPACT ON OUR NUCLEAR COOPERATION. MANY BELIEVE OUR NEW EXPORT REQUIREMENTS DEPART WIDELY FROM PAST U.S. NUCLEAR EXPORT POLICY AND GO SIGNIFICANTLY BEYOND THE REQUIREMENTS OF OTHER NUCLEAR EXPORTERS. THIS IS NOT THE CASE.

Immediate Criteria

The export licensing criteria that are immediately applicable under the Act are already met by all states with whom we cooperate on a bilateral basis. Some criteria are not met under our present agreements with the European Community and the International Atomic Energy Agency, but there are provisions in the Act that allow us to continue nuclear cooperation with these partners for at least two years while we negotiate amendments to these agreements, with the President able to extend the period to allow additional time to reach agreement.

Moreover, the Act's export criteria are consistent with the requirements of other nuclear exporters or the Nuclear Suppliers Guidelines. The provision that U.S. nuclear exports be subject to IAEA safeguards, a no explosives use commitment, adequate physical security and retransfer controls are similar to the nuclear export requirements of other exporters. Controls over the reprocessing of supplied materials are found not only in U.S. policy but also in the export criteria of such suppliers as Canada and Australia.

Full Scope Safeguards

There is an additional export criterion which becomes effective for exports after March 1980. This requirement is

THAT A NON-NUCLEAR WEAPON STATE HAVE ALL ITS PEACEFUL NUCLEAR ACTIVITIES UNDER IAEA SAFEGUARDS IN ORDER FOR US TO CONTINUE COOPERATION.

THIS SECTION OF THE LAW, WHICH MAY REQUIRE US TO DISCONTINUE SOME EXISTING COOPERATION ARRANGEMENTS, PROVOKES PERHAPS THE MOST CONTROVERSY. IT IS A COMPROMISE AMONG SEVERAL POINTS OF VIEW THAT WERE ADVANCED WHEN THIS LEGISLATION WAS PUT TOGETHER. AT ONE END OF THE SPECTRUM WAS THE VIEW THAT BECAUSE IAEA SAFEGUARDS ARE THE FUNDAMENTAL INSTITUTION OF PEACEFUL NUCLEAR COOPERATION, WE SHOULD CONTINUE NUCLEAR COOPERATION ONLY WITH STATES THAT ACCEPT NPT-TYPE FULL SCOPE SAFEGUARDS AS WELL AS OTHER NEW CONDITIONS WITHIN A SPECIFIED PERIOD. AT THE OTHER END WAS THE VIEW THAT, WHILE ANY NEW COOPERATION SHOULD DEPEND ON A STATE HAVING ALL ITS NUCLEAR ACTIVITIES UNDER INTERNATIONAL SAFEGUARDS, WE SHOULD NOT CHANGE THE RULES FOR OUR COOPERATION UNDER EXISTING AGREEMENTS. THE COMPROMISE REACHED WAS A "DE FACTO" FULL SCOPE SAFEGUARDS APPROACH THAT WOULD TAKE EFFECT AFTER A 24 MONTH GRACE PERIOD FOR NEGOTIATION. WE BELIEVE THAT THIS APPROACH IS REASONABLE FOR THE FOLLOWING REASONS.

THE "DE FACTO FULL SCOPE SAFEGUARDS APPROACH

THE VAST MAJORITY OF STATES, BOTH NUCLEAR SUPPLIERS AND RECIPIENTS, ADHERE TO THE NPT. THEY ACCEPT THAT SAFEGUARDS SHOULD BE APPLIED TO ALL PEACEFUL NUCLEAR ACTIVITIES. A NUMBER OF SUPPLIERS, INCLUDING CANADA AND AUSTRALIA,

MAKE NPT-TYPE FULL SCOPE SAFEGUARDS A CONDITION OF ANY NEW NUCLEAR COOPERATION. WE BELIEVE AN INTERNATIONAL CONSENSUS IS EMERGING THAT FULL SCOPE SAFEGUARDS ALONG THE LINES OF NPT SAFEGUARD ARRANGEMENTS ARE APPROPRIATE. HOWEVER, IN THE MEANTIME WE HAVE ADOPTED THE "DE FACTO" FULL SCOPE APPROACH. THIS APPROACH DOES NOT ENTAIL A COMMITMENT TO PUT ALL FUTURE PEACEFUL NUCLEAR ACTIVITIES UNDER SAFEGUARDS, AS NPT-TYPE FULL SCOPE SAFEGUARDS DO. THIS MEANS THAT WE CAN CONTINUE NUCLEAR COOPERATION WITH STATES WHICH--FOR POLITICAL REASONS--ARE NOT PREPARED TO MAKE AN NPT-TYPE COMMITMENT ALTHOUGH THEY WILL ACCEPT SAFEGUARDS ON ALL THEIR PRESENT NUCLEAR ACTIVITIES. THESE STATES ALSO KNOW THAT IF THEY LATER ACQUIRE OR DEVELOP UNSAFEGUARDED FACILITIES, WE WOULD NO LONGER BE ABLE TO CONTINUE NUCLEAR COOPERATION.

THIS SECTION OF THE LAW DOES GO BEYOND CONDITIONS IN CURRENT US NUCLEAR COOPERATION AGREEMENTS. AS I HAVE NOTED IT MAY MEAN THAT WE MUST DISCONTINUE NUCLEAR COOPERATION WITH A FEW STATES WHICH MAY NOT AGREE TO PLACE ALL THEIR PRESENT NUCLEAR ACTIVITIES UNDER SAFEGUARDS BY THE MARCH, 1980 DEADLINE. MOST NON-NPT PARTIES WITH WHICH WE COOPERATE, HOWEVER, EITHER HAVE ALL OF THEIR NUCLEAR ACTIVITIES UNDER SAFEGUARDS OR ARE MOVING IN THIS DIRECTION.

THE EURATOM AND IAEA "EXEMPTION"

ANOTHER PROVISON OF THE ACT AFFECTS ONLY OUR AGREEMENTS WITH EURATOM AND THE IAEA. AGAIN, THIS PROVISION HAS A

LEGISLATIVE HISTORY. OUR AGREEMENTS FOR PEACEFUL NUCLEAR COOPERATION WITH THE EUROPEAN COMMUNITY AND THE INTERNATIONAL ATOMIC ENERGY AGENCY DO NOT PROVIDE FOR U.S. APPROVAL RIGHTS OVER THE REPROCESSING OF U.S.-SUPPLIED MATERIAL. IN ADDITION, THE US-IAEA AGREEMENT HAS NO PROVISION FOR U.S. APPROVAL RIGHTS OVER RETRANSFERS. AS I HAVE NOTED, THESE ARE TWO OF THE IMMEDIATELY APPLICABLE NUCLEAR EXPORT CRITERIA IN THE ACT.

WHEN THE LEGISLATION WAS UNDER CONSIDERATION THERE WERE ALSO TWO SCHOOLS OF THOUGHT ON HOW TO HANDLE THIS PROBLEM. ONE VIEW WAS THAT WE SHOULD CONTINUE TO EXEMPT EURATOM AND THE IAEA FROM THESE CONDITIONS. THE OTHER WAS THAT WE SHOULD MAKE NO EXCEPTION FROM THE GENERALLY APPLICABLE NUCLEAR EXPORT CRITERIA, AND THAT WE SHOULD BREAK OFF COOPERATION UNDER THESE AGREEMENTS UNTIL WE HAD SECURED THESE RIGHTS. NEITHER OF THESE EXTREMES PROVED ACCEPTABLE.

UNDER THE COMPROMISE THAT DEVELOPED, COOPERATION WOULD CONTINUE UNDER EXISTING CONDITIONS FOR A PERIOD OF THIRTY DAYS AFTER ENACTMENT OF THE LAW, AND FOR A PERIOD OF TWENTY-THREE MONTHS THEREAFTER IF THESE ORGANIZATIONS AGREED TO RENEGOTIATE THEIR AGREEMENTS WITH US. THE LAW ALSO PROVIDES THAT THIS PERIOD MAY BE EXTENDED BY THE PRESIDENT BY A NOTIFICATION TO THE U.S. CONGRESS IN ONE-YEAR INCREMENTS, IF HE DETERMINES THAT FAILURE TO CONTINUE COOPERATION WOULD BE SERIOUSLY PREJUDICIAL TO THE ACHIEVEMENT OF U.S. NON-PROLIFERATION OBJECTIVES OR OTHERWISE JEOPARDIZE THE COMMON DEFENSE OR SECURITY.

The IAEA quickly agreed to negotiations and our cooperation with or through the Agency was not interrupted. EURATOM was not prepared to renegotiate its agreement with us within the thirty days specified in the law. We were therefore unable to license exports to the Community.

After about two months we worked out a compromise with the Community. It agreed to discussions on our agreement with the understanding that issues being addressed in the International Fuel Cycle Evaluation would not be raised until the completion of INFCE. With this agreement, our nuclear cooperation with the European Community was restored.

With the possible exception of our cooperation with two states, therefore, we believe that the export criteria of the Non-Proliferation Act will not interfere with on-going nuclear relations. Indeed, I should note that the law allows the President to authorize exports, subject to Congressional review, which do not meet any of the criteria or which the Nuclear Regulatory Commission fails to approve for any reason. To do so he must determine that withholding the export would be seriously prejudicial to the achievement of US non-proliferation objectives or otherwise jeopardize the common defense and security. The President exercised this authority last year to allow the export of low enriched uranium to India. This authority is important to ensure that the President is able to respond to exceptional circumstances. However, the nuclear export criteria in our law are fundamental

TO OUR APPROACH TO NON-PROLIFERATION, AND WE HOPE THAT IN PRACTICE SUCH PRESIDENTIAL AUTHORIZATION WILL SELDOM BE NECESSARY.

B. <u>CONDITIONS RESULTING IN TERMINATION OF US NUCLEAR EXPORTS</u>

I WOULD LIKE TO TURN TO THE SECTION OF THE LAW WHICH SPECIFIES ACTIVITIES BY OUR PARTNERS THAT COULD RESULT IN THE TERMINATION OF U.S. NUCLEAR COOPERATION. MOST OF THE ACTIVITIES DELINEATED IN THIS SECTION ARE CLEAR: DETONATION OF A NUCLEAR EXPLOSIVE DEVICE; VIOLATION, TERMINATION, OR ABROGATION OF SAFEGUARDS BY A NON-NUCLEAR WEAPONS STATE; OR MATERIAL VIOLATION OF THE TERMS OF COOPERATION WITH THE U.S. BY ANY COOPERATING PARTY. TWO OF THE CONDITIONS ARE, HOWEVER, MORE COMPLEX.

<u>ACTIVITIES RELATING TO NUCLEAR EXPLOSIIONS</u>

THE LAW REQUIRES THAT WE TERMINATE COOPERATION WITH ANY NON-NUCLEAR WEAPONS STATE THAT "ENGAGES IN ACTIVITIES INVOLVING SOURCE OR SPECIAL NUCLEAR MATERIAL AND HAVING DIRECT SIGNIFICANCE FOR THE MANUFACTURE OR ACQUISITION OF NUCLEAR EXPLOSIVE DEVICES" AND WITH ANY STATE, WEAPON OR NON-WEAPONS, THAT ASSISTS, ENCOURAGES OR INDUCES A NON-NUCLEAR WEAPONS STATE TO ENGAGE IN SUCH ACTIVITIES, UNLESS IN THE PRESIDENT'S JUDGMENT SUFFICIENT PROGRESS HAS BEEN MADE TOWARD TERMINATING THESE ACTIVITIES. THE INTENT OF THIS SECTION, WHICH IS DOCUMENTED IN ITS LEGISLATIVE HISTORY, IS CLEARLY DIRECTED TO NUCLEAR EXPLOSIVE PROGRAMS, BUT

SOME CONCERN HAS BEEN EXPRESSED THAT THIS PROVISION MAY BE INTERPRETED AS APPLYING TO ANY SENSITIVE NUCLEAR ACTIVITY, EVEN IF SUCH A PROGRAM IS CLEARLY UNDERTAKEN FOR EXCLUSIVELY PEACEFUL PURPOSES. THIS IS NOT THE WAY WE ARE IMPLEMENTING THIS SECTION. WE DO HAVE STRONG RESERVATIONS ABOUT NATIONAL ENRICHMENT AND REPROCESSING PROGRAMS, BUT OUR NUCLEAR COOPERATION WOULD BE TERMINATED UNDER THIS SECTION ONLY IF WE BELIEVE THAT THESE PROGRAMS ARE DESIGNED FOR OTHER THAN PEACEFUL PURPOSES.

TRANSFERS OF REPROCESSING EQUIPMENT

THE LAW ALSO REQUIRES US TO END COOPERATION WITH ANY STATE THAT HAS ENTERED INTO AN AGREEMENT AFTER THE DATE OF ENACTMENT OF THE ACT FOR THE TRANSFER OF REPROCESSING EQUIPMENT, MATERIALS OR TECHNOLOGY TO A NON-NUCLEAR WEAPONS STATE, EXCEPT IN CONNECTION WITH AN INTERNATIONAL FUEL CYCLE EVALUATION IN WHICH THE US IS A PARTICIPANT OR PURSUANT TO A SUBSEQUENT INTERNATIONAL AGREEMENT OR UNDERSTANDING TO WHICH THE US SUBSCRIBES. TO OUR KNOWLEDGE, NO SUCH AGREEMENT HAS BEEN ENTERED INTO SINCE MARCH 10, 1978 WHEN THE LAW WAS ENACTED. WE HOPE THAT ANY FUTURE TRANSFERS OF REPROCESSING TECHNOLOGY OR EQUIPMENT WILL BE UNDER CONDITIONS TO WHICH WE WILL BE ABLE TO SUBSCRIBE.

AS WITH OTHER SECTIONS OF THE LAW, THE PRESIDENT MAY WAIVE THE TERMINATION OF COOPERATION CALLED FOR IN THIS SECTION IF HE DETERMINES THAT CESSATION OF COOPERATION WOULD PREJUDICE US NON-PROLIFERATION OBJECTIVES OR OTHERWISE JEOPARDIZE THE COMMON DEFENSE AND SECURITY. AGAIN, SUCH A WAIVER WOULD BE SUBJECT TO CONGRESSIONAL REVIEW.

C. REQUIREMENTS FOR US APPROVAL OF THE REPROCESSING OF US-SUPPLIED MATERIAL

OUR ATTITUDE TOWARD REPROCESSING IS A CENTRAL ASPECT OF OUR LAW AND POLICY. THE LAW HOLDS, IN EFFECT, THAT WE MAY APPROVE REPROCESSING OR TRANSFERS FOR REPROCESSING OF MATERIAL SUBJECT TO US CONTROL ONLY IF WE JUDGE THAT SUCH REPROCESSING OR RETRANSFER WILL NOT RESULT IN A SIGNIFICANT INCREASE OF THE RISK OF PROLIFERATION.

THE LAW STATES THAT AMONG ALL THE FACTORS RELATED TO THIS JUDGMENT, FOREMOST CONSIDERATION SHOULD BE GIVEN TO WHETHER OR NOT THE CONDITIONS FOR REPROCESSING OR RETRANSFER WOULD ALLOW "TIMELY WARNING" TO THE US OF ANY DIVERSION OF MATERIAL. THE LAW EXEMPTS FROM THIS PROVISION REPROCESSING FACILITIES THAT HAVE ALREADY PROCESSED POWER REACTOR FUEL OR HAVE BEEN THE SUBJECT OF A US APPROVAL FOR REPROCESSING PRIOR TO ENACTMENT OF THE NNPA. BEFORE AUTHORIZING REPROCESSING OF US-SUPPLIED FUEL AT SUCH FACILITIES, THE SECRETARY OF ENERGY MUST NEVERTHELESS "ATTEMPT TO ENSURE" THAT THE ABOVE CONDITIONS ARE MET.

IN IMPLEMENTING THIS SECTION OF THE LAW, WHETHER FOR EXISTING FACILITIES OR NEW FACILITIES, WE HAVE APPROVED RETRANSFER ONLY WHEN WE HAVE DETERMINED THERE WILL BE NO SIGNIFICANT INCREASE IN THE RISK OF PROLIFERATION. ALL OF THE TRANSFERS WE HAVE APPROVED TO DATE HAVE ALL BEEN TO THE UK OR FRANCE, BOTH STATES WITH A STRONG COMMITMENT TO NON-PROLIFERATION, AND THAT WE ALSO HAVE THE RIGHT TO APPROVE THE TRANSFER OF THE SEPARATED PLUTONIUM RESULTING FROM THE REPROCESSING.

US POLICY ON RETRANSFERS DURING INFCE

IN ADDITION TO THE PROVISIONS OF THIS SECTION OF THE ACT, THE ADMINISTRATION HAS ADOPTED FURTHER GUIDELINES FOR APPROVING THE TRANSFER FOR REPROCESSING OF US-ORIGIN FUEL DURING THE PERIOD OF THE INTERNATIONAL NUCLEAR FUEL CYCLE EVALUATION (INFCE). THESE GUIDELINES ARE THAT SUCH REQUESTS WILL BE REVIEWED ON A CASE-BY-CASE BASIS AND WILL BE CONSIDERED FOR APPROVAL IF:

-- (A) THE REQUEST INVOLVES A CLEAR SHOWING OF NEED (I.E., SPENT FUEL STORAGE CONGESTION), AND (B) THE REQUESTING COUNTRY HAS MADE APPROPRIATE EFFORTS TO EXPAND ITS SPENT FUEL STORAGE CAPACITY; OR

-- (A) THE REQUEST INVOLVES A CONTRACT PREDATING CURRENT US POLICY TOWARD REPROCESSING (I.E., PRIOR TO APRIL 1977, (B) THE REQUESTING COUNTRY IS COOPERATING IN EXPLORING MORE PROLIFERATION RESISTANT METHODS OF SPENT FUEL DISPOSITION, AND (C) APPROVAL WILL DIRECTLY FURTHER NON-PROLIFERATION OBJECTIVES.

WE ALSO REQUIRE APPROVAL RIGHTS OVER THE SUBSEQUENT TRANSFER OF ANY PLUTONIUM RESULTING FROM THE REPROCESSING, INCLUDING RETURN TO THE COUNTRY THAT OWNS THE MATERIAL.

THIS POLICY IS MEANT TO ENCOURAGE THE STORAGE OF SPENT FUEL INSTEAD OF REPROCESSING WHILE MORE PROLIFERATION-RESISTANT ALTERNATIVES ARE EXPLORED IN INFCE AND ELSEWHERE. WE KNOW, HOWEVER, THAT SOME STATES DO NOT YET HAVE THE PHYSICAL CAPACITY FOR LONG-TERM STORAGE OF SPENT FUEL.

ALSO, CERTAIN STATES ENTERED INTO LONG-TERM CONTRACTS WITH REPROCESSORS PRIOR TO OUR NEW POLICY, AND THEY WOULD FACE SUBSTANTIAL COMMERCIAL PENALTIES AND OTHER DISRUPTIONS TO THEIR NUCLEAR PROGRAMS IF THEY DO NOT HONOR THESE CONTRACTS.

D. RENEGOTIATIONS

I WOULD NOW LIKE TO TURN TO ANOTHER MAJOR ELEMENT OF THE ACT--THE REQUIREMENT THAT WE INITIATE A PROGRAM TO RENEGOTIATE OUR EXISTING AGREEMENTS OF COOPERATION TO INCLUDE IN THEM THE CONDITIONS THE LAW ESTABLISHES FOR NEW AGREEMENTS. THESE CONDITIONS PARALLEL IN MOST RESPECTS THE NUCLEAR EXPORT CRITERIA I HAVE JUST DISCUSSED. MANY OF THEM ARE ALREADY CONTAINED IN OUR EXISTING COOPERATIVE ARRANGEMENTS. THE MAJOR NEW CONDITION IS THAT WE ASK RETRANSFER AND REPROCESSING APPROVAL RIGHTS NOT ONLY ON U.S.-SUPPLIED MATERIAL BUT ALSO ON ANY OTHER MATERIAL USED IN U.S.-SUPPLIED NUCLEAR REACTORS. IN ADDITION, WE ASK APPROVAL RIGHTS ON WHICH FACILITIES MAY BE USED TO STORE WEAPONS-GRADE MATERIAL SUBJECT TO U.S. CONTROL. A THIRD NEW CONDITION IS THAT WE HAVE THE RIGHT TO REQUIRE THE RETURN OF ANY MATERIAL OR EQUIPMENT WE HAVE SUPPLIED (OR MATERIAL PRODUCED FROM THAT) IF THE COOPERATING PARTY DETONATES A NUCLEAR EXPLOSIVE DEVICE OR TERMINATES OR ABROGATES IAEA SAFEGUARDS.

THERE HAS BEEN CONSIDERABLE CONFUSION AT HOME AND ABROAD ON THE TIMETABLE FOR THESE RENEGOTIATIONS. THE ACT DOES NOT SET A DEADLINE BY WHICH AGREEMENTS MUST BE RENEGOTIATED.

NEVERTHELESS THE INTENT OF THE CONGRESS AND THE ADMINISTRATION IS THAT THIS PROGRAM BE CONCLUDED AS EXPEDITIOUSLY AS POSSIBLE.

THE PROGRAM IS WELL UNDERWAY. WE HAVE INITIALED AN AGREEMENT WITH AUSTRALIA, AND WE EXPECT THAT OTHERS WILL SOON FOLLOW. WE EXPECT THAT AS MORE AGREEMENTS ARE RENEGOTIATED, OTHER STATES WILL BE MORE READY TO MOVE FORWARD, PARTICULARLY BECAUSE THE NEW CONDITIONS DO NOT GO VERY FAR BEYOND THOSE ALREADY EXPLICIT OR UNDERSTOOD IN CURRENT AGREEMENTS.

THESE ARE THE MAJOR PROVISIONS OF LAW WITHIN WHICH WE PURSUE OUR NON-PROLIFERATION POLICY. WE BELIEVE THAT THIS FRAMEWORK IS BROAD ENOUGH TO ALLOW US TO MAKE SOME ADJUSTMENTS AND COMPROMISES, SO THAT WE CAN REACH CONSENSUS WITH OTHER GOVERNMENTS ON THE STRUCTURE OF THE NUCLEAR FUEL CYCLE.

II. THE NUCLEAR FUEL CYCLE

I WOULD LIKE NOW TO TURN TO SOME OF OUR THOUGHTS ON A POSSIBLE FUTURE STRUCTURE OF THE NUCLEAR FUEL CYCLE AND HOW WE COULD IMPLEMENT OUR LAW UNDER SUCH A REGIME.

OUR OBJECTIVES, SIMPLY STATED, IS TO FIND ACCEPTABE ARRANGEMENTS UNDER WHICH NUCLEAR POWER COULD BE EMPLOYED BY ANY STATE TO MEET ITS LEGITIMATE ENERGY REQUIREMENTS WITHOUT INCREASING THE RISK OF NUCLEAR WEAPONS PROLIFERATION. THESE ARRANGEMENTS MUST ALSO PROVIDE FOR SAFETY, ENVIRONMENTAL PROTECTION AND REASONABLE ECONOMICS.

IN TRYING TO DEVELOP SUCH ARRANGEMENTS, WE RECOGNIZE THAT WE HAVE NEITHER THE WISDOM TO FIND ALL THE ANSWERS NOR THE ABILITY TO IMPOSE ANY SOLUTION ON THE INTERNATIONAL COMMUNITY. THE PROLIFERATION PROBLEM CAN ONLY BE RESOLVED IF ALL INVOLVED AND CONCERNED STATES COOPERATE. ANY NEW ARRANGEMENTS WILL HAVE TO BE WIDELY ACCEPTED IF THEY ARE TO SUCCEED IN GOVERNING THE DEVELOPMENT OF NUCLEAR ENERGY THROUGH THE END OF THE CENTURY. WE DO NOT BELIEVE, HOWEVER, THAT SUCH A CONSENSUS SHOULD BE BASED ON THE LEAST COMMON DENOMINATOR AMONG MANY DIVERGENT VIEWS. AT THE SAME TIME, WE ARE WILLING TO MAKE ADJUSTMENTS IN OUR OWN APPROACH TO TAKE INTO ACCOUNT THE INTERESTS OF OTHERS, INCLUDING THE SPECIAL ENERGY PROBLEMS OF DEVELOPING COUNTRIES.

THE INTERNATIONAL NUCLEAR FUEL CYCLE EVALUATION (INFCE) WILL CONCLUDE ITS WORK NEXT FEBRUARY. IT IS A CENTRAL PART OF OUR EFFORT TO ACHIEVE AGREEMENT ON THE FUTURE TECHNICAL AND INSTITUTIONAL STRUCTURE OF THE FUEL CYCLE. INFCE BY ITSELF WILL NOT SOLVE THE PROBLEMS WE FACE. BUT WE HOPE IT WILL PROVIDE A COMMON TECHNICAL BASIS FOR NUCLEAR FUEL CYCLE POLICIES.

IN MOVING TOWARD THE CONCLUSION OF INFCE, WE HAVE HAD SOME PRELIMINARY IDEAS ON HOW THE POST-INFCE FUEL CYCLE MIGHT BE STRUCTURED. THE IDEAS WE SUGGEST ARE DESIGNED TO BUILD UPON THE TWO CORNERSTONES OF THE PRESENT INTERNATIONAL NON-PROLIFERATION REGIME: THE POLITICAL COMMITMENTS CONTAINED IN THE NPT; AND THE SYSTEM OF IAEA SAFEGUARDS. THE NPT AND

IAEA SAFEGUARDS ARE AND MUST REMAIN THE FOUNDATION OF THE CIVIL NUCLEAR FUEL CYCLE. ANY NEW STRUCTURES SHOULD REINFORCE AND NOT UNDERMINE THESE ESTABLISHED ARRANGEMENTS. HOWEVER, WE ARE CONCERNED THAT THE NPT AND CURRENT IAEA SAFEGUARDS ALONE MAY NOT BE ADEQUATE TO MAINTAIN THE BARRIER BETWEEN PEACEFUL AND NON-PEACEFUL USES OF NUCLEAR ENERGY, ESPECIALLY IF SEPARATED PLUTONIUM OR OTHER WEAPONS-GRADE MATERIAL ENTERS INTO WIDER USE.

OUR TENTATIVE APPROACH IS EVOLUTIONARY IN TWO SENSES: FIRST, IT ADDRESSES IMMEDIATE PROBLEMS INDIVIDUALLY, BUT COULD LEAD EVENTUALLY TO A MORE COMPREHENSIVE REGIME. SECOND, OUR APPROACH RECOGNIZES THAT ALL STATES WHICH MEET BASIC NON-PROLIFERATION CONDITIONS HAVE THE RIGHT TO DEVELOP NUCLEAR ENERGY FOR PEACEFUL PURPOSES WITHOUT DISCRIMINATION, AS STIPULATED IN THE NPT. AN EVOLUTIONARY APPROACH WOULD ALLOW TIME TO DEVELOP TECHNICAL AND INSTITUTIONAL ARRANGEMENTS TO HANDLE THE SPECIAL PROBLEMS AND RISKS ASSOCIATED WITH WIDER USE OF PLUTONIUM AND WITH OTHER SENSITIVE ACTIVITIES. NO NATION, DEVELOPED OR DEVELOPING, WOULD BE DENIED ACCESS ON AN EVOLUTIONARY BASIS TO BENEFITS RELATED TO ANY IMPORTANT ASPECT OF THE NUCLEAR FUEL CYCLE. AS ENERGY REQUIREMENTS INCREASE AND TECHNOLOGICAL AND INSTITUTIONAL ARRANGEMENTS FOR PREVENTING PROLIFERATION ARE DEVELOPED, NEW FUEL CYCLES CAN BE INTRODUCED IN A MANNER THAT IS CONSISTENT WITH BOTH ENERGY REQUIREMENTS AND NON-PROLIFERATION CONCERNS.

SPECIFICALLY, WE THINK THAT THE FOLLOWING BASIC PRINCIPLES SHOULD BE EXAMINED WITH CARE.

A. SENSITIVE NUCLEAR FACILITIES

WE EXPECT THAT FOR BOTH NON-PROLIFERATION AND ECONOMIC REASONS THERE SHOULD ONLY BE A LIMITED NUMBER OF URANIUM ENRICHMENT FACILITIES, ALL OF WHICH SHOULD BE LARGE, AND RELATED TO GLOBAL REQUIREMENTS FOR NUCLEAR ENERGY RATHER THAN STRICTLY NATIONAL NEEDS.

FOR REPROCESSING FACILITIES, ADDITIONAL CAPACITY SHOULD IN OUR JUDGMENT ALSO BE RELATED TO INTERNATIONAL CAPACITY AND REQUIREMENTS. WE BELIEVE THAT REPROCESSING CAPACITY SHOULD NOT BE DRIVEN BY SPENT FUEL MANAGEMENT NEEDS. IT SHOULD RATHER BE LIMITED TO MEET PLUTONIUM NEEDS FOR BREEDER AND ADVANCED REACTOR RESEARCH AND DEVELOPMENT, WITH EFFORTS MADE TO MINIMIZE SEPARATION OF PLUTONIUM ABOVE THESE NEEDS. IF PLUTONIUM IN EXCESS OF THIS AMOUNT IS SEPARATED, ITS STORAGE UNDER INTERNATIONAL ARRANGEMENTS WOULD BE PREFERABLE TO NATIONAL STORAGE. AN INTERNATIONAL PLUTONIUM STORAGE REGIME, HOWEVER, SHOULD NOT IN ITSELF MAKE EARLY REPROCESSING APPROPRIATE.

WHEN NEW SENSITIVE FACILITIES ARE APPROPRIATE, WE BELIEVE THEY SHOULD INCORPORATE TECHNOLOGICIAL AND INSTITUTIONAL BARRIERS TO PROLIFERATION.

B. PLUTONIUM USE

IN OUR VIEW, PLUTONIUM USE FOR FAST REACTOR R&D WOULD BE APPROPRIATE IN STATES WHERE ELECTRICAL GRID AND NUCLEAR ENERGY REQUIREMENTS, TOGETHER WITH ECONOMIC AND RESOURCE CONSIDERATIONS, INDICATE THAT A SUBSTANTIAL NUMBER OF BREEDERS MAKE SENSE FOR THE LONG TERM. HOWEVER, WE BELIEVE THAT PLUTONIUM SHOULD NOT BE RECYLCED NOW IN LIGHT WATER REACTORS, BECAUSE THE EARLY WIDESPREAD PRESENCE OF PLUTONIUM FUELS WOULD ENTAIL A SIGNIFICANT PROLIFERATION RISK BY OVERWHELMING OUR SAFEGUARDS AND INSTITUTIONAL MECHANISMS BEFORE THEY ARE CAPABLE OF PROVIDING THE NECESSARY PROLIFERATION RESISTANCE. THE ECONOMIC AND RESOURCE BENEFITS OF SUCH RECYCLE-- AT LEAST IN THE NEAR TERM-- ARE PROBABLY MARGINAL AT BEST.

C. SPENT FUEL MANAGEMENT

HOWEVER FUEL CYCLE PLANS DEVELOP, SUBSTANTIAL SPENT FUEL SHORTAGE CAPACITY WILL BE NEEDED FOR THE NEAR AND MEDIUM TERM. MORE CAPACITY SHOULD BE INSTALLED AT REACTOR SITES, AT AWAY-FROM-REACTOR STORAGE FACILITIES (AFRS), AT EXISTING REPROCESSING PLANTS, AND UNDER INTERNATIONAL SPENT FUEL STORAGE REGIMES. THE CARTER ADMINISTRATION HAS RECENTLY PROPOSED LEGISLATION TO DEAL WITH OUR DOMESTIC SPENT FUEL PROBLEMS. IT PROVIDES THAT WE MAY ACCEPT LIMITED AMOUNTS OF FOREIGN SPENT FUEL WHEN THIS SERVES NON-PROLIFERATION OBJECTIVES. WE ARE ALSO GIVING MUCH THOUGHT TO POSSIBLE INTERNATIONAL

SPENT FUEL STORAGE CENTERS OUTSIDE OF THE CONTINENTAL UNITED STATES, AND WE STRONGLY SUPPORT THE IAEA CONSULTATIVE MEETING ON SPENT FUEL STORAGE THAT WILL BE HELD IN JUNE.

D. FUEL ASSURANCES

VARIOUS FUEL ASSURANCES SHOULD BE PROVIDED FOR STATES COMMITTED TO NON-PROLIFERATION. RELIABILITY OF SUPPLY IS ESSENTIAL IF STATES ARE TO FOREGO NATIONAL ENRICHMENT AND REPROCESSING FACILITIES. WE BELIEVE THAT NUCLEAR FUEL SUPPLIES CAN BE ASSURED THROUGH A MULTIPLICITY OF DOMESTIC, BILATERAL, AND INTERNATIONAL ARRANGEMENTS -- A FUEL BANK FOR ONE -- SO THAT THE ECONOMIC COSTS AND PROLIFERATION RISKS OF MANY INDEPENDENT FUEL CYCLES CAN BE AVOIDED.

TO THE DEGREE THAT IN INTERNATIONAL CONSENSUS ALONG THESE LINES EMERGES, OUR BILATERAL NUCLEAR EXPORT CONTROLS WILL ASSUME LESS PROMINENCE. THESE BILATERAL CONTROLS WILL OF COURSE REMAIN, BUT THEY WOULD THEN BE IMPLEMENTED IN A MANNER CONSISTENT WITH AGREED NORMS.

III. IMPLEMENTATION OF U.S. LAW AND POLICY AFTER INFCE

I WOULD LIKE TO DISCUSS BRIEFLY HOW WE MIGHT IMPLEMENT OUR LAW AND POLICY IN THE POST INFCE PROGRAM ON THE BASIS OF THE NORMS I HAVE DISCUSSED.

A. REPROCESSING APPROVAL

I EXPECT THAT SPENT FUEL STORAGE CONGESTION AND PRE-EXISTING REPROCESSING CONTRACTS WILL CONTINUE TO INFLUENCE OUR RESPONSE TO REQUESTS FOR THE REPROCESSING OF SPENT FUEL SUBJECT TO US CONTROL. AS PROVIDED IN OUR LAWS, WE MUST BE REASONABLY ASSURED THAT SUCH APPROVAL WILL NOT RESULT IN A SIGNIFICANT INCREASE IN THE RISK OF PROLIFERATION. A BIG ELEMENT IN THIS CONSIDERATION, OF COURSE, WILL BE THE TIMELINESS OF THE WARNING PROVIDED TO MINIMIZE OPPORTUNITY FOR SUCCESSFUL DIVERSION OF NUCLEAR MATERIALS INTO NUCLEAR EXPLOSIVES. IN ADDITION I BELIEVE THAT WE WOULD CONSIDER A NUMBER OF FACTORS INCLUDING: (I) THE NON-PROLIFERATION COMMITMENT OF BOTH THE STATE REQUESTING THE REPROCESSING AND THE STATE WHERE THE REPROCESSING WOULD TAKE PLACE; (II) THE TECHNICAL AND INSTITUTIONAL ARRANGEMENTS ASSOCIATED WITH THE REPROCESSING FACILITY, INCLUDING SAFEGUARDS AND MULTINATIONAL PARTICIPATION; (III) THE NEED FOR REPROCESSING, INCLUDING ALTERNATIVES AVAILABLE FOR THE DISPOSITION OF THE SPENT FUEL AND THE INTENDED USE OF THE SEPARATED PLUTONIUM; (IV) THE ADEQUACY OF PHYSICAL PROTECTION AND SAFEGUARDS ARRANGEMENTS BOTH FOR THE SPENT FUEL PRIOR TO REPROCESSING AND FOR THE SEPARATED PLUTONIUM; AND (V) ADEQUACY OF ARRANGEMENTS TO ENSURE THAT THE US HAS THE RIGHT TO PRIOR APPROVAL OF ANY RETURN OR RETRANSFER OF THE SEPARATED PLUTONIUM.

NONE OF THESE FACTORS ALONE WOULD DETERMINE WHETHER WE COULD APPROVE A REQUEST. NEITHER WOULD ALL OF THESE FACTORS NECESSARILY HAVE TO BE POSITIVE. WE ALSO RECOGNIZE THAT OUR

CURRENT CASE-BY-CASE CONSIDERATION OF EACH REQUEST PLACES A HEAVY BURDEN OF UNCERTAINTY AND DELAY ON BOTH REQUESTING AND REPROCESSING STATES AND MAKES IT DIFFICULT FOR THEM TO DEVELOP LONG TERM FUEL CYCLE PLANS. WE HOPE THAT WE CAN REACH AGREEMENT WITH OUR COOPERATING PARTNERS ON THE SITUATIONS IN WHICH US APPROVAL CAN BE EXPECTED ON A REGULAR AND ROUTINE BASIS.

B. APPROVAL OF PLUTONIUM TRANSFERS

ONE OF THE FUNDAMENTAL ASPECTS OF THE US POLICY IS TO ENSURE THAT PREMATURE COMMERCE IN SEPARATED PLUTONIUM IS AVOIDED. I AM THEREFORE QUITE CERTAIN THAT WE WILL CONTINUE TO TAKE A VERY RESTRICTIVE APPROACH TO APPROVING THE TRANSFER OR RETRANSFER OF PLUTONIUM SUBJECT TO OUR CONTROL. AS I HAVE NOTED, HOWEVER, WE BELIEVE THAT THE USE OF PLUTONIUM FOR BREEDER AND OTHER ADVANCED REACTOR R&D IS APPROPRIATE IN STATES WHERE PROJECTED ENERGY REQUIREMENTS INDICATE THE POSSIBLE DEPLOYMENT OF SUBSTANTIAL NUMBERS OF SUCH REACTORS FOR THE NEXT CENTURY. IF PLUTONIUM IS REQUIRED FOR THESE PURPOSES BY SUCH STATES, I BELIEVE THAT WE SHOULD BE PREPARED TO CONSIDER REQUESTS FOR PLUTONIUM TRANSFER IF OTHER APPROPRIATE CRITERIA OF OUR LAW AND POLICY ARE MET. EVEN IN SUCH CASES, HOWEVER ADDITIONAL STEPS NEED TO BE TAKEN TO REDUCE THE RISKS INHERENT IN USE OF PLUTONIUM.

C. TRANSFER OF SENSITIVE NUCLEAR FACILITIES AND TECHNOLOGY

IT IS CURRENT POLICY NOT TO TRANSFER URANIUM ENRICHMENT OR REPROCESSING FACILITIES. IN ADDITION, AS I HAVE NOTED, THE NON-PROLIFERATION ACT REQUIRES THAT WE TERMINATE COOPERATION

WITH STATES THAT ENTER INTO AGREEMENT FOR THE TRANSFER OF REPROCESSING EQUIPMENT, MATERIAL OR TECHNOLOGY TO A NON-NUCLEAR WEAPON STATE, EXCEPT PURSUANT TO AN INTERNATIONAL AGREEMENT OR UNDERSTANDING TO WHICH THE US SUBSCRIBES. MOREOVER, AS RECENT DEVELOPMENTS IN PAKISTAN HAVE EMPHASIZED, OUR FOREIGN ASSISTANCE ACT REQUIRES GENERALLY THAT WE TERMINATE AID UNDER THAT ACT TO STATES THAT TRANSFER OR RECEIVE ENRICHMENT OR REPROCESSING EQUIPMENT, MATERIAL OR TECHNOLOGY.

WE REMAIN CONCERNED ABOUT THE PREMATURE TRANSFER OF SUCH FACILITIES AND TECHNOLOGY, AND I BELIEVE THAT RECENT EVENTS INDICATE THAT THIS CONCERN IS JUSTIFIED. WE RECOGNIZE, HOWEVER, THAT THERE MAY BE SITUATIONS IN THE FUTURE WHERE SUCH TRANSFERS SHOULD BE CONSIDERED. THESE SITUATIONS MIGHT INCLUDE:

--THE WORLD REQUIREMENT FOR ENRICHED URANIUM FOR NUCLEAR POWER PROGRAMS OR FOR PLUTONIUM FOR ADVANCED REACTOR AND BREEDER R&D OR START-UP JUSTIFIED NEW FACILITIES.

--THE STATE OR STATES CONCERNED HAVE STRONG NON-PROLIFERATION COMMITMENTS AND RECORDS.

--THERE IS APPROPRIATE MULTINATIONAL INVOLVEMENT IN THE FACILITY AS A DETERENT TO ABROGATION OF SAFEGUARDS ON OTHER MISUSE OF THE FACILITY.

--SAFEGUARDS, ADEQUATE PHYSICAL PROTECTION, AND OTHER TECHNICAL ARRANGEMENTS ARE INCORPORATED TO MINIMIZE THE RISK OF DIVERSION OF MATERIAL AND SENSITIVE TECHNOLOGY.

I SHOULD ADD THAT WE DO NOT EXPECT THE WORLD DEMAND FOR EITHER ENRICHED URANIUM OR PLUTONIUM TO REQUIRE NEW FACILITIES BEYOND THOSE CURRENTLY IN OPERATION THROUGH AT LEAST THE NEXT DECADE. WE DO NOT BELIEVE THAT ENERGY SECURITY REQUIRES OTHER NEW NATIONAL SENSITIVE FACILITIES; RATHER, SECURITY SHOULD BE SOUGHT THROUGH BILATERAL AND MULTILATERAL FUEL ASSURANCES AND INTERNATIONAL ARRANGEMENTS SUCH AS A FUEL BANK.

I WOULD LIKE TO MAKE A FEW FINAL POINTS. I HAVE FOCUSED ALMOST EXCLUSIVELY ON THE "RESTRAINT AND CONTROL" ASPECTS OF US NON-PROLIFERATION LAW AND POLICY BECAUSE THEY HAVE HAD THE MOST IMMEDIATE IMPACT AND HAVE PROVOKED THE MOST CONTROVERSY. I DO NOT WISH TO LEAVE YOU WITH THE IMPRESSION THAT WE BELIEVE PROLIFERATION CAN BE PREVENTED SIMPLY BY CONTROLLING THE FLOW OF SENSITIVE NUCLEAR MATERIAL AND EQUIPMENT, OR BY CREATING TECHNICAL AND OTHER BARRIERS TO PROLIFERATION, INCLUDING SAFEGUARDS. OUR LAW AND POLICY RECOGNIZE THAT TO DEAL EFFECTIVELY WITH PROLIFERATION DANGERS WE NEED A MUCH BROADER APPROACH. SUCH AN APPROACH MUST ADDRESS THE POLITICAL AND SECURITY MOTIVIATIONS FOR STATES TO ACQUIRE A NUCLEAR WEAPONS CAPABILITY AND IT MUST OFFER INCENTIVES TO STATES TO FOREGO NATIONAL SENSITIVE FACILITIES. BILATERAL AND MULTILATERAL SECURITY GUARANTEES, THE NON-PROLIFERATION TREATY, AND SUCCESSFUL CONCLUSION OF SALT AND CTB NEGOTIATIONS ARE ESSENTIAL ELEMENTS IN MEETING THESE POLITICAL AND SECURITY CONCERNS. SUPPLY ASSURANCES,

INCLUDING INTERNATIONAL ARRANGEMENTS WITH SUPPLIER AND RECIPIENT PARTICIPATION, CAN HELP DIMINISH INCENTIVES FOR NATIONAL SENSITIVE FACILITIES.

I HAVE ALSO NOT SPOKEN TO OUR CONCERN OVER SAFETY. IN THE WAKE OF THE 3 MILE ISLAND INCIDENT IT IS IMPORTANT THAT ALL OF US WHO SEE A ROLE FOR NUCLEAR POWER WORK TOGETHER TO MAKE NUCLEAR FACILITIES AS SAFE AS REASONABLY POSSIBLE. WE HAVE BEEN ACTIVE IN THE IAEA'S WORK ON REACTOR SAFETY, AND WE EXPECT TO WORK CLOSELY WITH EXPERTS IN OTHER COUNTRIES IN THIS AREA.

FINALLY I WISH TO EMPHASIZE THAT WE RECOGNIZE THE ROLE OF NUCLEAR POWER IN THE ENERGY STRATEGIES OF MANY DEVELOPING COUNTRIES IS A MATTER OF SPECIAL INTEREST AND CONCERN. WE WANT TO BE RESPONSIVE TO THESE CONCERNS. THE US IS WORKING COLLABORATIVELY WITH A SMALL NUMBER OF DEVELOPING NATIONS IN A PILOT EFFORT TO PROVIDE TECHNICAL AND ANALYTICAL EXPERTISE IN THIS AREA. THE PRODUCT OF THESE STUDIES IS A JOINT COMPREHENSIVE ENERGY ASSESSMENT THAT WILL IMPROVE THE ABILITY OF A NATIONAL PLANNERS TO DETERMINE ENERGY STRATEGIES THAT WILL MEET NATIONAL DEVELOPMENT GOALS MOST EFFECTIVELY, INCLUDING APPROPRIATE USE OF NUCLEAR ENERGY.

NEVERTHELESS WE BELIEVE THAT CONTROLS AND RESTRAINTS ARE ESSENTIAL ELEMENTS IN PREVENTING PROLIFERATION. THESE ELEMENTS CAN BE, AND MUST BE, IMPLEMENTED IN A WAY THAT TAKES ACCOUNT OF THE NUCLEAR ENERGY REQUIREMENTS OF ALL STATES. AS I HAVE INDICATED, WE HOPE THAT BOTH SUPPLIERS

AND RECIPIENTS CAN ACHIEVE TOGETHER A CONSENSUS ON THE APPROPRIATE BALANCE BETWEEN NUCLEAR FUEL CYCLE RESTRAINTS AND CONTROLS, ON THE ONE HAND; AND ACCESS TO TECHNOLOGY, MATERIAL, AND EQUIPMENT NECESSARY TO MEET ENERGY NEEDS ON THE OTHER. THIS IS THE ESSENTIAL TASK WHICH ALL OF US WHO SHARE A COMMON COMMITMENT TO NON-PROLIFERATION MUST FACE. WORKING TOGETHER IN A SPIRIT OF COOPERATION, I BELIEVE THAT WE CAN ENSURE A GREATER AND MORE RESPONSIBLE USE OF NUCLEAR POWER WHILE AVOIDING PROLIFERATION OF NUCLEAR WEAPONS.

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International Conference on

RECONCILING ENERGY NEEDS AND NONPROLIFERATION:
Perspectives on Nuclear Technology and International Politics

13-16 May 1979, Rheinhotel Dreesen, Bonn-Bad Godesberg

The Multinazionalization of Reprocessing and Enrichment: How and Where?

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The Multinationalization of Reprocessing and Enrichment: How and where?

Rudolf Rometsch

The idealists package of non-proliferation measures contains invariably the suggestion to internationalize the sensitive parts of the nuclear fuel cycle. They are generally recognised to be primarily the enrichment of the isotope U-235 in uranium and the reprocessing of spent fuel, i.e. the chemical separation of plutonium and U-233. Logically the further handling of the special fissionable materials should be included.

Institutional Conditions

It is, however, rarely discussed how to construct an agreement on which such internationalization should be based, an agreement without which the internationalization would have no effect - or even the wrong one - on preventing or limiting the possibilities of proliferation of nuclear weapons. The IAEA-study (1977) on "Regional Fuel Cycle Centers" (RFCC) mentions several indirect effects on meeting non-proliferation objectives and then formulates carefully as a third advantage of an agreement for a RFCC that it "could define limitations on the other programmes of the participants that might otherwise be detrimental to the non-proliferation objectives of the RFCC"

I consider it an essential pre-condition for making at all possible any kind of multinational industrial operation to define clearly its institutional basis. Only an international understanding which cannot be doubted again after a few years would induce industrialists to enter into a joint venture of any importance. Therefore, an understanding on a nuclear fuel cycle centre must contain all elements recognised as effective in decreasing the risk of proliferation of nuclear weapons and at the same time ensure the satisfaction of national needs for nuclear energy development for peaceful purposes; they are:

1. Obligations to carry out defined fuel cycle steps exclusively at the multinational plant.	but	guarantee that these fuel cycle steps will be carried out in accordance with participation in the total plant capacity.
2. Obligation not to accumulate special fissionable material (s.f.m.) beyond limits defined in accordance with accessibility for weapon's manufacture.	but	guarantee of availability of s.f.m. for use up in peaceful activity.
3. Complete access of IAEA to all phases of construction, operation and storage for application of safeguards.	but	no influence on management of plant operation other than automatic consequences of agreed non-access (s.previous para) to s.f.m.
4. Particular protection in IAEA deposits of s.f.m. exceeding the above mentionned (2.) intermediate storage limits.	but	automatic release of s.f.m. from IAEA-deposits for immediate manufacturing and use up for peaceful purposes.
5. Particular employment conditions for operators as well as for inspectors to ensure limitation of know how transfer.	but	no discrimination between nationals from states party to the treaty on multinational fuel cycle operations.

These main and minimum elements would have to be formulated as obligations as well as guarantees in one or more treaties between the governments of those states from which organisations or companies want to take part in the multinational industrial venture.

Further elements of inter-national arrangements, such as exterritoriality, licensing authority, custom tax exemption, could be dealt with in special subsidiary agreements with the host state or with an international organisation playing its rôle. It can, of course, not be expected that all industrialized states with substantial peaceful nuclear fuel cycle programmes would enter into such treaties as soon as they are negotiated. However, e.g. half a dozen European states might form a first nucleus. Easy possibilities to join the treaty (and difficult ones to leave it) should be established. The only acceptance criterion for any state should be full scope safeguards, of the same type as those accepted by parties to the non-proliferation treaty, on its one territory.

Basis for an Industrial Venture

Those parts of the nuclear fuel cycle which are considered for multinationalization because of their key rôle with regard to non-proliferation have also a particular economic characteristic: They represent a high absolute investment threshold. This is particularily pronounced for reprocessing installations and enrichment plants based on gaseous diffusion, but less so for centrifuge enrichment facilities. It is due to the economics of scale. A modern reprocessing plant e.g. should have a capacity to satisfy a group of LWR-power stations totalling at least 30'000 MW(e) installed in order to yield a reasonable cost per unit throughput at full load.

The trivial economic formulae relating capacity to unit cost of service is of course in practice complicated by a number of factors. And some of them have changed considerably over the past decade. To mention only a few: Safety and security requirements have increased, release limits have been pushed down, new waste conditioning criteria have been introduced, and so on - always in the direction of increasing fixed as well as variable cost. Together with the uncertainty about the influence of non-proliferation politics and the problems related to public acceptance this has caused the investors in chemical industry to drop quietely out of the business. The utilities can no longer expect to be able sooner or later to pick and choose from a largely sufficient offer of services.

It seems that - I take again the European situation with regard to reprocessing as an example - most European utility operators are aware of this and are ready to organise self help. Extensive reprocessing contracts have been concluded; down payments are beeing made which are used for building new facilities. But contrary to different approaches with regard to enrichment there is no direct participation neither of government organisations nor of utility companies. On the other hand it appears that reprocessing capacities would become insufficient in the nineties. Therefore it is now time to start preparations if in addition to the already decided reprocessing plants further facilities, for instance an European back-end fuel cycle centre would be needed.

Sharing in the investment of a RFCC as a joint venture of utilities, thus aquiring the right to use a corresponding share of its capacity, appears to be an attractive long-term solution. Not more than 10% of the capital invested in the power-plants would have to be invested in common fuel cycle facilities. Hence, a fundamental readiness of quite some utility companies to go for just that type of investment - but also a fundamental reluctance to decide for it as long as it seems not possible to stick to a non-proliferation understanding for more than some years. Assuming that the latter uncertainty could be overcome by a treaty of the kind mentioned as an introduction the practical problems would be comparatively easy to solve.

Sites and Site Arrangements

There are several siting possibilities, but the technical selection for reprocessing centres is complicated by the local public acceptance discussions. That is the reason for the not very original idea to look for otherwise uninhabited islands. Such islands are numerous, but usually at the wrong spot. For Europeans an interesting possibility has shown up as a result of oil drillings on the continental shelf in the north sea. Several locations were found where shallow waters and large salt domes under the sea bed are combined. Using the Dutch technique, proven e.g. at the Delta works, it appears quite possible to build an artificial island, exactly at the right spot, with a view to co-locate on it all steps of the back end of the fuel cycle including the final storage of solidified waste in the underlying salt formation. An artificial island for other purposes is at present being built between the natural dutch islands. Preliminary studies have shown that an artificial island for a RFCC would not add prohibitive extra cost to the installation.

With regard to any site a particular arrangement between the RFCC and the host country government would have to be concluded. (For an artificial island in international waters it might be necessary to construct also an artificial host country). In that respect the model used for the Eurochemic Company appears still valid. It regulates the extent of exterritoriality, clarifies the relations to health and safety and licensing authorities, defines custom tax exemption and foresees other practical arrangements. Those models would be used again, but of course the essential error in the Eurochemic joint venture, not to provide for the possibility of truly industrial economic operation within and independant of the overlaying political understanding should not be repeated.

Stepwise Realization

Not all the five steps of a back end fuel cycle centre are needed at the same time. Forecasts of the development of nuclear power utilization in general and the development of the use up of the produced plutonium (or U-233 or mixtures thereof) in particular suggest stepwise realisation of such a centre. The overall lead time could well be around twenty years. But a good overall planning should be established now and first steps should be initiated along two separate lines of action.

The political line is related to INFCE results. The fundamental elements for a political understanding between nations interested in multinational fuel cycle operations are not my invention. They emerged in several INFCE discussions of institutional means to assure non-proliferation. If those states having announced rigid non-proliferation requirements as a condition of supply would be able to declare that these requirements are automatically fulfilled by states party to a fuel cycle centre treaty, speedy conclusion of such a treaty appears quite possible.

The industrial line of action would then have a good starting point. Constitution of a multinational company, establishment of a financing plan and a general technical project would take a few years. But it appears quite possible to realize the first step, a central spent fuel storage, at the same location where later on reprocessing should take place, around 1990. It is certainly premature to discuss now the timing of further steps.

Conclusions

A constructive approach to multinational operation of sensitive parts in the nuclear fuel cycle offers a way out of disagreement and controversy on non-proliferation politics. To prevent or limit the proliferation of nuclear weapons requires a complex set of understandings between people and between nations; it is a question of balancing interests, not a question of power equilibrium; its basic element is co-operation between people. The co-operative endeavour to achieve a multinational industrial venture goes certainly in the right direction.

4. Mai 1979

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Exploring Nuclear Futures: A Statement of the Issues Regarding Nuclear Energy and Proliferation

Henry S. Rowen

Exploring Nuclear Futures: A Statement of the Issues Regarding Nuclear Energy and Proliferation

During the past year I have chaired a series of meetings which have brought together leaders from the American nuclear industry and utilities, physical scientists, geologists, economists, specialists in international relations and government officials. These meetings have been intended to define the issues on nuclear energy in its relation to the spread of the ability to make nuclear weapons, in particular those issues on which there have been serious differences of views. The attempt has been to try to achieve a consensus on policy directions where possible but at least second-order agreement, i.e. agreement on what the differences are. Not surprisingly, the latter has been less difficult to accomplish than the former.

What follows are excerpts from a report which summarizes the results of the first phase of this effort. It is based on a two-week long meeting in August, 1978 and was prepared late in 1978. It therefore is fairly current although it does not reflect new data or changes in views since then.

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The U.S. policies and proposed technical and institutional initiatives which were particularly relevant for our effort include the following:

1. Support of the Non-Proliferation Treaty (NPT).
2. Effort to limit the export of concentrated fissile materials and of technologies important for producing them, especially those for isotope separation and for chemical reprocessing of spent fuel.
3. The decision in 1976, to defer commercialization of reprocessing of spent fuel, a decision as part of a strategy for discouraging

wide circulation of plutonium abroad; also its reinforcement in 1977 and the related decision to slow development of the fast breeder.

4. The Nuclear Non-Proliferation Act of 1978* which will ultimately require, among other things, that U.S. exports of sensitive nuclear technology and materials be conditioned on the recipient's willingness to accept full scope IAEA safeguards on all relevant nuclear facilities and not to detonate a nuclear explosive device.
5. Support for improvements in IAEA safeguards.
6. Measures proposed to assure that fuel would be available to countries operating within the international system to limit nuclear explosives access in order to strengthen incentives for reliance on the international market for enrichment fuel instead of building national isotope separation plants.
7. Proposals for helping to reduce the burden of spent fuel and its dangers as a source of nuclear explosive material by arrangements for its safeguarded storage and removal at least from certain countries.
8. Proposals for developing and using fuel cycles that are resistant to diversion for weapons use.

Some members of the group agreed with the essentials of these policies. On the other hand they have been subjected to various criticisms and some members of our group agreed with these criticisms. These include the following:

1. Growth in global energy demand will be so great as to deplete low cost oil, gas, and uranium resources in the next few decades. There may be serious environmental obstacles to expanding coal production greatly and, in any case, many countries do not have access to low cost coal. Therefore, the breeder reactor may be needed on a sizeable scale at the beginning of the 21st century and development and demonstration are needed soon to have the option of installing breeders when they may be needed.
2. Aside from global fuel depletion, many countries do not have the energy endowment of the United States and some are committed to early use of plutonium and especially the breeder in order to avoid excessive energy dependence or insecurity. Moreover, the U.S. as a major supplier of nuclear fuel services has not managed its enrichment business so as to generate confidence about its reliability as a supplier.

* The conduct that would result in termination of Nuclear Exports is prescribed in Sec.307 of the Act.

3. The example of a once-through fuel cycle set by our self-imposed limit on LWR reprocessing and FBR development will not significantly influence other nations. One reason is that we continue military reprocessing and stockpiling nuclear weapons; further, the danger of proliferation is only fractionally increased by civilian reprocessing facilities. Our policy also increases dependence on foreign supplies of oil and uranium (which destabilizes international fuel markets and poses a risk to national security). On this view, the U.S. example will not be followed by other countries unless they are independently persuaded of its merits for their own situations.
4. Deferring LWR reprocessing and FBR development is unlikely to reduce proliferation dangers significantly because these activities do not provide the most ready paths to nuclear weapon development, although they contribute to a nation's nuclear expertise and indirectly to the risk of weapons proliferation.
5. Several of the Administration's non-proliferation related actions have hindered the expansion of nuclear power capacity at home, injured U.S. nuclear sales abroad and weakened U.S. leadership in energy technology and policy. Further, our policy may lead other countries to take actions which would increase proliferation risks. A related criticism often voiced abroad is that U.S. actions have been in violation of Article IV of the NPT.
6. Variations in degrees of industrialization and in ties to the U.S. need to be more explicitly reflected in non-proliferation policy. International institutions and arrangements which take account of this diversity need to be developed for the management of sensitive technologies and materials.
7. The barrier to getting nuclear explosive materials presented by radiation in spent fuel in once-through systems (or radiation that might be added to fresh fuel) is uncertain but probably small and certainly diminishing. The carefully controlled recycle of plutonium would be preferable to the indefinite storage of spent fuel and would simplify waste disposal. Moreover, the spread of competence in nuclear technology, including the further development and

spread of isotopic separation technologies, will ease the paths to nuclear explosive materials. Chemical reprocessing technology is generally well known already.

8. In contrast, fresh plutonium fuel can be given substantial protection by the introduction of a radiation barrier, as for instance in the CIVEX proposals.

9. Existing institutions and agreements such as the IAEA safeguard system and the NPT are the only real basis for dealing with diversion of nuclear explosive materials. These existing international institutions and agreements need strengthening as opposed to the U.S. taking unilateral actions or the creation of new institutions.

Other members of the group disagreed with some or all of these points.

It could hardly be expected that a two week summer study could resolve these issues. It did, however, cause some of the differences to be reformulated and sharpened. . .There are, in addition, some questions which cut across the scope of the two panels or which were discussed separately.

A point of great importance that surfaced in several different contexts is the fludity that seems to exist with regard to the future actions of many governments. Many changes have taken place in the non-proliferation policies of several countries in recent years, most obviously in the United States but also in a number of other countries. These include the decisions by France and Germany not to export reprocessing technology; Germany has said that it will make no more "Brazilian" deals (at least until the INFCE review is completed); and we understand that France has under review the question of restraints that might be imposed on the export of plutonium. Moreover, we were told that plans for "sensitive facilities" have been suspended in several countries, and that many more countries are in compliance with the terms of the U.S. Nuclear Non-Proliferation Act than would have been the case in the absence of the push provided by the U.S. and other supplier countries.*

Perhaps a central observation is that there are large uncertainties of several kinds including technological (e.g., the proliferation resistance of once-through cycles or the effectiveness of CIVEX-type radiation barriers relative to the barriers in once-through systems), economic (e.g., energy

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*The term "sensitive facilities" as used in this report refers to those parts of a fuel cycle which provide relatively easy production of, or access to, nuclear explosive materials, such as enrichment plants, fuel reprocessing plants, and fuel manufacturing plants. "Sensitive materials" are the products of these plants, nuclear explosive materials, or materials which can readily be converted to such concentrated fissile material. Power reactors are not defined as "sensitive."

demands and costs early in the 21st century), political (e.g., how enduring might an international non-proliferation regime be based on such a distinction as that between "stable" and "non-stable" states). It clearly will take time--in some instances a long time--to narrow greatly or eliminate many of these uncertainties; some can never be eliminated. It is this perception that underlies U.S. non-proliferation strategy for deferring possibly irreversible commitment to courses of action seen as dangerous, especially where the costs of deferral are judged to be low.

An important example of how uncertainty affects non-proliferation strategy concerns the stance we should take on developing international institutions for the management of sensitive facilities and materials. At present there are only a few reprocessing and enrichment facilities in non-weapon states. These exist and somehow must be dealt with. In the view of some participants, several major countries are on the path to reprocessing and U.S. initiatives for international management would be a constructive step to reducing future access to weapons material, a step taken when national systems are not so industrially embedded as to inhibit international arrangements among the major powers. A different view is that firm predictions that their number will grow greatly in the next few decades are not warranted in light of the changes in perception that are taking place in many countries. Widespread deployment of the breeder, even in industrial countries, is not an imminent prospect. The problem, which is described more fully in the Institutional Panel report, is that to the extent sensitive facilities are not limited to weapon states we would like to see them under some form of international control. Yet to move towards building institutions for their regional or global management assumes the alternative is the wide spread of sensitive national facilities, an assumption which is questioned. Moreover, U.S. initiatives, for example, for the international management of plutonium recycle, would, in the view of some, be perceived as U.S. weakening of opposition to early and widespread reprocessing and plutonium circulation and would strengthen moves by other countries towards undertaking these activities nationally. In any case, what is meant by international "management" of reprocessing and plutonium and what would be achieved remains to be described. The report of the Institutional Panel [not included in these excerpts] suggests that any U.S. proposals to study such institutional arrangements at the least should make evident their risks and uncertainties as well as their potential benefits.

There is also a good deal of uncertainty on future growth in energy use around the world, the growth in electricity demand, and especially, nuclear electricity demand. For the United States, an analysis was presented to the group which showed that the range of energy demand prospects for the year 2000 is large but that the spread is significantly below earlier estimates. Prospective U.S. energy consumption is important because we have a large impact on world energy markets and can affect the date when the commercial use of plutonium might become competitive with alternatives; besides, U.S. technology choices have an influence on the rest of the world. Although electricity demand was not explicitly modeled in this study, the results raised questions about U.S. energy demand rising so rapidly as to require early breeder introduction. Low growth in energy demand is, of course, compatible with a higher growth in electricity demand and such growth is expected (although we were also told that industry estimates of future electricity growth are being lowered). This lowered range is also compatible with a disproportionate growth in nuclear as compared with coal technology by the year 2000 and beyond, perhaps as the result of tightened environmental standards on all aspects of the coal cycle.

Because evidence on consumer response to changing real energy prices is accumulating rapidly, and also because of significant changes in economic growth forecasts, we believe that more comprehensive energy demand modeling effort with projections to the year 2000 and beyond is needed for the U.S. and for the world. Nuclear capacity projections for the year 2020 submitted in INFCE Working Group 1 span an unrealistically narrow range (2600 - 2800 GWe) and in the view of some participants are too high; a competent analysis which reflected the real uncertainty that exists should show wider variation in installed nuclear capacity. In making this suggestion, we appreciate the advice that nuclear capacity estimates submitted in INFCE are likely to be highly politically determined. Nonetheless, we see value in preparing and submitted technically competent analyses in INFCE which reflect the range of energy demands on the basis of existing information. Whatever their utility in INFCE, there will be other settings in which such analyses will be useful.

In an exercise, we explored the sensitivity of choices among nuclear technologies to variations in several key parameter values. This exercise lends support to the proposition that the uncertainties call for an R&D strategy which is sequential in character and which contains hedges. The report of the Technology Panel [not included] describes an R&D strategy which includes the development of a number of technical options.

Another issue which came up in several contexts is the relationship between estimates of various parameters and values that should be assumed for purposes of "prudent planning." What is prudent in one context may be imprudent in others. For instance, to those who have a responsibility of providing for energy needs, it seems prudent to insist on high confidence in uranium supply availability. However, such "prudence" in uranium supply estimates enhances the incentive for plutonium recycle and the breeder, and to the extent that this eases the path to weapons material acquisition such a procedure may be far from prudent in a larger context. We propose no formula for avoiding imprudence but simply urge that forecasters and planners be sensitive to this point.

This point was underscored by a presentation on world uranium resources. Using several estimation methods, all highly speculative, the range of resources in the under $50 per pound (1978 dollars) was 13 to 32 million tons of U_3O_8. If the low end of this range is valid, uranium resources appear likely to be able to meet demands into the second quarter of the 21st century. If so, the major remaining uncertainty, emphasized by several participants, is the rate of discovery and development of this resource base. Especially if nuclear demand is relatively high, the constraint on production could be binding. (Even with an adequate aggregate global uranium supply, some governments could have concern about its distribution and about reliability of their access to this supply.) This discussion highlighted the value of obtaining and disseminating information on world uranium resources.

Although our efforts were largely concentrated on INFCE and NASAP materials, we became aware of the need to explore many of the issues we discussed more deeply for the purposes of bilateral discussions as well as for INFCE purposes. This was true, for example, on the subject of the different cycles. A good deal of discussion took place during the Study on this topic which is not covered in this report. However, an important issue deserves comment. It was proposed that the relevant costs of a nuclear weapon program are not the total costs of starting from scratch but those incremental to an ongoing civilian nuclear (research or power) program. Such programs inevitably contribute to a nation's nuclear competency; moreover, some fuel cycles are much closer to weapons than others. The proposition was advanced that, at least for purposes of analysis, different fuel cycles should be made as nearly equivalent as possible in terms of proliferation resistance and that the costs of the required measures be included in the evaluation of each cycle. This would take as a benchmark of protection spent fuel of given vintage (say five years) and have fresh fuel designed to provide a comparable barrier. (The CIVEX proposal is based on a similar concept.) It would be an exaggeration to report that there was a consensus on the utility of this "benchmark." In any case, there are practical problems both in measuring diversion resistance for different cycles and in estimating costs of protection. The principal issue discussed is the likely efficacy of the barriers of radiation and of isotopic separation. Some hold that the radiation barrier in spent fuel is adequate. Others hold that its adequacy is uncertain but that it is substantial. Differences also exist with regard to the radiation barrier in fresh fuel with some holding that the barrier can be made substantial and others disagreeing. However, if the radiation barrier in spent fuel, say at five years, is inadequate, there is the possibility of earlier removal. (This assumes that there is a radiation level high enough to be a significant barrier to reprocessing but low enough to permit removal of spent fuel from national control; but as a practical matter large quantities of spent fuel will remain stored in reactor pools for a long time to come.) It was also suggested that tighter international controls over fresh fuel might be needed if plutonium is used as fuel or if the isotopic barrier is seriously eroded, an arrangement that may conflict with security of fuel supply objectives that many governments have. If, everything taken into account, barriers do not promise much protection (except against diversion by subnational groups), some participants questioned the utility of international safeguards and of international fuel service centers, and at least one questioned the use of nuclear power. In short, the subject of proliferation resistance measures is a topic which the Study may have helped to clarify but not to settle.

The perception of large uncertainties, the long lead time needed to resolve them, and the need for hedges was generally accepted by the participants but with divergent interpretation for U.S. policy. Without attempting to identify schools of thought more sharply than is warranted, perhaps three can be identified. One group was generally supportive of the Administration's position that the international risks outweighed the ones to the domestic energy sector, which were seen to be small. Once-through operations and similar limitations together with changes in international nuclear agreements may not be demonstrably safe from diversion, but they are safer than alternatives available. This group emphasizes the changes that have occurred to limit the spread of sensitive technologies and judges that more changes are likely. Some suspect that in the absence of changes to limit the perceived risks of military use that the future of civil nuclear power will be in doubt. It sees merit in international arrangements to reduce incentives for having access to nuclear explosive materials (e.g., through spent fuel storage arrangements and fuel assurances) or making access more difficult (e.g., through export controls); it recognizes that something must be done about the existing sensitive facilities in non-weapon states but does not favor action that will legitimate the spread of plutonium or of reprocessing technology (e.g., through multinational reprocessing plants).

A second view concentrates on the need to move ahead now to make international arrangements for managing existing sensitive facilities and for developing institutions to function when and if breeders are operating commercially. It would consider international arrangements for the operation of commercial reprocessing facilities both in non-weapon and weapon states sufficient to provide plutonium for breeder R&D and demonstration plants, safeguarded international storage of any "excess" plutonium stocks, and international arrangements for the operation of various aspects of a future commercial breeder fuel cycle. However, this group would discourage recycling of plutonium in dispersed thermal reactors. Members of this group are not of one mind as to whether breeders will ever become commercially important but they give weight to the importance of creating an international framework within which some non-major states can participate in developing and using this technology whatever its ultimate commercial fate.

Just as those in the first group have to deal with opposition abroad to the U.S. position on deferring commercial recycling and to the existence of sensitive facilities in a number of non-weapon states, members of the second group need to show how internationalizing plutonium mangement for the breeder, which is not a near term commercial prospect, will help or how it will deal with the dangers of easier access to explosive materials. Our study did not proceed to the point of discussing specific proposals for plutonium management (nor parallel proposals that might be advanced on isotopic separation facilities management)...

A third group focuses more on energy supply uncertainties and favors moving ahead with thermal recycle and early creation of a breeder option. It sees spent fuel as presenting a danger with a diminishing radiation barrier and the spent fuel storage problem as unlikely to be resolved soon. It holds that spent fuel is an impediment to the growth of nuclear power and is likely to lead a number of nations to opt for thermal recycle. Such a choice would have a small impact economically but the consequent reduction in uranium consumption will be valued by a number of governments. Such a strategy would ease the transition to a more efficient breeder system; also one better designed to manage proliferation risks. This group would place the burden of limiting the acquisition of nuclear weapons on the working of international diplomacy. This group has to grapple with the implication of easier access to nuclear explosive materials throughout the world, a situation which may prove beyond the capabilities of diplomacy; it therefore cannot escape the question as to whether practical and substantial barriers to diversion can be devised and win wide acceptance.

In all of this, one point was evident. The choices are not between "institutional" or "technical" measures, but a combination of the two that seeks to harness marketplace and political incentives so as to minimize risks.

Contained within these differing views there are a number of concrete issues: the prospects for energy demand growth and supplies in the U.S. and abroad, the firmness of the commitment of various governments to the acquisition of sensitive facilities, how the prospective international reprocessors, especially Britain and France, are going to manage their plutonium export businesses, the proliferation resistance of various fuel cycles, and the possibility of implementing an international spent fuel management system, among others.

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Finally, I would like to add a few comments on developments since the above was written. The following list admittedly somewhat selective and incomplete (e.g. it excludes the impact of the troubles at the Three Mile Island reactor). First, the recent public revelations concerning efforts by Pakistan to acquire enrichment technology - and to do so from Western firms - provides additional data for consideration on the relation between civilian and military uses of nuclear energy. Second, projections of installed nuclear capacity continue to decline; it now appears that installed nuclear capacity in the world outside communist areas will be no more than about 200 GWe in 1985 and 300 GWe in 1990. (There is a good deal more uncertainty for 2000 but my estimate of the most likely level is around 600 GWe - a level well below the INFCE low). Third, large discoveries of uranium continue to be made, most recently in Canada. The findings of the International Uranium Evaluation Program are supportive of the analysis presented in the excerpts above to the effect that supplies of relatively inexpensive uranium are likely to be available well into the 21st century - in abundance great enough to support once-through systems. Fourth, interesting progress is being made in reactor technology, both through incremental improvements to increase the fuel efficiency of LWRs and through potentially more radical innovations. I am thinking in particular of the Fast Mixed Spectrum Reactor concept which has been devised by Herbert Kouts and others at Brookhaven Laboratory.

The upshot of these recent developments is to provide support to the proposition that, although the case for moving ahead with nuclear energy remains strong in many situations, the case for deciding <u>now</u> to adopt the most dangerous form of this technology has been weakened. The method of decision that is most applicable in today's world, given the uncertainties that we all face, is a <u>sequential</u> one, one which allows for changes as additional information is acquired.

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Das Konzept der deutschen Elektrizitätswirtschaft für die Entsorgung der Kernkraftwerke*

The concept of the German electric power industry for the disposal of spent fuel from nuclear power plants*

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Abstract

The following report describes the German concept for the disposal of spent nuclear fuel elements. The Deutsche Gesellschaft für Wiederaufarbeitung von Kernbrennstoffen (DWK) was founded by German utilities to realize the project, which was originally initiated by the Federal Government as an integrated Centre for the Disposal of Spent Fuel. In this centre all installations, fuel element storage, reprocessing, re-use of uranium and plutonium, and final storage of wastes, are concentrated at one site.

1. Historische Entwicklung

Ursprünglich sollte die Wiederaufarbeitung von abgebrannten Brennelementen nicht in den Aufgabenbereich der Elektrizitätswirtschaft fallen, denn die chemische Industrie hatte diesen chemischen Prozeß zunächst übernommen und die Entwicklungsarbeiten hierfür mit finanzieller Unterstützung der Bundesregierung begonnen. Deshalb soll der Erläuterung des Entsorgungskonzeptes hier vorangestellt werden, wie es dazu kam, daß sich die Elektrizitätswirtschaft der ihr in seinem wesentlichen Bestandteil, nämlich dem chemischen Prozeß der Wiederaufarbeitung, wesensfremden Aufgabe angenommen hat. Dazu ist ein Rückblick bis in das Jahr 1970 erforderlich.

1970 waren in der *Bundesrepublik Deutschland* die Leichtwasser-Kernkraftwerke Kahl, Grundremmingen, Obrigheim und Lingen mit einer elektrischen Netto-Leistung von 725 MW in Betrieb, und der jährliche Anfall an abgebrannten Brennelementen aus diesen Kraftwerken betrug etwa 30 t. Eine über die Gesellschaft für Kernforschung (GfK) vom Bundesministerium für Forschung und Technologie (BMFT) finanzierte und nach amerikanischen Vorbildern geplante und errichtete Wiederaufarbeitungsanlage mit 40 t Jahreskapazität – die WAK in Karlsruhe – stand damals kurz vor der Inbetriebnahme. Betreiber der WAK war die Gesellschaft für Wiederaufarbeitung von Kernbrennstoffen mbH (GWK), gegründet von den Chemieunternehmen Bayer und Hoechst sowie Gelsenberg und Nukem.

In *Großbritannien* wurde die Aufarbeitungsanlage in Windscale, die bis dahin nur für Magnox-Brennelemente ausgelegt war, durch ein zusätzliches neues Headend (Eingangsteil) modifiziert, um in der ersten Ausbaustufe auch 400 t/a LWR-Brennelemente verarbeiten zu können. In *Frankreich* waren damals gerade die Umbauarbeiten an der zunächst für die Wiederaufarbeitung von Gas-Graphit-Brennelementen ausgelegten Anlage bei La Hague in Gang, um für die Wiederaufarbeitung von LWR-Brennelementen eine Kapazität von 800 t/a zu schaffen.

Gleichzeitig begannen die Planungsarbeiten für eine große deutsche 1400-t/a-Anlage, basierend auf den Erfahrungen mit der WAK. Diese Anlage sollte das Kernstück eines vom BMFT entworfenen integrierten Entsorgungskonzeptes werden.

Diese drei europäischen Länder entschlossen sich, ihre Planungen zukünftig so zu koordinieren, daß es nicht zu den damals befürchteten Überkapazitäten kommen sollte. Deshalb wurde 1971 die *United Reprocessors GmbH* (URG) gegründet, deren Gesellschafteranteile zu je einem Drittel von der englischen *British Nuclear Fuels Ltd.* (BNFL), dem französischen *Commissariat à l'Énergie Atomique* (CEA) und der deutschen *Kernbrennstoff-Wiederaufarbeitungsgesellschaft mbH* (KEWA) gehalten werden.

* Überarbeitete Fassung eines Vortrags, gehalten am 19. 10. 1977 bei der KEST, Hamburg, und am 20. 10. 1977 im Haus der Technik, Essen.

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1. Historical background

Originally, the reprocessing of spent nuclear fuel assemblies was not intended to fall into the ambit of the electric power industry at all, because the chemical industry had taken up this chemical process and had started development work in this field with the financial support of the Federal Government. Before discussing the current waste disposal concept, which is the actual subject of this paper, it is therefore necessary first to describe how it came about that the electric power industry took over this task entailing as its major component the chemical reprocessing which essentially belongs within the competence of an altogether different industry. For this historic review it is necessary to go back to the year 1970.

In 1970 in the *Federal Republic of Germany* there were in operation the nuclear power stations at Kahl, Gundremmingen, Obrigheim and Lingen, all with light water reactors (LWR) and with an aggregate net electric power rating 725 MW. The total generation of spent fuel assemblies by these power plants amounted to about 30 t per year. At that time the fuel reprocessing plant in Karlsruhe (WAK), with a reprocessing capacity of 40 t/a, had already been built and was due to be commissioned shortly. The WAK had been financed by the Federal Ministry for Research and Technology (BMFT) through the Society for Nuclear Research (GfK), and had been planned and built following American prototypes. The Operator of the WAK was the Company for the Reprocessing of Nuclear Fuels (GWK) which had been founded jointly by the chemical companies Bayer and Hoechst with the participation of Gelsenberg and Nukem.

In *Britain* in those days the fuel reprocessing plant at Windscale, originally designed only for Magnox fuel assemblies, was being modified by the addition of a new head end to enable it, in the first extension phase, to process an additional quantity of 400 t/a of LWR fuel assemblies. In *France* construction work was in progress at the reprocessing plant at La Hague, originally designed for the reprocessing of gas-cooled graphite fuel elements, to enable this plant to process an additional quantity of 800 t/a of LWR fuel assemblies. In *Germany* at the same time planning work was in progress on a 1400 t/a plant, based on the experience gained at the WAK. This plant was intended to form the core of an integrated waste disposal concept formulated by the BMFT.

These three European countries decided to coordinate their future planning so as to avoid excess capacities which seemed likely at that time. In pursuit of this aim the *United Reprocessors Ltd.* (URG) was founded in 1971, with joint participation in equal shares by the *British Nuclear Fuels Ltd.* (BNFL), the French *Commissariat à l'Énergie Atomique* (CEA) and the German *Kernbrennstoff-Wiederaufarbeitungsgesellschaft mbH* (KEWA).

* Revised version of a paper read on 19. 10. 1977 at KEST in Hamburg and on 20. 10. 1977 in the House of Technology in Essen

Die Aufgabe der URG bestand einerseits in der Abwicklung der Wiederaufarbeitungsverträge mit den Kraftwerksbetreibern und andererseits in der Vermittlung des Know-how zwischen den drei Gesellschaftern, die die URG auch als Instrument benutzten, um die Errichtung der geplanten Wiederaufarbeitungsanlagen zu koordinieren.

In den folgenden Jahren änderte sich jedoch die Sachlage.

Das neu konzipierte Headend der britischen Anlage in Windscale mußte 1973 als Folge einer Störung stillgelegt werden; damit war das Experiment, ein modernes Eingangsteil für hochabgebrannte LWR-Brennelemente einer älteren Anlage vorzuschalten, fehlgeschlagen.

Die Umbauarbeiten für die Verarbeitung von abgebrannten LWR-Brennelementen in der französischen Anlage verzögerten sich derart, daß erst 1976 die erste Charge mit 15 t LWR-Brennelementen aus dem schweizerischen Kernkraftwerk Mühleberg aufgearbeitet werden konnte.

Die Planungsarbeiten für die deutsche großtechnische Wiederaufarbeitungsanlage ließen statt der ursprünglich geschätzten 500 Mio. DM durch die zwischenzeitlich im Bereich der Kerntechnik stark erhöhten Kosten und Sicherheitsanforderungen eine Investitionssumme von weit über 2 Mrd. DM erwarten, so daß eine Rentabilität des Wiederaufarbeitungsprozesses in dem Sinne, daß die Kosten für das Verfahren niedriger als die durch Plutonium und Uran erzielbaren Rückvergütungen sein würden, nicht mehr erwartet werden konnte.

Diese Entwicklung hatte zwei Folgen: Einmal wurde aus der erwarteten Überkapazität ein Mangel an Aufarbeitungskapazität; zum anderen verlor die bei der KEWA bislang engagierte chemische Industrie aufgrund der Kostenentwicklung das unternehmerische Interesse an der Wiederaufarbeitung, zumal auch die Bundesregierung zu erkennen gab, daß sie zu einer Finanzierung der Wiederaufarbeitung nach dem Modell der Anreicherung nicht bereit sein würde.

Somit mußte die Elektrizitätswirtschaft, um die Entsorgung und den Betrieb ihrer Kernkraftwerke sicherzustellen, die Finanzierung und Durchführung des Projektes im Sinne des inzwischen vielzitierten Verursacherprinzips übernehmen. Zu diesem Zweck wurde 1975 die *Projektgesellschaft Wiederaufarbeitung von Kernbrennstoffen* (PWK) durch 12 deutsche Elektrizitätsversorgungsunternehmen (EVU) gegründet. Das satzungsgemäße Unternehmensziel der PWK war die Schaffung der technischen, wirtschaftlichen und rechtlichen Voraussetzungen für die Errichtung und den späteren Betrieb einer großen deutschen Wiederaufarbeitungsanlage, und die erste diesem Ziel dienende unternehmerische Aktion war der Abschluß eines Vertrages mit der KEWA über die Ausarbeitung eines Vorprojektes für das Entsorgungszentrum auf der Basis der bereits angefertigten Konzeptstudie. Den größten Umfang der Arbeiten der PWK nahm jedoch die Vorbereitung des für die Einleitung eines Genehmigungsverfahrens erforderlichen Sicherheitsberichtes ein, wofür eine Reihe von Planungsaufträgen parallel zu dem Vorprojektauftrag erteilt wurden.

2. Aufgabe und Struktur der DWK

Schon in der Phase der Erstellung des oben genannten Sicherheitsberichtes sowie auch im Zuge der den Vorprojektauftrag an KEWA begleitenden Arbeiten stellte sich heraus, daß die organisatorische Form einer – teilweise sogar nur nebenamtlich – koordinierenden Projektgesellschaft für die endgültige Realisierung eines so großen Zieles wie des deutschen Entsorgungszentrums nicht ausreichen würde. Durch Beschluß ihrer Gesellschafterversammlung wurde deshalb am 28. 2. 1977 die PWK in die *Deutsche Gesellschaft für Wiederaufarbeitung von Kernbrennstoffen mbH* (DWK) umgewandelt und ihr Gesellschaftskapital auf 100 Mio. DM erhöht.

The main intended functions of the URG were, firstly to coordinate the flow of reprocessing contracts with the operators of nuclear power plants and, secondly, to ensure an interchange of know-how between the three founder members who were also using the URG as an instrument for coordinating the construction of planned reprocessing plants.

In the next few years, however, the situation changed in several respects.

In Britain, the newly designed head end of the Windscale plant had to be closed down in 1973 owing to a malfunction. This put an end to the attempt of grafting a modern head end for LWR fuel assemblies with a high burnup onto an existing older plant.

In France, the reconstruction work at the La Hague plant, intended to enable this plant to process spent LWR fuel assemblies, was delayed to such an extent that the first batch of 15 t of LWR fuel assemblies, from the Mühleberg nuclear power station in Switzerland, was only reprocessed in 1976.

In Germany, the original capital cost estimate for the large scale reprocessing plant had been of the order of 500 million DM. As the planning work proceded the capital cost estimates rose far in excess of 2 billion DM, owing to sharp increases in costs as well as the stringency of the safety specifications in the field of nuclear engineering. This put an end to expectations of commercial profitability in the sense of balancing the costs of the process against the resale value of the recovered plutonium and uranium.

These developments had two main consequences. Firstly, the originally anticipated excess capacity turned into insufficient capacity. Secondly, owing to the greatly increased cost estimates, the chemical companies participating in the KEWA lost their commercial interest in fuel reprocessing, especially after the Federal Government let it be known that it would not be prepared to subsidise fuel reprocessing according to the model of fuel enrichment.

This placed the onus of financing and implementing the project on the German electric power industry in order to ensure waste disposal and thus the continuing operation of their nuclear power plants, this being consonant with the "polluter pays-prin-

Tabelle: Die 12 EVU-Gesellschafter der DWK

Table: The 12 electric power utilities holding shares in the DWK

DWK	%
Badenwerk AG, Karlsruhe	7
Bayernwerk AG, München	10
Elektromark, Kommunales Elektrizitätswerk Mark AG, Hagen	1
Energie-Versorgung Schwaben AG, Stuttgart	7
Hamburgische Electricitäts-Werke, Hamburg	8
Isar-Amperwerke AG, München	2
Neckarwerke Elektrizitätsversorgungs-AG, Eßlingen	3
Nordwestdeutsche Kraftwerke AG, Hamburg	11
Preußische Elektrizitäts-AG, Hannover	11
Rheinisch-Westfälisches Elektrizitätswerk AG, Essen	31
Technische Werke der Stadt Stuttgart AG, Stuttgart	2
Vereinigte Elektrizitätswerke Westfalen AG, Dortmund	7
DWK – DWK-Gesellschafter	März 1977

Ihre Gesellschafter sind nach wie vor jene 12 Kernkraftwerke planende oder betreibende EVU mit einem ihrem künftigen Entsorgungsbedarf ihrer Kernkraftwerke in etwa entsprechenden Anteil am Gesellschaftskapital (Tabelle). In Erweiterung der Aufgaben ist das Unternehmensziel der DWK nunmehr die Planung, Errichtung, Erwerb und Betrieb von Anlagen sowie Dienstleistungen aller Art zur Entsorgung von Kernkraftwerken, insbesondere der Lagerung und Aufarbeitung von ausgedienten Brennelementen. Ausgenommen sind jedoch Anlagen zur Endlagerung von radioaktiven Abfällen, die nach den Bestimmungen des Gesetzes über die friedliche Verwendung der Kernenergie und zum Schutz gegen ihre Gefahren (Atomgesetz) in die Zuständigkeit der Bundesregierung fallen.

Aufgrund der Vorarbeiten konnte die DWK am 31.3.1977 den Genehmigungsantrag für die Anlagen des Entsorgungszentrums nach § 7 des Atomgesetzes unter Vorlage eines rund 3000 Seiten umfassenden Sicherheitsberichtes beim dafür zuständigen Niedersächsischen Ministerium für Soziales einreichen. Für diese Auftragsstellung war die Benennung eines geeigneten Standortes durch die Niedersächsische Landesregierung erforderlich, wobei die Wahl nach eingehender Prüfung aller in Niedersachsen liegenden Salzstöcke unter Berücksichtigung der vom Bundesinnenministerium aufgestellten Standortkriterien für kerntechnische Anlagen auf den im Kreis Lüchow-Dannenberg bei Gorleben gelegenen Salzstock fiel (Fig. 1). Daneben waren zuvor die Salzstöcke Wahn im Landkreis Aschendorf-Hümling, Lichtenhorst bei Nienburg und Lutterloh bei Celle in die engere Wahl gezogen worden. Im Rahmen des durch die Antragstellung der DWK eingeleiteten Genehmigungsverfahrens wird auch zu prüfen sein, ob der Standort Gorleben für die dortige Errichtung des Entsorgungszentrums geeignet ist.

ciple" much discussed lately. In pursuit of this aim 12 German electric power utilities (EPU) founded in 1975 the *Project Company for the Reprocessing of Nuclear Fuels* (PWK). The statutory objective of the PWK was the creation of technical, economic and legal preconditions for the construction and subsequent operation of a large German spent nuclear fuel reprocessing plant. The first step of the PWK in pursuit of this aim was to place with the KEWA a contract for the elaboration of a preliminary project study for the waste disposal centre on the basis of the already completed concept study. The bulk of the work of the PWK, however, lay in the preparation of the Safety Report required to initiate the statutory licensing procedure. In this connection the PWK placed contracts for several planning studies running parallel to the preliminary project study by the KEWA.

2. Functions and structure of the DWK

In the course of preparation of the Safety Report and of the ancillary work connected with the preliminary project study by the KEWA, it became obvious that the organisational form of a coordinating project company (which even had some part-time participants) was inadequate for the definitive realisation of such a major objective as the German Nuclear Waste Disposal Centre. The decision was therefore taken at a shareholders' meeting held on 28.2.1977 to convert the PWK into the *German Company for the Reprocessing of Nuclear Fuels* (DWK), and the equity capital was at the same time raised to 100 million DM.

The shareholders in the DWK are the same 12 EPUs operating or planning to operate nuclear power stations (see Table), and their shareholdings are approximately proportional to the esti-

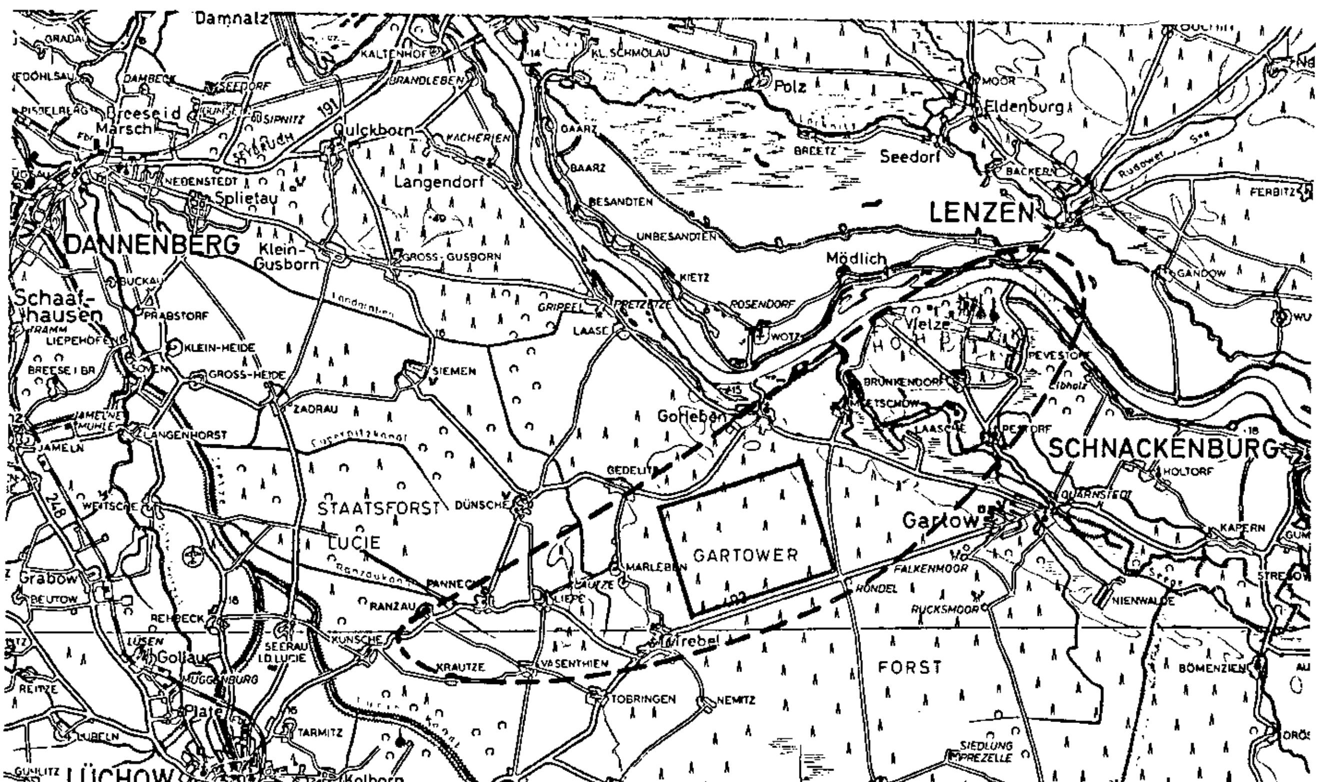

Fig. 1: Der Standort und der Salzstock Gorleben

Fig. 1: The site and the Gorleben salt mine

Parallel hierzu wird die von der Bundesregierung beauftragte Physikalisch-Technische Bundesanstalt in Braunschweig (PTB) in einem Ende Juli 1977 beantragten Planfeststellungsverfahren die Eignung des Salzstockes als Endlager für radioaktive Abfälle prüfen. Auch für dieses Verfahren ist die Genehmigungsbehörde das Niedersächsische Sozialministerium.

Im Hinblick auf den in Niedersachsen gelegenen Standort als auch wegen des überwiegend in Hannover ablaufenden Genehmigungsverfahrens wurde der Sitz der DWK am 1.7.1977 nach Hannover verlegt.

Auf der Gutachterseite wurde in Hannover die *Arbeitsgemeinschaft Nukleares Entsorgungszentrum der TÜV* gebildet. In dem Maße, wie das unternehmerische Interesse der chemischen Industrie an der Wiederaufarbeitung nachließ und die Verantwortung der DWK für eine ordnungsgemäße Entsorgung der Kernkraftwerke stieg, mußte die DWK bemüht sein, das gesamte in Deutschland vorhandene industrielle Know-how für die Planungsarbeiten für das Entsorgungszentrum verfügbar zu machen oder zu erhalten. In Verhandlungen mit den Gesellschaftern von KEWA und GWK, den Firmen Bayer, Gelsenberg, Hoechst und Nukem, wurde deshalb vereinbart, daß die DWK mit Wirkung vom 1.9.1977 100% der Gesellschafteranteile der KEWA und 20% der GWK übernimmt, wobei gleichzeitig die 100prozentige Übernahme der GWK am 1.1.1979 festgelegt wurde. Mit dieser Reorganisation wird es der DWK auch möglich, über die URG zu einem direkten Erfahrungsaustausch mit den britischen und französischen Wiederaufarbeitern zu gelangen.

3. Das Konzept des deutschen Entsorgungszentrums

Die vorgesehene Entsorgung der Kernkraftwerke in der Bundesrepublik Deutschland basiert auf dem Entsorgungskonzept, das vom BMFT Ende der 60er Jahre initiiert und für das die KEWA bis 1974 eine Konzeptstudie erstellt hat. Dieses Konzept faßt alle erforderlichen Verfahrensschritte, die für die Behandlung der abgebrannten Brennelemente nach dem Abtransport aus den Kernkraftwerken erforderlich sind, an einem Standort zusammen: Hierzu gehören Annahme und Lagerung der abgebrannten Brennelemente, Wiederaufarbeitung, Rückführung des Plutoniums und des unverbrauchten noch leicht angereicherten Urans, Behandlung der radioaktiven Abfälle und deren Endlagerung (Fig. 2).

Die erste zu realisierende Anlage des Entsorgungszentrums ist das Brennelementlagerbecken, in welches die in bis zu 120t schweren Transportbehälter aus den Kraftwerken kommenden abgebrannten Brennelemente bis zu ihrer Wiederaufarbeitung

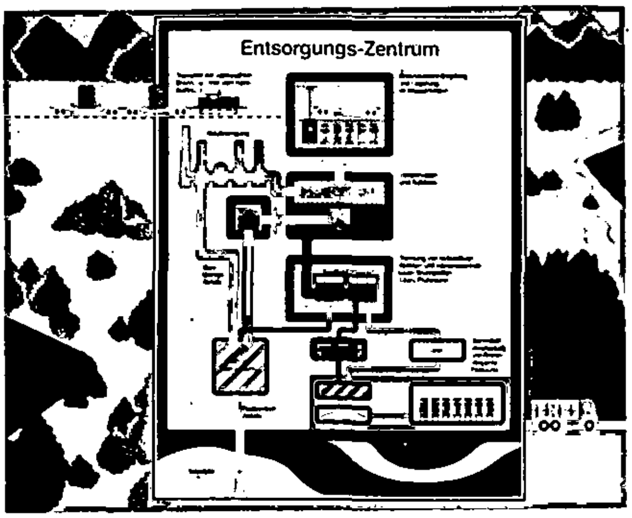

Fig. 2: Schema des Entsorgungszentrums
Fig. 2: Schema of the waste disposal centre

mated future waste disposal requirements of their nuclear power plants. The statutory objectives of the DWK include the planning, construction, acquisition and operation of facilities and the provision of services of all kinds required for disposing of nuclear power plant wastes, especially the storage and reprocessing of spent fuel assemblies. Excluded from the statutory objectives, however, are facilities for the definitive storage of radioactive wastes because, according to the Atomic Energy Act, such facilities fall within the scope of responsibilities of the Federal Government.

On 31.3.1977, thanks to the completed preliminary work, the DWK was able to file with the competent Ministry for Social Affairs of Lower Saxony an application for the licensing of the facilities of the Nuclear Waste Disposal Centre pursuant to Section 7 of the Atomic Energy Act, supported by a Safety Report comprising about 3000 pages. This application had to be based on a location named by the state Government of Lower Saxony. The choice of site was made after detailed study of all the salt domes in Lower Saxony, taking also into account the location criteria for nuclear engineering facilities laid down by the Federal Ministry for Internal Affairs. The site finally chosen is the salt dome located near Gorleben in the District Lüchow-Dannenberg (Fig. 1). The other possible sites on the short list of those originally considered were the salt mines Wahn in the District Aschendorf-Hümling, Lichtenhorst near Nienburg and Lutterloh near Celle. The suitability of the Gorleben site for the construction of the waste disposal centre will now be studied in greater detail in the course of the licensing procedure initiated by the DWK.

In parallel, the Federal Government has initiated in July 1977 a planning enquiry procedure and has commissioned the Physikalisch-Technische Bundesanstalt (National Standardizing Laboratory) in Braunschweig (PTB) to prepare a study on the suitability of the Gorleben salt mine as a definitive storage site for radioactive wastes. The competent licensing authority for this procedure is also the Ministry for Social Affairs of Lower Saxony.

In view of the fact that the proposed site is located in Lower Saxony and that the work connected with the licensing procedure is taking place mainly in Hannover, the DWK was transferred from Essen to Hannover on 1.7.1977.

The Authorized Inspection Agency, in turn, has formed a *Working Group of the TÜV for the Nuclear Waste Disposal Centre,* with seat also in Hannover.

In the measure in which the commercial interest of the chemical industry in nuclear fuel reprocessing flagged, and the responsibility of the DWK for an orderly disposal of nuclear power plant wastes increased, the DWK found itself obliged to obtain and to make available the entire industrial know-how existing in Germany and relevant for the planning work on the waste disposal centre. In pursuit of this aim it has been agreed in negotiations with the shareholders of KEWA and GWK (the companies Bayer, Gelsenberg, Hoechst and Nukem) that the DWK will acquire 100% of the shares in the KEWA and 20% of the shares in the GWK with effect as of 1.9.1977, and the remainder of the shares in the GWK with effect as of 1.1.1979. This reorganisation will also enable the GWK to enter via the URG into a direct exchange of know-how with the British and the French reprocessors.

3. Concept of the German Nuclear Waste Disposal Centre

The planned disposal of wastes from nuclear power plants in the Federal Republic of Germany is based on the waste disposal concept initiated by the BMFT in the late 1960s and for which the KEWA had prepared a concept study up to 1974. This concept concentrates on one site all the process steps required for eingelagert werden. Das Lagerbecken hat eine Kapazität von 3000 t und ist, unterteilt in mehrere Einzelbecken, in einem etwa 125 m langen, 75 m breiten und 40 m hohen Gebäude untergebracht. Um den strengen Sicherheitsvorschriften in der Bundesrepublik zu genügen, ist es mit Wandstärken von 140 bis 200 cm ausgestattet, die ausreichende Sicherheit auch im Fall von äußeren Einwirkungen wie Flugzeugabsturz und Erdbeben gewährleisten. Die Brennelemente werden unter Wasser gelagert, wobei die Kühlwasserkreisläufe eine maximale Beckentemperatur von 40 °C garantieren.

Die sich im Funktionsablauf des Entsorgungszentrums an die Lagerbecken anschließende Wiederaufarbeitungsanlage ist das eigentliche Herzstück des Entsorgungszentrums. Sie stellt die chemische Anlage dar, in welcher zunächst die abgebrannten Brennelemente zerkleinert und in siedender Salpetersäure aufgelöst werden. Dabei werden das noch unverbrauchte Uran, das beim Abbrand im Kernkraftwerk gebildete Plutonium und die radioaktiven Spaltprodukte voneinander getrennt. Hierfür wird das PUREX-Verfahren (Plutonium Uranium Recovery by Extraction) verwendet, das in den USA entwickelt wurde.

Für die Wiederaufarbeitungsanlage ist die Aufteilung in zwei oder mehr parallele Prozeßabläufe typisch, um bei den komplizierten chemischen Anlagen, bei denen für die Einzelaggregate die mittlere Verfügbarkeit nur bei etwa 50 % liegt, eine ausreichend hohe Gesamtverfügbarkeit zu erzielen.

Im Gebäude für den Eingangsteil (Headend) werden die Brennelemente in heißen Zellen fernbedient zerkleinert, wobei die Vorgänge im Gegensatz zur WAK weitgehend automatisiert sein werden.

Im Headend werden auch bei der Zerkleinerung der Brennelemente gasförmige radioaktive Spaltprodukte freigesetzt. Wie bei allen Gebäuden für kerntechnische Anlagen ist deshalb neben der Sicherheit gegen Einwirkungen von außen ein absolut gasdichter Abschluß des Gebäudes erforderlich. Alle Gase werden zentral über Gasrückhalteeinrichtungen, in denen insbesondere die Radionuklide J 129 durch geeignete Filter und Kr 85 durch Tieftemperatur-Rektifikationsverfahren zurückgehalten werden, bevor die unschädlichen und verdünnten Abgase über einen 200 m hohen Schornstein abgegeben werden.

Interessant ist eine kurze Analyse der Verhältnisse der tatsächlichen anfallenden Materialmengen: Bei einem Durchsatz von 1400 t/a ursprünglich in den Brennelementen eingesetztem Uran enthalten die abgebrannten Brennelemente immer noch rund 1350 t auf knapp 1 % U 235 angereichertes Uran. Daneben haben sich rund 14 t Plutonium gebildet, und nur 30 bis 40 t – je nach Vorgeschichte und Abbrand der Brennelemente – sind der eigentliche Atommüll, ein Gemisch aus rund 300 verschiedenen überwiegend radioaktiven Isotopen. Wenngleich dieser Menge wegen ihrer Radioaktivität im Rahmen der Entsorgung besondere Aufmerksamkeit geschenkt wird, so wird doch hinsichtlich ihrer geringen Menge im Vergleich zu den Abfallmengen konventioneller Kraftwerke wieder deutlich, daß die Energieausbeute im Bereich der Kernenergie, auf ein einzelnes Atom bezogen, um einen Faktor von rund 10^6 größer ist als bei der Ausnutzung fossiler Energien. Schließlich darf nicht vergessen werden, daß der volle Durchsatz des geplanten Entsorgungszentrums einer installierten Kernkraftwerksleistung von rund 45 000 MW entsprechend einer erzeugten Arbeit von rd. 300 Milliarden kWh entspricht.

Nach der Aufarbeitung der Brennelemente liegen also die drei Teilströme Uran, Plutonium und Spaltprodukte getrennt vor. Uran und Plutonium werden nach Mischung bzw. erneuter Anreicherung und nach Verarbeitung zu Brennstoffpellets in Form von Brennelementen wieder in den Kraftwerken eingesetzt. Alle hiermit zusammenhängenden Fabrikationsvorgänge werden im Rahmen des integrierten Entsorgungskonzeptes auf dem

dealing with spent fuel assemblies after they are shipped away from the nuclear power plants. This includes acceptance and storage of the spent fuel assemblies, reprocessing, recovery of the plutonium and of the unused, still slightly enriched uranium, conditioning of the radioactive wastes, and their storage (Fig. 2). The first priority in the implementation of the waste disposal centre is the construction of the fuel assembly storage pool in which the spent fuel assemblies, arriving from the nuclear power stations in transport flasks weighing up to 120 t, will be unloaded and stored until they can be processed. The storage pool is designed with a capacity for 3000 t of spent fuel assemblies. It is subdivided into several individual basins and is accommodated in a building about 125 m long, 75 m wide and 40 m high. In compliance with the stringent safety specifications applicable in the Federal Republic of Germany, this building has walls 140 to 200 cm thick and is capable of safely withstanding external events such as an aircraft crash and earthquake. The fuel assemblies will be stored under water, and adequate cooling circuits will be provided to ensure that the temperature of the pool water does not exceed 40 °C.

The functionally next component of the waste disposal centre is the reprocessing and separation plant which is the main component of the entire centre. This is a chemical plant in which, as a first step, the spent fuel assemblies are comminuted (chopped up) mechanically and the spent fuel is dissolved in boiling nitric acid. In the subsequent steps the unused uranium, the plutonium formed in the course of the burnup in the nuclear power plants, and the radioactive fission products are separated from each other. The process used for this separation is the PUREX process (Plutonium Uranium Recovery by Extraction) which was developed in the USA.

The average availability of the individual aggregates of the complex chemical equipment required is of the order of only about 50 %. It is therefore typical of reprocessing plants that the operation is split into two or more parallel process lines in order to ensure a sufficiently high overall availability.

In the head end building the fuel assemblies coming from the storage pool are comminuted under remote control in hot cells. Unlike the procedure at the WAK plant, it is intended to largely automate this step of the process.

The comminution of the fuel assemblies in the head end building is accompanied by a release of gaseous radioactive fission products. The head end building, as all buildings for nuklear engineering facilities, must therefore be provided with an absolutely gastight enclosure adequately secured against damage by external occurrences. All the gases are exhausted and are processed centrally in a gaseous waste processing plant in which, in particular, the radionuclides I 129 and Kr 85 are retained, the first by means of appropriate filters and the second by low temperature rectification. The residual harmless and strongly diluted gases are finally released into the atmosphere via a 200 m high stag.

It is interesting briefly to consider the quantitative ratios of the amounts of materials passing through such a reprocessing plant, assuming a throughput of 1400 t/a referred to the uranium originally contained in the fuel assemblies in the new condition. The spent fuel assemblies still contain about 1350 t of uranium, enriched to about 1 % U 235, and about 14 t of newly formed plutonium. The actual atomic waste, a mixture of some 300 different nuclides most of which are radioactive, amounts to only about 30 to 40 t, depending on the history and on the burnup of the fuel assemblies. Owing to its radioactivity this waste represents a major problem in waste disposal, but it should nevertheless be noted that the quantities involved are extremely small compared to the quantities of waste generated by coal-fired power plants. This illustrates the fact that, on an

Standort des Entsorgungszentrums durchgeführt. Es ergeben sich somit keine Plutoniumtransporte. Für alle, die einen Mißbrauch der von der Kernenergie gebotenen Möglichkeiten zu Terror- und Erpressungsakten befürchten, ist dies sicherlich ein beruhigender Tatbestand.

Am Beispiel der Weiterverarbeitung des Urans und des Plutoniums wird die Vielfältigkeit der Aufgaben eines Entsorgungszentrums besonders deutlich. Der Plan, daß das Plutonium den Standort nur in der Durchmischung mit Uran 235 in Form fertiger Brennelemente für Leichtwasserreaktoren verläßt, bedingt die Errichtung und den Betrieb einer vollständigen Produktionsstätte für plutoniumhaltige Brennelemente. Das Vorbild hierfür ist die Brennelementfabrik der ALKEM in Wolfgang. Es gilt deshalb das Prinzip, daß die fachkundigen Firmen unter geeigneten finanziellen und unternehmerischen Bedingungen sowohl in der Planungsphase als auch an der Errichtungs- und Betriebsphase verantwortlich mitwirken. Durch eine umfassende Arbeitsgemeinschaft aller Beteiligten wird dabei eine unkoordinierte Planung verhindert.

Ähnliches gilt auch für den Bereich der Abfallendbehandlung. Alle flüssigen und festen radioaktiven Abfälle, die in den verschiedenen Betrieben des Entsorgungszentrums, vor allem aber in der eigentlichen Wiederaufarbeitungsanlage, anfallen, werden in eine für ihre Endlagerung geeignete Form gebracht. Dabei werden die leicht- und mittelaktiven Abfälle entsprechend dem in der Asse erprobten Verfahren in 200-l- oder 400-l-Fässer eingebracht und in Bitumen oder PVC, je nachdem, ob die Abfälle in wäßriger oder organischer Lösung vorliegen, verfestigt. Die Gesamtmenge der mittelaktiven Abfälle von ca. 1600 m^3/a führt zu rund 6000 Fässern pro Jahr, die der leichtradioaktiven Abfälle zu rund 50 000 Fässern pro Jahr. Diese Mengen können, wie der Betrieb der Asse zeigt, ohne Schwierigkeiten gehandhabt werden.

Die hochaktiven Abfälle fallen zum einen in fester Form im Bereich der Zerlegung und Auflösung der Brennelemente an und umfassen die Bauteile der Brennelemente und die in Stücke zerschnittenen Brennstabhülsen. Sie werden in Zement eingelagert und in Container mit einem Volumen von 2 m^3 für die Endlagerung vorbereitet. Zum anderen fallen bei der Wiederaufarbeitung jährlich rund 600 m^3 an flüssigen hochaktiven Abfällen an. Diese werden zunächst für rund 5 Jahre in gesicherten und zwangsgekühlten Behältern gelagert, bevor sie durch Kalzinierung vom Wasser befreit und in Oxide umgewandelt und durch Hinzufügung von Glasbildnern in eine homogene Glasschmelze überführt werden.

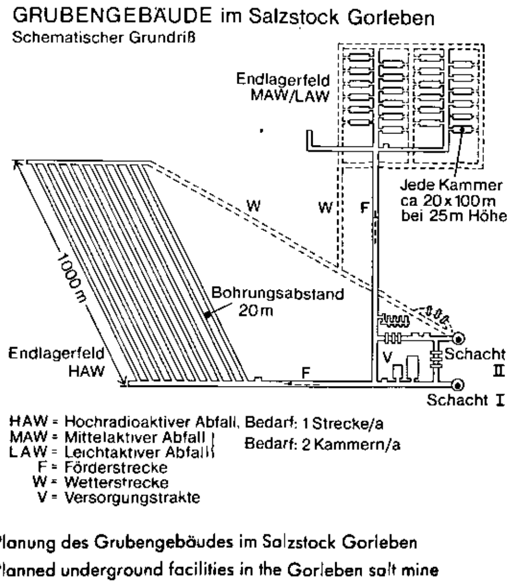

Fig. 3: Planung des Grubengebäudes im Salzstock Gorleben
Fig. 3: Planned underground facilities in the Gorleben salt mine

atom for atom basis, the amount of energy released by nuclear fission is greater than that released by burning fossil fuels by a factor of the order of 10^6. It should also be remembered that the full capacity of the planned waste disposal centre is sufficient to serve an aggregate installed nuclear power plant capacity of about 45 000 MW, corresponding to a power generation of about 300 millard kWh.

The separation process yields uranium, plutonium and fission products in three separate material flows. The uranuim is re-enriched by addition of fresh uranium with an appropriately high enrichment level, and is then mixed with the plutonium. This mixture is processed to fuel pellets. The pellets are used to make new fuel assemblies ready for use in nuclear power plants. An important feature of the integrated waste disposal concept is that all the processing and fabrication steps required for this purpose take place on the primises of the waste disposal centre. All transport of plutonium is thus avoided entirely. This should allay the fears of those who are apprehensive that nuclear technology might be misused for purposes of terrorism and blackmail.

This example of complete reprocessing of uranium and plutonium illustrates particularly clearly the multiplicity of the functions of the planned waste disposal centre. The intention that the plutonium which is produced should leave the centre only after mixing with uranium, and then only in the form of ready-for-use fuel assemblies for light water reactors, imposes the construction and operation on the premises of the centre of a complete production plant for plutonium-containing fuel assemblies. A suitable prototype is the fuel assembly fabrication plant of ALKEM in Wolfgang. This illustrates the principle that all specialist firms in the several relevant fields should participate in the planning, construction and operation of the waste disposal centre. This will require the formulation and negotiation of appropriate financial and commercial conditions and the formation of a broadly based working group including all the participants in order to avoid uncoordinated planning.

Similar considerations apply to the processing and disposal of the radioactive wastes. All the liquid and solid radioactive wastes generated in various parts of the waste disposal centre, particularly in the actual reprocessing and separation plant, will be converted into a form suitable for definitive storage. The low active wastes (LAW) and the medium active wastes (MAW) will be filled into 200-litre or 400-litre drums and consolidated with bitumen or with PVC, depending on whether they are in an aqueous or an organic solution. This method has been successfully tried out at Asse. The total quantity of MAW of about 1600 m^3/a will result in about 6000 drums per year, in addition to about 50 000 LAW drums per year. The operations at Asse show that these quantities can be handled without difficulty.

The high active wastes (HAW) will be generated in solid and in liquid form. The solid HAW originate at the head end of the process and include the structural components of the fuel assemblies and the fuel cladding tubes cut into short pieces. These solid HAW will be embedded in concrete in containers with a capacity of 2 m^3, and will be conveyed to definitive storage in this form. The liquid HAW originate in the course of reprocessing and separation and will amount to about 600 m^3 per year. These liquid HAW will first be stored for about 5 years in appropriately secured tanks with forced cooling. They will then be dehydrated by calcination, the residues will be converted to oxides and finally vitrified with addition of appropriate vitrifying agents.

At the full planned operating capacity, the waste disposal centre will produce daily 4 or 5 such vitrified blocks enclosed hermetically in metal containers with a capacity of 70 litres each. These blocks will first be stored for the necessary period of time in

Bei voller Leistung des Entsorgungszentrums entstehen täglich 4 bis 5 solche metallumschlossene Glasblöcke mit einem Volumen von je 70 l, die nach weiterer Zwischenlagerung in luftgekühlten Tieflagern schließlich in das Endlager im Salzstock eingebracht werden. Entsprechende Vorversuche mit elektrisch beheizten Probekörpern sind in der Asse bereits angelaufen. Die dabei und bei der Endlagerung der schwach- und mittelaktiven Abfälle in der Asse gewonnenen Erfahrungen werden bei der Anlage des Grubengebäudes im Salzstock Gorleben voll berücksichtigt (Fig. 3).

4. Terminliche Abstimmung

Durch die funktionelle Verknüpfung der einzelnen Anlagenbereiche des Entsorgungszentrums ergibt sich eine zeitliche Folge für deren Errichtung, die in einem Rahmenplan (Fig. 4) dargelegt ist. Die als erstes benötigten Lagerbecken werden bei realistischer Einschätzung der Dauer des Genehmigungsverfahrens und eventuell nachfolgender Verwaltungsgerichtsverfahren kaum vor 1985/86 zur Verfügung stehen. Dann folgt die Wiederaufarbeitungsanlage, deren Inbetriebnahme für 1989/90 geplant ist; an diesem Termin orientiert sich auch die Inbetriebnahme der Uran- und Plutoniumweiterverarbeitung.

Schließlich muß die Errichtung des Grubengebäudes im Salzstock so erfolgen, daß die Aufnahme der schwach- und mittelaktiven Abfälle spätestens kurz nach Inbetriebnahme der Wiederaufarbeitungsanlage und die Aufnahme der hochaktiven Abfälle etwa 5 bis 7 Jahre später, also in den Jahren 1994/95, erfolgen kann.

An diesen wenigen Terminbeispielen wird deutlich, daß es sich bei dem Entsorgungszentrum für die deutschen Kernkraftwerke wohl um das derzeit langfristigste Industrieprojekt in der Bundesrepublik handelt. Es ist deshalb natürlich, daß es für viele

air-cooled underground interim storage facilities, and will finally be conveyed to final storage in the salt dome. Preliminary experiments in this connection are already in progress at Asse, using electrically heated dummy blocks. The experience gained in these experiments and in the storage of LAW and MAW at Asse will be fully taken into account in planning the definitive storage facilities in the Gorleben salt (Fig. 3).

4. Coordination of time schedules

The functional schema of the individual facilities of the nuclear waste disposal centre results in a sequence for their implementation, illustrated in the overall time schedule shown in Fig. 4. The first facility required is the storage pool for the incoming spent fuel assemblies. Taking a realistic view of the delays involved in the licensing procedure and in the possible subsequent court proceedings, it is unlikely that the storage pool will be ready much before 1985/86. Then will follow the reprocessing and separation plant and all the facilities for the further processing of the recovered uranium and plutonium, the commissioning of which is planned for 1989/90. The definitive storage facilities in the salt mine must be ready to accept the LAW and MAW shortly after the commissioning of the reprocessing and seperation plant in 1989/90 at the latest, and they must be ready to accept the HAW about 5 to 7 years later, i.e., in 1994/95.

These few time schedule data illustrate the fact that the construction of the waste disposal centre for the German nuclear power plants is undoubtedly the most long-term industrial project in Germany at present. It is only to be expected therefore that continuing research and development work on various aspects of this project will result in improvements of the concept and/or

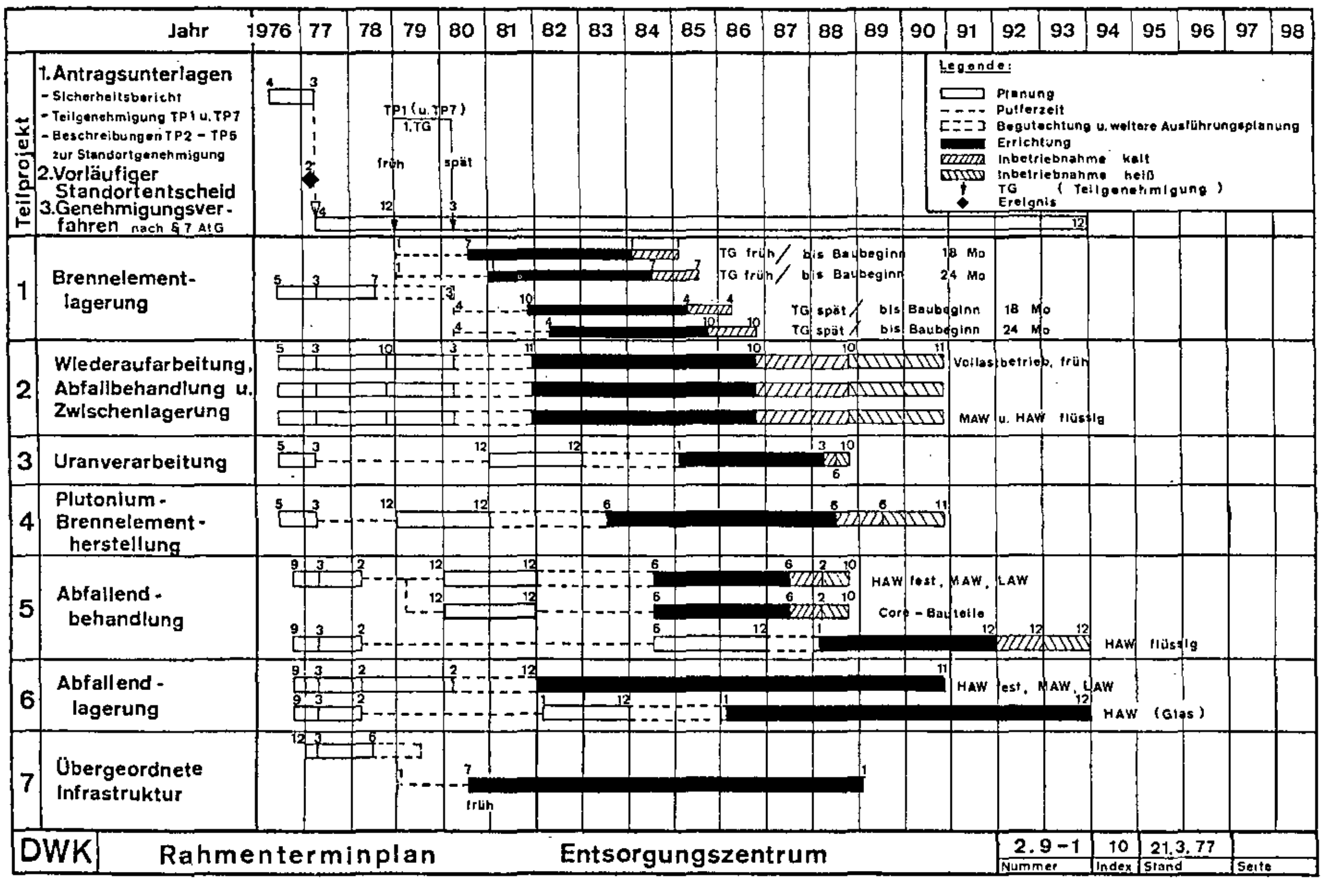

Fig. 4: Rahmenterminplan für das Entsorgungszentrum

Fig. 4: Overall time schedule for the waste disposal centre

Teilbereiche des Zentrums projektbegleitende Forschungsvorhaben geben wird, die zu Änderungen oder Verbesserungen am Konzept oder an den Anlagen führen werden. Hierbei ist die Mitarbeit der deutschen Kernforschungszentren, vor allem des KfK, hervorzuheben, obwohl auch der Informationsfluß aus den anderen europäischen Wiederaufarbeitungsanlagen sehr zur Vervollkommnung unseres Entsorgungszentrums beiträgt.
Es ist allerdings wichtig, in diesem Zusammenhang festzustellen, daß die Realisierung des Entsorgungszentrums im Grunde auch schon heute möglich wäre, da jeder einzelne der dort zusammengefaßten Verfahrensschritte bereits für sich erprobt wurde. Lediglich ihre Verbindung im Rahmen des integrierten Konzeptes könnte hier neue Verhältnisse schaffen, die hingegen keine ernsten Schwierigkeiten erwarten lassen.

5. Kosten und Finanzierung

Eine neuere, sicherlich ebenfalls noch vorläufige Kostenschätzung für das gesamte Entsorgungszentrum wurde von der DWK im vergangenen Jahr unter Einbeziehung der Angaben von beteiligten Firmen vorgenommen und führte nach heutigem Preisniveau zu einem Investitionsvolumen von über 4 Mrd. DM. Unter Berücksichtigung der Bauzinsen, Steuern, Versicherungskosten und der zu erwartenden Preiseskalation wird der gesamte Investitionsaufwand auf mindestens 10 Mrd. DM errechnet.
Diese Summen schließen nicht den Erwerb des Standortgrundstückes und die Ausrichtung des Salzstockes ein, wofür weitere 1,5 Mrd. DM anzusetzen sein dürften. Diese Beträge sind von der Bundesregierung im Rahmen der von ihr mit der 4. Atomgesetznovelle übernommenen Verantwortung für Errichtung und Betrieb von Anlagen zur Sicherstellung und zur Endlagerung radioaktiver Abfälle aufzubringen; sie werden dann aber voraussichtlich im Rahmen einer Gebührenordnung von der DWK zurückgenommen werden.

6. Zwischenlösungen

Seit einiger Zeit steht fest, daß es sowohl aufgrund der geringen Wiederaufarbeitungskapazität im Ausland als auch wegen der Verlängerung des Genehmigungsverfahrens und der Bauphase für das Brennelementlagerbecken ab etwa 1982 zunehmend zu Schwierigkeiten bezüglich des Abtransportes abgebrannter Brennelemente aus den heute in Betrieb befindlichen Kernkraftwerken kommen wird. Dabei ist schon vorausgesetzt, daß die Endlademengen der Jahre 1977 bis 1979 aufgrund von Verträgen mit der französischen Aufarbeitungsfirma COGEMA ordnungsgemäß von der Anlage in Cap de la Hague abgenommen und dort aufgearbeitet werden. Durch nachträglichen Einbau von Kompaktlagerstellen in die kraftwerksinternen Lagerbecken läßt sich zwar die Lagerkapazität erhöhen und damit der Anschluß an die Fertigstellung des Lagerbeckens für das Entsorgungszentrum erreichen, jedoch ist auch hierbei mit genehmigungstechnischen Schwierigkeiten zu rechnen.
Die DWK wurde deshalb von ihren Gesellschaftern beauftragt, geeignete Zwischenlösungen zu untersuchen. Sie hat zu diesem Zweck Verhandlungen mit Frankreich und Großbritannien über den Ankauf von Wiederaufarbeitungs-Dienstleistungen für abgebrannte Brennelemente für die Jahre 1980 bis 1985 geführt. Als die einzige eigene realisierbare Zwischenlösung müssen wir heute die Errichtung von großen Zwischenlagerbecken ansehen, die ähnlich wie das zuvor erwähnte Eingangslagerbecken des Entsorgungszentrums aufgebaut sein werden. Es wurden mehrere für solche Zwischenlagerbecken geeignete Standorte in der Bundesrepublik untersucht. Im Rahmen einer Konferenz der Ministerpräsidenten der Länder wurde dann festgelegt, daß zunächst ein Genehmigungsverfahren für einen Standort in Nordrhein-Westfalen, später auch für einen in Bayern und Hessen eingeleitet werden soll.

of the equipment. Particular importance attaches in this connection to the cooperation of the German nuclear research centres, particularly of the KfK, although the flow of information from the other European reprocessing plants should also make a substantial contribution.

Having mentioned the ongoing research and development work, it is important to stress that the realisation of the waste disposal centre would in principle be already possible today, because each individual process step involved has already been tried out. New problems could arise only in the linking together of these individual steps within the framework of the integrated concept, but these are not expected to cause serious difficulties.

5. Costs and financing

A new cost estimate for the complete waste disposal centre has recently been prepared by the DWK, taking into account partial cost estimates by the participating companies. This provisional cost estimate, based on current prices, amounts to over 4 billion DM. Taking into account the interest charges during construction, taxes, insurance costs and the expected general price inflation, the total capital cost of the project is unlikely to be less than 10 billion DM.

This cost estimate does not include the cost of acquisition of the site and the cost of the necessary development work in the salt dome. These costs are estimated at a further 1.5 billion DM. Pursuant to the provisions of the 4th Addendum to the Atomic Energy Act, which places the responsibility for the construction and operation of facilities for the securing and definitive storage of radioactive wastes on the Federal Government, these costs will be met by the Federal Government, but they will probably be recovered from the DWK later in the form of user's fees.

6. Interim solutions

It has been obvious for some time that, owing to the limited reprocessing capacities in other countries and to the delays in the licensing procedure and thus in the construction of the storage pool for spent fuel assemblies at the planned German nuclear waste disposal centre, difficulties will arise starting in about 1982 in connection with the removal of spent fuel assemblies from the nuclear power stations operating at present. These difficulties will arise despite the fact that, pursuant to contracts entered into with the French reprocessing company COGEMA, the spent fuel assemblies discharged in years 1977 to 1979 will be accepted on schedule for reprocessing at the Cap de la Hague plant.

One possibility of bridging the gap until the storage pool at the waste disposal centre is ready would be to increase the capacity of the fuel storage pools at the existing nuclear power plants by equipping these pools with compact storage compartments, but this solution is likely to run into licensing difficulties.

The DWK has therefore been instructed by its shareholders to study appropriate interim solutions of the spent fuel storage problem. The DWK has therefore been conducting negotiations with the French and the British reprocessors for the purchase of reprocessing services for spent fuel assemblies for the years 1980 to 1985. The only possible interim solution within Germany would be the construction of large interim storage pools similar to the incoming storage pool at the waste disposal centre. Several prospective sites for such interim storage pools within Germany have already been investigated. At a recent conference of the Prime Ministers of the Federated States it has been decided that an application for a licence should be filed first for a site in North Rhineland/Westphalia, and later also for a site in Bavaria and for a site in Hessen.

7. Öffentlichkeitsarbeit

Eine der sehr wichtigen Aufgaben im Zuge der Abwicklung des Projektes ist die Öffentlichkeitsarbeit, vor allem am geplanten Standort. Hier ergab sich die Situation, daß Proteste und Opposition in die Bevölkerung hineingetragen wurden, bevor diese umfassend über das Projekt informiert war.

Seit der Benennung des Standortes Gorleben durch die Niedersächsische Landesregierung ist die DWK ständig am Standort vertreten. Zur ausführlichen sachbezogenen Unterrichtung, insbesondere der zuständigen Behörden, ist jetzt von der DWK auch der Bericht über das in der Bundesrepublik geplante Entsorgungszentrum herausgegeben worden, der als Kurzfassung den Inhalt des umfassenden Sicherheitsberichtes wiedergibt.

Außerdem ist der Bau eines Informationszentrums in Gorleben vorgesehen, um auch hierdurch einen ständigen informativen Dialog mit der Bevölkerung zu gewährleisten.

(Eingegangen am 18.1.1978)

7. Public relations

One of the very important tasks in the course of development of the project lies in the field of public relations, especially at the proposed site of the project. The general public, and particularly the local population, have been exposed to vehement protest activity before they were given any factual information on the project. Since the site at Gorleben was named by the State Government of Lower Saxony, the DWK has maintained a permanent representation at the site. In order to provide to all interested parties, and especially to the local authorities, detailed factual information on the planned nuclear waste disposal centre, the DWK has recently issued a report on this project, which presents in an abridged form the contents of the comprehensive Safety Report.

It is also intended to build in Gorleben a fully equipped information centre for maintaining a continous flow of information to the public.