第16回原産年次大会 英語論文

1983年 3月

社団法人 日本原子力産業会議

第16回原産年次大会プログラム

基調テーマ：原子力産業—成熟化への課題と展望

〈総括プログラム〉

	第　1　日	第　2　日	第　3　日
	3月23日（水）	3月24日（木）	3月25日（金）
午前	**開会セッション** （9：30～10：40） 大会準備委員長挨拶 原産会長所信表明 原子力委員長所感	**セッション2** （9：00～12：00） **「高速増殖炉の開発戦略」** 〔パネル討論〕	**セッション4** （9：30～12：30） **「原子力安全の方向と目標」** 〔パネル討論〕
午後	**セッション1** （前半10：45～12：20） （後半14：00～17：00） **「エネルギー政策と原子力開発の進路」** 〔講　演〕	**午餐会** （12：20～14：15） 通商産業大臣所感 〔特別講演〕於ホテル・オークラ - - - - - **原子力関係映画上映** （13：00～14：10） 於　ニッショー・ホール - - - - - **セッション3** （14：30～18：00） **「新しい国際秩序の確立へ向けて」** 〔パネル討論〕	**セッション5** （14：00～17：00） **「軽水炉成熟時代の原子力産業」** 〔パネル討論〕
	レセプション （18：00～19：30） 於　ホテル・オークラ		

3月23日（水）

開会セッション（9：30〜10：40）

	議　長	圓城寺　次　郎	日本経済新聞社顧問 日本原子力産業会議副会長
9：30	大会準備委員長挨拶	大　来　佐武郎	国際大学学長
9：50	原産会長所信表明	有　澤　廣　巳	日本原子力産業会議会長
10：20	原子力委員長所感	安　田　隆　明	原子力委員会委員長，科学技術庁長官

セッション1　エネルギー政策と原子力開発の進路（10：45〜17：00）

	議　長	四ツ柳　高　茂	北海道電力(株)社長
10：45	「エネルギーと国際協調」		
		L．ブリンクホースト	駐日ＥＣ委員会代表
11：30	「フランスにおける電力・原子力開発戦略」		
		J．ギアモン	フランス電力庁総裁
	〈休憩　12：20〜14：00〉		
	議　長	末　永　聰一郎	三菱重工業(株)社長
14：00	「インドの原子力開発—再処理・廃棄物管理を中心に」		
		H．セ　ト　ナ	インド原子力委員会委員長
14：45	「日本の原子力開発と国際協力—より積極的な方向を」		
		向　坊　　隆	原子力委員会委員長代理
	議　長	両　角　良　彦	電源開発(株)総裁
15：30	「アメリカの原子力発電開発計画」		
		S．ブリューワー	アメリカエネルギー省原子力担当次官補
16：15	「中国のエネルギー政策と原子力開発利用」		
		周　　　秩	中国原子力工業省顧問

レセプション（18：00〜19：30）

ホテル・オークラ別館Ｂ２　曙の間

3月24日（木）

セッション2　高速増殖炉の開発戦略（9：00～12：00）

議長　大島恵一　東京大学名誉教授

〔パネル討論〕

F．カラー	アメリカ電力研究所理事長
瀬川正男	動力炉・核燃料開発事業団理事長
堀一郎	東京電力（株）副社長
W．マーシャル	イギリス中央電力庁総裁
M．ラパン	フランス原子力庁産業技術開発研究所（IRDI）理事長
G．レーア	西ドイツ研究技術省エネルギー研究技術局長

午餐会（12：20～14：15）

〈ホテルオークラ本館1F　平安の間〉

通商産業大臣所感

〔特別講演〕

当面の内外金融経済情勢について　前川春雄日本銀行総裁

原子力映画上映（13：00～14：10）

〈ニッショーホール〉

1「もんじゅへの道」（動力炉・核燃料開発事業団製作，日本語27分）
2「明日への町づくり－地域振興と原子力発電所－」
（日本立地センター製作，日本語24分）

セッション3　新しい国際秩序の確立へ向けて（14：30～18：00）

議長　松井明　日本原子力文化振興財団理事長
日本原子力産業会議副会長

〔パネル討論〕

D．ガザリ	マレーシア原子力研究所長
金善昶	韓国電力公社副社長
H．セトナ	インド原子力委員会委員長
B．セミョーノフ	国際原子力機関事務局次長
新関欽哉	原子力委員会委員
I．バドラン	エジプト科学研究技術アカデミー総裁
P．フェルテン	フランス原子力庁国際局日本担当
A．フリードマン	アメリカ国務省核不拡散問題担当無任所大使特別顧問
G．レーア	西ドイツ研究技術省エネルギー研究技術局長

3月25日（金）

セッション4　原子力安全の方向と目標（9：30～12：30）

議長	内田秀雄	原子力安全委員会委員
〔パネル討論〕		
	H．デントン	アメリカ原子力規制委員会原子炉規制局長
	A．ビルクホーファー	西ドイツ原子炉安全協会理事長
	村主　進	原子力工学試験センター理事・原子力安全解析所所長
	中村政雄	読売新聞社解説部次長

セッション5　軽水炉成熟時代の原子力産業（14：00～17：00）

議長	向坂正男	国際エネルギー政策フォーラム議長
〔パネル討論〕		
	L．アブダラム	フラマトム社事業本部長
	R．ケイロン	ベルゴニュークリア社会長
	西　政隆	日本電機工業会原子力対策委員長，(株)日立製作所常務取締役
	浜口俊一	関西電力(株)専務取締役
	林　政義	中部電力(株)副社長
	T．プライス	ウラン協会事務局長
	W．ブラウン	西ドイツクラフトベルクウニオン社副社長
	松田　泰	通産省資源エネルギー庁長官官房審議官
	D．ライアンズ	アメリカ原子力産業会議副会長，コンバッション・エンジニアリング社副社長

Chairman Arisawa's Keynote Address

16th JAIF Annual Conference

Nissho Hall

March 23 (Wed.), 1983

Let me state my opinion at the opening of the 16th annual conference of the Japan Atomic Industrial Forum.

This conference follows the one of last year in which I appealed for elimination of nuclear weapons in my capacity as a person promoting peaceful uses of atomic energy. Following a resolution adopted at the JAIF conference, a message calling for nuclear disarmament was sent to the United Nations special session on disarmament in June, 1982. Since then, nuclear disarmament has passed into a wide-ranging world public opinion. Recently, prominent Americans called for a substantial U.S.-Soviet nuclear weapons reduction in a proposal which attracted attention as it suggested, like our message, that nuclear weapons be dismantled and diverted to provide fuel for peaceful uses.

The Nuclear Non-Proliferation Treaty, while giving nuclear-weapons states guarantee of peaceful uses under appropriate safeguards, obligates them to use their endeavors toward nuclear weapons reduction. If only to maintain the international order of peaceful uses of atomic energy, we hope that the efforts toward the reduction and elimination of nuclear weapons will materialize.

Ten years have passed since the first oil shock of 1973 made things hard on the world economy, and now the price-cutting policy of oil-producing countries is bringing a new phase in it. The two oil shocks discouraged countries from making economic growth and caused a structural recession to overtake them simultanesouly. Japan was compelled to go through a period of slow growth which is expected to continue for some time to come.

The sharp rise in crude oil prices that followed the oil shocks set countries vying in achieving the reality of energy conservation and developing alternative energy sources. These efforts are now beginning to produce an effect. A reduction in crude oil prices coinciding with that seems to have a favorable effect, despite the difficulty in getting it felt, on the generality of world economic activities.

The role of nuclear power is gaining importance year after year as an economical alternative energy source or as a semi-domestic production of energy sources. We have energetically promoted nuclear power generation regarding it as the most important step for Japan to take toward a drift away from oil. Last year, the Itaka-2 of Shikoku Electric Power Co. and the Fukushima II-1 of Tokyo Electric Power Co.

started up, bringing Japan's installed capacity of nuclear power generation to more than 17 million KW. This could produce nuclear electric energy to the amount of 103,700 million kilowatt-hours, or 20.3% of the nation's total generated energy.

Failures and troubles had prevented the nuclear power plants from operating at more than 50% capacity until the capacity factor began to rise a few years ago and registered 70.2% last year. Considering the 90 days or so out of each year required for periodical inspection in Japan, this could be regarded practically as a 95% capacity operation. I think it can safely be said that light water reactor generation has come to take root.

This high capacity factor is a figure in which we can take pride around the world. This is an indication of the efforts we have made in a bid for a higher availability factor to promote the prevention of troubles and other countermeasures. In a way, it is a reflection of the level of techniques, such as for quality assurance, that has been attained by the Japanese nuclear industry which stands in the forefront of the world.

The Japan Atomic Industrial Forum found out in a fact-finding survey ~~conducted~~ concluded in December, ~~1982~~ 1982, that mining and manufacturing gross sales relating to nuclear power during fiscal 1981 rose to the ¥1,000 billion (about

$4,100 million) mark. I think this indicates that some 300 nuclear-related enterprises in Japan are attaining economic, as well as technical, maturity.

Now that we are at a period of slow economic growth, nuclear power generation is expected to play a greater role in lowering the cost of energy, as well as providing for energy security. The Ministry of International Trade and Industry, in a comparison of generating costs by power sources made in October, 1982, gave nuclear power about ¥12 per kilowatt-hour, nearly 60% of the equivalent of about ¥20 for oil-fired thermal power. Nuclear power is now the lowest-cost power source.

But we cannot entirely rely on nuclear power ~~just because~~ on grounds that it is cheap. ~~When the fuel cost is seen as a percentage of the generating cost of nuclear power, the exact reverse of oil-fired thermal power is the case with nuclear power as it shows about 20% as opposed to about 80%.~~ When seen in terms of the fuel cost as a percentage of the generating cost, nuclear power shows about 20% as opposed to about 80% for oil-fired thermal power, but in terms of fixed charges, the exact reverse is the case. A tangible rise in the cost of construction, which accounts for nearly 70% of the fixed charges on nuclear power generation, has in the past few years been an imposing strain on the cost merit that puts it at an advantage. The recent reduction in crude oil prices, while not ~~going far enough a~~ yet going so far as to reverse the economic ~~advantage~~ superiority of nuclear power, is a factor in recuding the cost difference that separates it from oil-fired thermal power.

Under the present conditions of slow economic growth, any sector of industry has to be very particular about cost accounting. No one can be so optimistic as to think that he could shift a rising cost over to a rising price. This must be brought ~~home to an~~ home, in particular, to any one supplying the wide-ranging industrial and individual requirements for energy.

The nuclear power generating cost in Japan is believed to be higher than in some other countries. The nuclear industry is called on to be as particular as other industries about cost accounting so that cost-cut efforts will be redoubled. The way things are going now, it might become impossible for nuclear power generation, in the years ahead, to play a vigorous role as may be expected from it as a motivation for lower energy costs and as a guide for economic revitalization. What is very important in this connection is to make sure that our remarkable achievements in the safety and dependability of light water reactors ~~ass~~ set the condition for further efforts to promote the standardization of machinery and the planning of plant construction, so that more economic improvements will be introduced and more technological sophistication assured for light water reactors. I believe all these efforts should be aimed at a cost cut of about 20%. These efforts must be continued if we are to put superannuated thermal power generating equipment out of order and convert it in gradual steps to nuclear power generation in ways that assure its expansion and continuation.

Uses of energy for industrial purposes are changing in recent years. Under circumstances of the transition in the main body of the industrial structure from energy-intensive heavy chemicals and basic materials to fine mechanics, it is impossible for some time to expect the elastic modulus of energy for industrial use to be in excess of one. Therefore, I would suggest that power charges be lowered for home life so that demand for home use will increase to expand electricity as a percentage of energy. This will also serve to improve the public welfare. After all, the time is ripe when the demand-and-supply situation for energy should be reexamined.

I believe the majority of people today recognize the necessity for nuclear power generation. I also believe that more and more people are coming to understand that it is an economical power ~~supplies~~ supply source. But the fact remains that quite a few have misgivings about ~~safety~~ the safety. The judgment that the general public pass on nuclear safety is, as often as not, inclined to be subjective and psychological. To the question "how safe is safe enough," the U.S. Nuclear Regulatory Commission has responded, in an attempt to measure it against an objective "yardstick," by deciding to introduce a "safety goal" concept on trial. This "yardstick" is expected to become instrumental in giving objective expression to a high level of nuclear safety and in revealing essential points for greater safety. But the state of affairs is different in Japan where no consensus is established on the risk benefit theory of industrialized society. Some Japanese doubt that this concept, if introduced into this country, would be accepted as a reasonable safety evaluation procedure. But I would think that now that we have built up a stock of data from our experience of operation, the time is ripe when we should consider the possibility of such a concept being introduced into this country.

The Atomic Energy Commission in June, 1982, revised its Long-Term Atomic Energy Development and Utilization Program formulated four years ago. In the revised edition of the program, the AEC calls for government-industry cooperation in promoting systematic commercialization of the technologies that this country, on the initiative of the government, has developed independently and brought to the point where they are "about to be used practically" for the development of a new power reactor, uranium enrichment and spent fuel reprocessing. The private sector is called on to contribute, as far as possible, toward practical application of these independent technologies so that energy security will be established. But since the private sector is called on to cover as much as ¥1,600 billion of a total of ¥5,400 billion estimated to finance research and development over a period of ten years, there still is a big technical and economic risk involved in the effort toward commercialization.

If we are to make steady headway, amid circumstances of international uncertainty about energy and everything else, in promoting the commercialization of our independent technologies, I would say that an organization, systematic and flexible enough to push the commercialization process, should be established which will make full use of the vitality of the private sector, the technology of the Power Reactor and Nuclear Fuel Development Corporation and government financing from the general account and diversification accounts. To this end, it is necessary to make drastic examinations, irrespective of the existing system, in search of the most efficient procedure that can ever be thought of. The Power Reactor and Nuclear Fuel Development Corporation has so far successfully played the leading role in promoting the development of independent technology. If ingenuity is exercised only in devising methods for the corporation and the private sector to divide work between them in their efforts toward commercialization, will it be possible to ensure success in the practical application of big technology such as for fast reactors? Since we are called on to make effective use of the valuable government and private resources to ensure progress of the commercialization process under circumstances of slow economic growth, the economic efficiency of development efforts is the first thing we have to take into consideration.

The treatment and disposal of radioactive wastes, as well as the safety of nuclear power generation, have often been a controversial point. With regard to the treatment and disposal of radioactive wastes, the Atomic Energy Commission last year came out with a policy calling for introduction of a new in-facility storage system, proposing that this be added to the experimental ocean and land disposal program that has so far been under consideration. The seventh conference in London last month of the parties to the Convention for the Regulation of Ocean Dumping adopted a resolution calling for a temporary halt to ocean dumping until examinations have been completed as to whether or not scientific grounds for fear and opposition can ever be found in the safety claimed for the dumping of low-level radioactive wastes, such as planned by Japan for trial dumping in the Pacific area. This resolution, although not legally binding, is casting a shadow on the outlook for safety, and so it seems necessary to make a strenuous effort to achieve an international consensus on the safety. Besides, I think we should go ahead with a concrete program along the lines of policy for land disposal and in-facility storage, so that we can provide against increases in low- and medium-level radioactive wastes.

The development of nuclear power in all its aspects require international cooperation. As you know, moves are being made toward a discussion among Japan, the United States and Europe of the possibility of cooperation in bringing fast breeder reactors to the point of practical application. As a matter of fact, difficult problems are in store for international cooperation in big projects. But I hope that specialists attending this conference here from all countries will make suggestions as to this possibility.

On the other hand, developing countries, although varying according to the state of national affairs and technical levels, hold out high hopes for the development of nuclear power. The advanced nuclear power states are advised to help meet the needs of these developing countries. Japan should play its role, by consideration of its geographical position, in extending technical cooperation in nuclear power to Southeast Asian countries. This technical cooperation will cover a wide range of functions, such as personal interchange and information exchange. To ensure that ~~Japanese~~ unified Japanese efforts are made to help meet various needs of the developing countries, the Japan Atomic Industrial Forum has decided to set up something like a nuclear technical cooperation center, beginning in the new fiscal year, to promote effective activities of cooperation. You are requested to help this organization.

Finally, I wish for this conference a success in working out instructive guidelines for the development of nuclear power in the years ahead. I close my keynote address by expressing my deep gratitude to all of you attending this conference from within Japan and other countries.

SPEECH TO THE ANNUAL CONFERENCE
OF THE
JAPAN ATOMIC INDUSTRIAL FORUM
23 March 1983

ENERGY AND INTERNATIONAL COOPERATION

by L.J. Brinkhorst

Head of Delegation
Commission of the European Communities
in Japan

Introduction

1. I am very pleased to have this opportunity to address your conference on the subject of "Energy and International Cooperation".

The Commission of the European Communities appreciates this important occasion to come and explain its own views as well as listen to those of others.

2. Mr. Audland's presence in Brussels during these days was indispensable. He regrets his absence today and has asked me to bring you his best wishes for the conference.

3. May I also at the outset of the conference congratulate the organisers on the choice of the basic theme: Nuclear Industry - Towards the Age of Maturity. It particularly well describes the present stage of development of nuclear energy for peaceful purposes. In a number of countries, nuclear energy is now achieving a high degree of maturity technologically, industrially, economically and, last but not least, in terms of safety. In the OECD area as a whole, nuclear provided for 12% of electricity supplies in 1980.

4. This has some important implications which I would like to mention:

First, we have reached the point of maturity almost 3 decades after having taken the initial steps towards the peaceful uses of nuclear energy. This is worth remembering when we discuss the future contribution of new energy technologies which we all hope will be able to relieve us further from our excessive dependence on oil. New technologies take time and often very considerable resources to develop, demonstrate and bring into full commercialisation. We should therefore make best use of the technologies we have at hand, such as nuclear, and be aware of the need to develop now the new energies we shall need by the turn of the century to enhance diversification of supplies.

Second, the degree of maturity which nuclear energy has reached means that countries wishing to introduce or expand nuclear energy production can do so with more confidence as to reliability and safety and on the basis of the greater experience achieved.

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Third, confidence also in economic terms. Nuclear energy is under most circumstances a competitive source of supply for electricity production. In countries where it covers a substantial share of energy needs, this has a positive impact more generally on the economy. I think, in terms of industrial competitivity, inflation, balance of payments and overall economic growth prospects.

Fourth, maturity does not mean absence of challenges. Nuclear energy must strengthen its longer-term prospects for energy security. Governments and industry must also continue to ensure that nuclear energy is at all times compatible with the objectives of public safety and environmental protection.

Finally, there is a need to improve the non-proliferation regime, without jeopardising the development of nuclear energy for peaceful purposes.

5. Having made these introductory remarks, I shall now attempt first to give you a view of international cooperation in the overall energy context, then proceed to explain the approach to energy strategy in the regional context of the European Community, with emphasis on the role of nuclear energy and finally deal somewhat more in detail with the challenges to future development of nuclear energy and international cooperation as we see them.

International cooperation in the energy field

6. It is in time of crisis, notably with respect to oil supplies, that international cooperation in the energy field has taken important steps forward. This is understandable for at such a time the advantages of joining efforts to cut the overall cost and time of developing new energy technologies is better understood and the need for solidarity is better perceived.

7. May I recall that the European Atomic Energy Community - also known as EURATOM - was established in 1958 - 25 years ago - in the aftermath of the Suez crisis. At that time and in the years that followed, nuclear energy was widely regarded as the main alternative to oil. There was only modest interest in developing other new energy sources or in energy conservation. The fact that both the IAEA and the NEA were established in this same period, is symptomatic for that view.

8. Following the first oil crisis in 1973/74, nearly all major oil-consuming countries set up the International Energy Agency in Paris in the framework of the OECD. Its aim is to deal with the problems of excessive oil dependence, notably in managing oil supply emergency situations and in fostering cooperation in the fields of energy conservation and the development of oil alternatives. With this, an important step was taken towards a broader strategy for diversification of energy supplies in the industrialised world.

9. The second oil crisis in 1979/80 again gave further impetus to international cooperation in energy. The vulnerability of our economies to excessive oil imports was a basic theme of the Tokyo World Economic Summit in 1979, where specific measures were taken to limit oil imports until 1985. The following Summit in Venice in 1980 brought agreement on a broad energy strategy for the '80s. Specific guidelines were laid down as regards oil share in total energy consumption - to come down to 40% by 1990 - and the role of energy conservation and alternative energies, including nuclear and coal were set out.

10. The international Community also focussed increasingly on the problems and needs of the developing countries and in particular as regards new and renewable energies, which were examined in particular in the United Nations Conference in Nairobi in 1981.

11. All this illustrates, I believe, that international cooperation on energy has grown in importance and breadth in response to our need for increased supply security. The role of nuclear energy continues to be important in this overall picture, but nuclear energy is now placed in the proper context of a much bigger effort to diversify our energy sources and restructure our economies away from excessive oil use.

12. Today, the shorter-term outlook for oil supplies gives rise to less concern than it has done for some time. The rising oil price trend has at least momentarily been broken. This has positive as well as negative implications. On the positive side, our economic growth prospects could improve (growth, employment, inflation, balance of payments). On the negative side, there is the risk that we regard "the pressure as off" and do not give sufficient priority to pursuing efforts to secure our economies against future oil price shocks. The

commitment to joint international undertakings to make equitable progress in oil substitution could also suffer. Such attitudes, should they materialise, would be short-sighted.

13. The present soft conditions in the oil market should therefore not lead us to place less emphasis on international cooperation in the energy field, but rather consolidate and pursue the objectives already agreed.

14. This is particularly important for EC and Japan. Both are poorly endowed with economically exploitable energy sources and are large users of energy. Our economies became almost by definition the world's biggest importers of all forms of primary energy, with oil taking a dominant position.

15. Our basic concern as regards longer-term energy security must therefore be the same. This implies continued progress in the economic efficiency in the use of energy - which is largely imported - and continued encouragement to investment in oil alternatives.

16. The Community is by its very nature open to cooperation on these matters and we see the OECD and IEA as particularly useful fora for joint analysis and action to strengthen our energy security situation.

Community energy strategy and the role of nuclear energy

17. Following the second oil crisis it became evident that a clarification of the Community energy strategy was needed as a guide for energy policy planning for the European Community and its Member States.

18. Already before the Venice Summit, in 1980, the E.C. had agreed on some specific Community energy policy objectives for 1990. They were

1) that we should reduce the share of oil in total energy consumption to 40%,
2) that 70-75% of electricity be generated through solid fuels and nuclear,
3) and that we should reach a ratio between energy and economic growth of 0.7.

19. The strategy we set out after the second oil crisis, to achieve these objectives comprises 5 main priorities:

- a first priority is to raise the level of energy investment in the Community, which is low in comparison with that in the USA and Japan. This means ensuring continuity in decision-making and reducing unnecessary barriers and disincentives to investment. In the electricity sector, where in most countries some of the largest investment takes place, low or even no growth in electricity demand put financial pressure on utilities. This may lead to a tendency to scale downwards plans for conversion or for the construction of new non-oil capacity. While no-one wishes to see new plant lying idle, it would be very damaging if we found ourselves without sufficient non-oil capacity to cope with electricity demand when economic growth picks up.

- a second priority is energy prices and taxation. We want to see the implementation of rational pricing policies to avoid distortion in trade. We have taken steps to monitor progress in this direction through improving the transparency of energy prices and otherwise.

- a third priority is research and development. Energy R&D is an important element in renewing the technological base of the Community and strengthening competitivity. We need to work on a broad front and cover all major fields in new energy sources and also investigate the possibilities for further energy conservation. But R&D is not enough. We must go beyond that to the stage of demonstration in order to speed up the introduction and commercialisation of new technologies. The Community demonstration programmes cover the most important new technologies, i.e. energy conservation, solar, geothermal, biomass, coal gasification and liquefaction.

The Community effort in energy R&D and demonstration has expanded considerably after the first oil crisis. Community R&D spending currently runs at 590 M US-$/yr, of which nearly 2/3 or 376 M US-$ is on energy. This year we have another 120 M. US-$ available for demonstration projects.

- a fourth priority is a more coordinated approach to external relations. The Community as a whole is dependent on third countries for nearly 50% of its energy supplies, and it is likely to remain so throughout this decade. Oil imports may cease to grow, but imports of natural gas and coal will increase - perhaps substantially. For oil, coal, gas and nuclear fuels, the Member States of the Community need to be able to operate within a framework of relations which ensures stable, secure and economic supplies. This can be more effectively achieved through collective action at Community level.

  The coordination of our cooperation and aid efforts in the energy sector in developing countries is a major concern for the EC. Energy aid has become in recent years a much more important part of the total aid activities of the Member States and it is already a very important aspect of the aid programme at Community level. But there is a great deal more to be done. Working more closely together, one can help to ensure that money is spent more effectively and, just as in our R&D policies, duplication is avoided.

- Finally, the fifth priority is the one we give to the need to stabilise the oil market. We already have both in the EC, and in the IEA, mechanisms to deal with major oil supply disruptions. We wish, however, also to avoid a repetition of the experience in 1979/80 when limited shortfalls in oil supplies led to huge increases in oil prices.

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Progress is being made to achieve our objectives. From a high point in 1973, the share of oil in our total energy consumption dropped from 61% (Japan 68%) to 50% (Japan 63%) in 1981. Likewise, the share of solid fuels and nuclear in electricity production has increased from 50% (Japan 14%) in 1973 to 67% (Japan 30%) in 1981. Also, the Community's supply dependence on imports has improved considerably from 64% (Japan 88%) in 1973 to 48% (Japan 84%) in 1981.

The outlook for 1990 shows, according to our Member States' forecasts, that the agreed aims should be within reach. The share of oil in the total energy consumption should come down to 40% and the share of coal and nuclear in electricity generation could total as much as 80% for the Community.

The role of nuclear energy in the European Community

20. Let me now turn more specifically to the role nuclear energy plays in the overall energy strategy of the EC.

21. The Euratom Treaty charges the Community with the basic task of creating the conditions for a speedy growth of nuclear industries within the Member States. This includes the following specific duties:

. the promotion of research
. the protection of health through basic and uniform safety standards in the Community
. the facilitation of nuclear investments
. ensure regular and equitable supplies of nuclear fuels in the Community
. safeguards against clandestine use of nuclear materials
. a nuclear common market
. external relations in the nuclear field.

22. In the light of these objectives and with the help of these instruments, the EC Council of Ministers examined last year the future role of nuclear energy in the EC and arrived at the following conclusions.

23. In the economic context of today, diversification away from oil on the necessary scale relies to a large extent on increased contributions from coal and nuclear.

In fact, nuclear energy should be the major source of diversification for the Community in this decade. Member States forecast that between 1980 and 1990

. nuclear energy will more than triple (from 43 Mtoe to 137 Mtoe (or more than 2 1/2 mbd)
. consumption of solid fuels and of natural gas will increase by 24% (from 223 Mtoe to 276 Mtoe and from 169 Mtoe to 210 Mtoe respectively)
. new and renewable energies will double (from 14 Mtoe to 27 Mtoe) and
. oil consumption will decrease by 11% (from 494 Mtoe to 441 Mtoe).

24. Nuclear energy will thus cover an increasing share of total energy demand, namely from about 7% at present to 13% in 1990.

In the electricity sector and for the Community as a whole, nuclear currently covers about 20% (Japan 17%) of fuel needs. By 1990, nuclear's share in electricity generation could increase to 36% (Japan 30%). In terms of electrical capacity, this means a growth from 45 GW at present to 105 GW in 1990.

25. This strong progress of nuclear energy is not evenly distributed throughout the Community, neither does our strategy require it to be so. At one end we have France which already generates about 40% of its electricity through nuclear energy, and at the other end we have Denmark, Ireland, Greece and Luxembourg with no nuclear programmes. Community policy does however imply an equivalence of effort. This means that those who do not opt for nuclear must use more coal. This is in fact happening in Denmark and Ireland.

26. Obviously, this development is only possible because nuclear electricity within a wide range of circumstances undoubtedly is cheaper than coal-based electricity. In the Community, the difference in costs varies from 30 - 90% in favour of nuclear. This can bring substantial competitive advantages to industry in the countries which can benefit from the cheap electricity supplies based on nuclear energy.

27. So the strategic objective of enhancing the role of nuclear energy is clear enough, in economic terms. But what challenges do we meet on our way towards its implementation and how do we cope with them? Basically, I see three challenges:

a. Improving the longer-term prospects for nuclear energy

28. Neither the Community (nor for that matter Japan) have the uranium resources needed to sustain their present nuclear programmes. This means heavy reliance on imports - in the case of the Community import, dependence is actually at 80% of total requirements. For the longer term, that is at the beginning of the next century, the pursuit of nuclear energy programmes could be constrained by availability of resources. Thus, if nuclear energy is to give us a lasting improvement in our supply security, we need to stretch available uranium supplies through the reprocessing of spent nuclear fuels. This will permit us to recover valuable uranium and plutonium fuels and further improve the conditions for the disposal of radioactive wastes.

29. The recovered fuels can then be used either in the present generation of reactors or with much improved efficiency in fuel utilisation through the fast breeder reactor.

30. Both the reprocessing step and the fast breeder reactor are well-developed in the Community, and we support keeping these options open. The fast breeder reactor, which is close to commercial demonstration in France, is being built through an important industrial cooperation effort in the Community.

31. In the longer term, fusion energy holds out the promise of abundant energy supplies, and the development of it is aggressively pursued in the Community. In this field, the Community dimension is fully exploited. Member States have realised that their interests are best served through the closest coordination of their effort - in fact, all R&D activities on fusion in the Member States are coordinated at Community level. This in turn gives considerable weight to the Community's programme. The Joint European Torus (JET) under construction in Culham (U.K.) is a concrete expression of the EC's approach to cooperation in this field.

32. Further, we believe that fusion research is particularly well-suited for wider international cooperation. Actually, the exploration of such cooperation with Japan and the US was part of the basic decision of the Council of Ministers to adopt the EC thermal nuclear fusion research

programme. Let me just mention as an example of fruitful cooperation the development of supraconducting magnets for fusion machines, where Japan, the USA and Europe have joined efforts in the large coil project, carried out in the framework of the IEA.

b. Continued commitment to safety

33. A second major challenge is that nuclear energy remains, throughout its industrial development, compatible with the objectives of public safety and environmental protection. In many countries, nuclear power is running into political problems. And even in those countries where the anti-nuclear mood can be contained, its existence in itself has forced authorities to scrutinise plans for new reactors or other nuclear facilities in such a detailed way that, for instance, in the United States it used to take, up to recently, 10 to 12 years between the first design and the full functioning of a nuclear power plant. It is not amazing that, under such circumstances, investors do not feel encouraged to go such a long way. In the densely populated areas of the EC and Japan, considerations of safety are particularly important and condition to a large extent public attitudes to nuclear energy. We have been encouraged by some recent progress in the licensing of nuclear power plants in the Community and it seems that perhaps a more balanced approach to the risk involved in nuclear energy production is developing.

34. Although nuclear safety is at a level at which few, if any, other industrial activities can compare, we need to continuously improve our knowledge of safety-related phenomena through further investigation. This concerns mainly reactor safety and waste management, as well as radiological protection. The Community role in this field is quite important. Almost all our research effort (worth ca. 130 M US$) in nuclear fission is oriented towards these ends and the Community research programme covers directly or indirectly - ca. 25% - of the combined spending of the Member States. In the radiological protection area, this percentage reaches 80%.

35. We see merits in increased international cooperation in this field also. We could avoid costly duplication of efforts, and achieve more results at an earlier time. A strengthened international consensus on nuclear safety matters could greatly benefit, I believe, the cause of nuclear power vis-a-vis public concern about this form of energy.

c. The non-proliferation regime

36. A third challenge is to achieve an improvement in the non-proliferation regime. In the end, nuclear suppliers have to build on the confidence that the nuclear material or equipment they provide will not be used for military purposes. One of the conclusions of the International Fuel Cycle Evaluation (INFCE) programme was that nuclear energy production is

compatible with non-proliferation objectives, but also that peaceful use of energy at world level can in future be envisaged only in the context of increased international cooperation.

37. Non-proliferation is a basic concern of all civilized nations. The EC is in the fortunate position of having one of the best safeguarded systems of the world: our own regional Euratom safeguards system is linked to the IAEA safeguards system through specific Verification Agreements.

38. This and other opportunities for increased cooperation both at regional and wider international levels must be fully explored, such as the work (which the Commission is supporting) in the IAEA on assurance of nuclear fuel supplies. More specifically, the Commission has emphasised the need for multilateral cooperation in the field of reprocessing. We believe that it would be most inefficient - also from an economic point of view - if each country with a nuclear programme had to develop its own fuel cycle including reprocessing in order to have assured access to such services. In the enrichment field, multilateral cooperation is the rule in the Community, whereas in reprocessing multilateral ventures should be studied more seriously.

39. To maintain full credibility, safeguards technology will have to adapt and improve to the development of nuclear energy installations. The Community realises this and has a sizeable R&D activity (more than 6 M US$/yr) in nuclear safeguards, apart from the contribution to the development of safeguards technology within the IAEA.

40. Also in the area of safeguards it makes great sense to adopt common approaches. This is in fact already happening in the case of centrifuge enrichment plants, where Japan and the Community are cooperating successfully with other parties.

41. The use of sensitive nuclear materials in the peaceful nuclear fuel cycle gives rise to special concern in some supplier countries. We think that efforts should be pursued to establish on as large a base as possible a satisfactory system of international surveillance of these materials.

Conclusion

42. In this last quarter of the twentieth century, one of the most spectacular phenoma is to see how nations, in spite of their national selfishness and traditional controversies, demonstrate growing interdependence in their common efforts to make increasing populations enjoy more wealth out of shrinking resources. International energy cooperation today is one such field and nuclear energy is a key area of major importance. Japan and the EC share major responsibilities in this area. In the framework of our steadily growing cooperation we will have to join hands here as well.

43. The European Community intents to contribute actively to such cooperation. With its experience in economically and politically integrating of national autonomous economies, it faces these international challenges, armed with an experience few other members of the world community can bring to the fore. It is resolved to use that experience and to respond to those challenges for the benefit of the entire international community.

§1. ギアモン総裁
EDF
本論文

THE NUCLEAR DEVELOPMENT STRATEGY OF E.D.F.

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 7th March, 1983

THE NUCLEAR DEVELOPMENT STRATEGY OF EDF

The oil price shocks of 1973 and 1979 had different effects on the economies of the various industrialized countries. Two of these countries were especially vulnerable, because they depended more than the others on imported oil for their supply of energy: Japan and France.

And yet, of the great industrial powers of the free-market world, only Japan and France have succeeded in taking up the energy challenge.

Only these two countries have taken, in time, the measures necessary to reverse the trend that had been established during the preceding decade, a trend to increasing dependence, increasingly dangerous, on oil-exporting countries.

Only these two countries got well out of it, by embarking resolutely on the nuclear course, while here and there political shillyshallying, local or regional conflicts opposed to the national interest, and the pursuit of fruitless debates were paralyzing for varying lengths of time the development of nuclear power in the other industrialized countries.

The nuclear development strategy of Electricité de France, undertaken by the authorities, must be understood in this international context: an analysis of the sequence of decisions that have enabled France, in the space of a decade, to build a nuclear power industry and acquire a production tool that have in turn enabled it gradually to break free of the ascendancy of the petroleum-exporting countries will be the subject of the first part of my paper.

But all this is now in the past: the decisions were made in time, and we are going to reap the expected benefits.

Today, we must face another objection: that we have overreached, that we have started up an oversized industry and finally that we have wasted public funds ; we were optimistic in our forecasts of the growth of consumption of electricity, and of the ability of the economy as a whole to recover from the two oil price shocks, and failed to anticipate the successive aftershocks of this long world crisis, the end of which is not yet in sight.

We thus now face a new and delicate situation; the second part of my paper will be an analysis of this situation.

This situation, uncomfortable for the producer of electricity, could have graver consequences: unless adequate measures are taken, the medium-term survival of our nuclear industry will be seriously imperilled.

This process can be checked only by substituting electricity for other forms of energy; but using electricity also means replacing imported forms of energy by a domestic form, and so improving the country's balance of trade. It is on these data that is based the strategy chosen by Electricité de France, which is both a producer and a distributor of electricity; this new strategy will be the subject of the third part of my paper.

Part one

A DECADE OF GROWTH

Let us begin with a brief look at the past : In 1973, French oil consumption amounted to 117 million tons, or 66 % of the country's total consumption of energy - 178 million TOE ; 98 % of this oil was imported. Because of this, our level of share of energy imported, which had been about 40 % in 1960, had risen to more than 75 % in 1973. For us, an oil crisis meant a failure of our sypply of energy.

The energy picture in Japan on the dawn of the first oil price shock was comparable, since, out of total consumption of about 300 million TOE, oil accounted for the lion's share : 215 million tons or 72 %.

In Japan as in France, we paid dearly for the fragility of our supply structures ; but, in both countries, the upheavals of the energy market have given rise to quite similar rational reactions: poor in resources, we have had to turn resolutely to alternative sources of energy. Among these alternatives, nuclear power combined the advantages of dependability of supply, reasonable cost, and the ability to meet our needs. Coal could, in certain cases, be used as a stop-gap measure, between oil that was henceforth too costly and nuclear power that would take some time to come on stream. And coal accordingly made an honourable come-back in French power generation: between 1973 and 1981, 15 oil-fired power stations, with a total capacity of 3400 MW, were converted to coal, and during this period the quantity of electricity produced by coal rose from 29 TWh to 51 TWh.

In addition, energy savings, now economically justified, could make a substantial contribution to righting the balance, just like the so-called "new" energies, but neither the one nor the other was really commensurate with the scale of the problem: with an annual energy consumption of 3 TOE per capita, France could hardly be regarded as a waster of energy among the industrialized nations ; and the soaring price of oil left us little respite for the implementation of the sophisticated and therefore costly processes required for the collection of diffuse forms of energy such as solar and wind energy, most of which still need years of research and development, with no assurance of results before the end of the century.

Nuclear power, by contrast, had already reached the stage of industrial maturity. We could call on the substantial body of experience already built up in France and elsewhere in the world; this experience had already enabled us, as early as 1971, to launch a large-scale programme; readjusted in 1974, it called for the construction of from five to seven 900-MW units per year until 1977 and from four to five units thereafter; in practice, we began construction of about 5000 MW every year from 1974 to 1981.

The scope and pace of the programme called both for mobilization of all the structures involved(industry, owner, operator) and for a degree of national consensus, in other words acceptance by nearly all parties concerned - political and socioprofessional groups. These conditions were met.

Naturally, Electricité de France had to face the same difficulties as other owners engaged in similar ventures: it was necessary to gather the engineering capacity to design the product, the industrial capacity to produce it, and teams to operate it.

But we had two major assets: unity - since, in France, EDF is at once the owner, industrial architect, and operator of its power stations - and the continuity of the programme.

We then staked everything on a single approach, the pressurized water reactor, in view (among other things) of the experience that had been acquired both in the United States and in Europe, where we had worked jointly with Belgium on power plants at Chooz (320 MWe) and Tihange (870 MWe).

The search for optimatization in all areas led us to standardize the units: we launched, in turn, a block of 34 900-MW units, in three series, then a second block of 18 1300-MW units, again in three series.

Allow me to insist on the positive aspects of this standardization, which seems to me to have been a decisive factor in bringing our programme in on time and making it a technical success; the reproduction of several copies of a single model, identical except for the adaptations made necessary by the differences among the various sites, indeed offers many advantages:

- first of all, it makes the total cost of implementation substantially lower, since nuclear generating capacity is no exception to the rule that, the more of something is made, the lower the unit cost;
- secondly, it makes obtaining the authorizations required for the various stages of construction and commissioning faster;
- and finally, it enhances the value of feedback from the operator to the industrial architect, since, from one series to another, in addition to the changes made necessary by considerations of safety, there may also be improvements justified by operating experience, and the larger the sample the more valuable this experience.

To be sure, within a given series, identical "hitches" may occur in cascade, within a few months of one another; on the other hand, the solutions employe are perfectly reproducible throughout the series: the recent problem with guide-tube locating pins, which I shall mention again later, is a case in poi Furthermore, the interchangeability of the parts, both in the starting-up stage and in the operating stage, affords a significant measure of flexibilit

A large part of this feedback from experience is in-house for EDF, which has integrated "after-sales service" of units in operation with its on-going construction programme.

Technical continuity is complemented by industrial and commercial continuity: EDF has entered into grouped contracts covering from 8 to 12 successive projects with its major industrial partners; these have favoured the setting up of an industrial tool with a capacity of five to six units a year, now fully operational - seven 900-MW units were connected to the network in 1980 and eight in 1981, or more than one every two months.

As it was growing, the French nuclear industry was also seeking for the means to independence; work under licence, to which we had recourse at the start, ended two years ago, and, with the new 1300-MW series, we are now developing French pressurized-water reactors.

Concurrently, thanks to the uninterrupted work of the French Atomic Energy Commission, France has built up a coherent set of installations giving it mastery of the entire fuel cycle; it has a definite technological lead in the area of fast breeder reactors

In this way, in the space of a decade, nuclear power has become a reality: 23 900-MW units are now in service, and 11 more under construction.

The 18 units of the 1300-MW standard are off to a good start, and Paluel 1, the first of the series, is to be connected to the network at the end of the year.

At this point, a rapid assessment may be offered:

. Henceforth, actual construction times are on target: the units commissioned in 1981 and 1982 took 60 months from the first work to connection to the network; today, barring the effects of the launching of a new block or special problems, we can count on a construction time of five years for a 900-MW section and six years for a 1300-MW section.

Similarly, starting-up times - from first loading to industrial commissioning, have been shortened, on the average, from ten to six months.

. Our installations reach, in the first few years of operation, performance levels quite comparable to those of other generating facilities (and superior to the levels used in our economic calculations).

Nevertheless, in 1982, the load factor of our nuclear power plants was only 58.5 % rather than the 62 % expected, because it was affected by a combination of factors:

- first of all, the difficulties encountered in starting up the second series of the 900-MW block (the "CP2" series), which affected the conventional part of the installations; however, following the making of modifications which will be extended to all the sections of the series, the first section affected (Saint Laurent B2) is now operating at full power;
- secondly, the concentration in a single year of seven of the complete inspections, each lasting four months (as against four in 1981 and three planned for 1983), required by French legislation at the end of the first 18 months of operation;
- and finally, the appearance of corrosion affecting certain control-rod guide tube locating pins.

It was in Japan that this corrosion was first discovered; it causes cracking that may result in failure of the locating pin. The same problem was found in the United States and, finally, in France, a few months apart, in five of our 900-MWe sections.

Thanks, in particular, to the information gathered by the mission we sent to Japan, repairs of three of the sections affected were made rapidly: this points up the value and effectiveness of international cooperation among operators. I should like to emphasize, in connection with this affair, how much we appreciated the cooperative spirit and abilities of the Japanese specialists.

. The final item in this assessment is that nuclear power has shown itself to be more than competitive.

When the latest constraints imposed by tighter regulations governing safety and protection against radiation are taken into account, the cost per installed kW of nuclear generating capacity in France seems to have stabilized - at a level that compares favourably to those found abroad, as shown by a recent UNIPEDE study.

Under French conditions, the nuclear kWh in "baseline" operation costs a third as much as the oil-fired kWh and two-thirds as much as the coal-fired kWh: this means that recourse to a nuclear power plant is profitable by comparison with coal even for operating times significantly shorter than 3000 hours per year.

Almost insignificant in 1962, French nuclear power production has grown tenfold since 1972, to more than a hundred TWh in 1982: 100 TWh was our total production of electricity in 1965.

Such are the fruits of the strategy followed by Electricité de France during the last decade.

Part two

WORRYING PROSPECTS FOR 1990

Let us now talk about the future: in 1990, our PWR power stations alone, with about 50,000 MWe on operation, will be capable of supplying the country with 290 TWh; if we add to this hydroelectric power (70 TWh), the contribution made by domestic coal (20 TWh), and about 30 TWh produced from imported coal and oil, we could offer the country 410 TWh of electricity, 95 % of it of domestic origin.

But what will be the level of demand in 1990? (It is now about 270 TWh/year.)

After a marked slowdown towards the end of the last decade, the beginning of the 1980s has been characterized by slow growth of the consumption of electricity in France, about 2 to 3 % per year, a consequence of slower economic growth.

France is not the only country so affected: it is following, with a slight lag, the course to be observed in most industrialized countries

Having given the country considerable assets to promote recovery, must Electricité de France too now suffer the effects of economic stagnation? Must it sacrifice the pursuit of its nuclear programme to short- and medium-term economic realities?

Today's conditions might lead us to consider the darkest scenarios in our forecasts: if we cease striving, if we do not quickly launch a new strategy capable of reversing the current trend, the country's total consumption might be less than 360 TWh in 1990. It should be noted that even this level already assumes some degree of recovery:

indeed, it would entail a 35 % increase in consumption over the level reached in 1982; in more concrete terms, it would mean that in 1990 the country would have to consume as much on an average day as it now does on the "peak" day of the year.

The consequences of such a scenario on the operation of production capacity of reasonable scale for the production of 410 TWh are not hard to guess: in absolute terms, nuclear and hydroelectric power together could cover almost all needs, but because of seasonal and daily variations, it would in practice mean:

- powerful nuclear generating plants kept idle during the off-peak periods of the year;
- the share of coal (whether domestic or imported) in the generation of electricity practically reduced to zero.

Electricité de France, concerned with the proper management of its production resources, cannot be content with such a prospect.

Moreover, would it be reasonable, looking forward to 1992-95, to continue the expansion of our nuclear capacity at the current rate of three 1300-MWe sections per year knowing full well that in the absence of determined action we will already have excess capacity by 1990?

Conversely, can we substantially reduce this rate of growth practically overnight without endangering our nuclear industry ?

This industry is today a high-performance tool and an international reference; directly and indirectly, it employs 200,000 people who constitute a unique scientific and technical potential for our country; finally, and most important of all, it bears the seeds of our complete and lasting independence in the area of energy. It can hardly be preserved if subjected to excessively great or sudden fluctuations in the level of its activities.

Some have put forth the idea that we might, for some time, put our nuclear industry on "standby", in the hope of better times; by postponing projects, slowing down the rate of orders, and spacing out the work of construction, we could in this way gradually adjust our production capacity; but it is manifest that if this were done the cost per nuclear KW would quickly rise. The various extra costs and expenses entailed by such a scenario would quite naturally have to be borne by the nation as a whole and would adversely affect the competitive position of all of French industry.

We have not given this scenario any serious consideration; on the contrary, we intend to persist in our course of maintaining the activity of our nuclear industry at a reasonable level, since we believe that what is at stake is sufficient to justify a short period of excess capacity to safeguard employment and our technological heritage; we have decided, concurrently, to improve our product still more.

With this in view, we are continuing our efforts to develop a product meeting the highest standards of reliability and safety, and incorporating the results of feedback from French and foreign power stations.

This is the point of the development in France of a new series of the 1300-MW block, the "N4" series, work on the first unit of which will be begun in the course of the 1983 programme; this product aims, on the one hand, at attaining a better cost price through a slight increase in power and better optimization of certain components and, on the other hand, at incorporating advances, in particular in electronics, data-processing, and robotics, to improve the man-machine interface and the protection of the personnel from radiation.

We are also pursuing a fast breeder reactor demonstration programme, a course upon which we embarked more than 20 years ago. Here again, France and Japan have followed remarkably similar paths: after two research fast breeder reactors (Harmonie and Masurca), our first experimental reactor, Rapsodie, was started up in 1967; it was finally closed down only last year, after nearly 15 years of good and faithful service. With the Joyo experimental reactor, in which the chain reaction was initiated in 1977, this stage of development has now been reached in Japan. We then launched a pre-industrial prototype, Phénix, that was already rather powerful (250 MWe). Its Japanese counterpart, Monju (280 MWe) is to be built in the next few years. We have today, working with other European producers, reached the stage of construction of a prototype of industrial size (Super-Phénix, 1200 MWe) at the Creys-Malville site. For its part, Japan has also entered the third stage by starting planning work on an industrial-sized demonstration reactor (1000 MWe). Phénix has been functioning remarkably since 1974, and the leaks from the steam generators followed by sodium-water reactions that have recently occurred in succession have served to confirm the validity of the concept and the mastery of these phenomena that has been acquired. As for the construction of Super-Phénix, it is continuing without major difficulties, and the first connection is expected next year.

Burning the impoverished uranium discharged by enrichment plants (for which there is no other known use) and the plutonium produced by the reprocessing of fuels from PWR power stations, the fast-breeder reactor feeds on the wastes of PWR reactors and closely complements them.

Plutonium fast breeder reactors are an assurance of energy that is clean, renewable, and available in virtually unlimited quantity. To be sure, the cost per KWh is still too high: the KWh produced by Super-Phénix will cost 2.2 times as much as the KWh from a standard PWR reactor, but even so is significantly less expensive than the KWh produced from oil. Our aim is gradually to reduce the cost of the fast-breeder KWh to a level close to that of current PWRs, with no sacrifice of safety or reliability.

This objective can be attained by the end of the century; an increase in the unit power of the reactors, closely-spaced launchings of several sections, optimum site occupancy by several identical sections, the gradual optimization of the corresponding industrial structure, and the knowledge gained from experience at Creys-Malville should make it possible to reduce the cost of the "fast breeder" KWh to 1.5 times that of the "PWR" KWh in a first stage, and to less than 1.2 times for a series of power stations built at the same rate as the current PWRs.

Our objectives are in two stages:
- the construction of a unit derived directly from Creys-Malville, but having a unit power about 20 % higher; the authorization procedures are expected to be initiated in 1985-86;
- the launching of new unit, preliminary plans for which are expected to be ready towards 1990, incorporating the technical advances of the coming decade.

In our thinking, none of this is conceivable without the simultaneous setting up of the corresponding reprocessing capabilities. The fuel cycle of the fast breeder reactors was mastered in 1969 (when reprocessing of the fuel of Rapsodie was begun) and since then we have reprocessed some ten tons of fuel from Rapsodie, then from Phénix.

In this manner, through close cooperation among the French Atomic Energy Commission, the nuclear power industry, and EDF, our country has laid the foundations for the long-term future of its energy supply; it has counted on electricity as a major vehicle of its independence in energy: it must now win for electricity a preponderant place with both industrial and home users.

Having optimized our production resources, we must now promote the use of electricity. This work of promotion must henceforth take over from the work of production: it is essential to the continued development of our nuclear programme.

Part three

REPLACING OTHER FORMS OF ENERGY BY ELECTRICITY

In two years, practically tomorrow, oil will have been almost completely eliminated from French production of electricity.

As a producer of electricity, we shall have attained a major goal, by freeing ourselves from dependence on imported oil and by substantially lowering our production costs.

As a distributor of electricity, we face an arduous task: replacing as much imported energy as possible, in particular oil, with electricity, now the only domestic form of energy that is growing.

What are our assets?

- We offer the assurance of a dependable supply of energy.
- Our prices are unaffected by the fluctuations of the market, for, while nuclear power calls for larger investments, the cost of production of a nuclear kWh, on the other hand, is largely independent of that of the fuel, which accounts for only 10 % of the price of a kWh (as against 45 % in the case of coal and 70 % in that of oil); there are therefore no nasty surprises waiting for us in the area of prices.

We should point out in passing that the price of oil, in real terms, has increased fourfold since 1973, while that of high-voltage electricity has increased 29 % and that of low-voltage electricity has declined slightly.

What are the obstacles?

- There are, of course, technical or financial obstacles: users cannot be required to alter their patterns of consumption overnight. We may even say that the current situation is frankly against us: in industry, as elsewhere, the economic growth that did so much to promote the profound changes of the 1960s is today sadly lacking. Furthermore, we are going through a period in which the scarcity of energy is giving way to a scarcity of money. However, since the gap between the price of imported energy and the price of the domestic kWh grows larger every day, the user's thinking should quite naturally turn to the most economical form of energy, in so far as he is in possession of all the objective data to guide his choice. Confident of the value and competitiveness of our product, we should be able, through vigorous commercial action and a whole series of incentive measures that I shall return to later, to overcome reluctance and other obstacles.

- But, most important of all, there are psychological obstacles, which even amount in some cases to freezes, which are the consequence of a way of thinking that has grown up since 1973 but is now, fortunately, on its way out of fashion.

Some people, faced with the successive oil price shocks, believed that mankind, suddenly weaned from black gold, would soon be totally without energy, and that its survival necessarily entailed the most rigorous application of policies aimed at saving primary energy.

No matter, then, what the prices were: it was first and foremost necessary to preserve for as long as possible the precious resources that had accumulated in the earth over millenia, regardless of their form; this meant that "conservation" had to be favoured over all other factors, such as prices and foreign exchange savings. No longer could prices be allowed to arbitrate; absolute priority had to be given to the single criterion of economizing primary energy that was headed for depletion.

This reasoning seems to us to be doubly false:

- in the first place, the world is not short of primary energies; to want to save them at any price, by favouring "conservation" over "processing and use", is to diminish their value; conserving them, not taking advantage of them, especially when they are abundant, is the worst possible way to use them;

- then too, this reasoning overlooks the notion of cost price; it is of course always possible to improve the efficiency of the apparatus of transformation, but it is not always economically justified.

For the ultimate user, intermediate efficiencies, thermal efficiencies, losses because of the Joule effect, eddy currents, and so on are of little importance; what counts is value for money. At the level of a country concerned with its balance of payments, the saving in foreign currency yielded by one form or another of supply will also be a criterion of choice.

In the comparison of electricity and fossil fuels, for a given application, we have also often been charged with wasting energy, when 1 kWh ultimately replaced less than 2.5 Mcal of fossil fuel.

This is simply the quantity of fuel needed to produce that kWh.

This type of reasoning was, moreover, justified, when, as in 1973, nearly half of our electricity was produced from oil. Heating a house with resistors would in those circumstances waste both primary energy and foreign currency. This is no longer the case today, and we believe that the primary energy criterion should be replaced by a criterion based on savings of foreign currency, a criterion that now consistently favours electricity in those applications in which it is competitive.

To make the number of such applications as large as possible, we have concentrated on developing increasingly efficient ways of using electricity, by supporting, for example, research and development work on induction heating, high-temperature heat pumps, the mechanical recompression of steam, and the like.

As for household uses, we have launched a major campaign to promote the heat pump, aimed at building up rapidly to a rate of 100,000 pumps installed per year.

A new concept has also been introduced in recent years, that of two-energy systems.

It should be pointed out first of all that with the growth of electric heating, the period of greatest demand on the network is the winter, and this situation seems likely to persist for a long time. The idea of the two-energy approach is to offer both industrial and household customers very attractive rates during the summer and between-seasons period and very high rates during the coldest season.

It would then be in the interest of a large number of customers, who would have to make only a modest investment, to use electricity for from six to nine months of the year, and to revert to their current form of energy, generally a petroleum product, during the period of heaviest demand for electricity.

Our strategy, then, is no longer to emphasize only those applications in which electricity is most efficient, but to propose any solution that is reasonably economical for the customer, bearing in mind that this solution also suits the supplier of electricity (since the rates are set accordingly) and benefits the nation, since it leads to a saving of foreign currency.

In practice, what measures must we take right now?

First of all, specific measures to make it easier to finance the change to electricity.

While it is easy for an industrialist building a new plant to equip it to use electricity, it is corresponding difficult, especially in the midst of an economic crisis, to persuade users to invest in a change of energy.

Again, and this is where Electricité de France has a major role to play, offering rate structures that enable the consumer benefit from the large investment made by the community as a whole in the nuclear programme.

This applies in particular to industrial customers.

The new rates offered place particular emphasis on the large seasonal variations in the cost of producing electricity.

The firm's strategy is thus to have rates precisely reflect costs, for the greater common good.

Again, the promotion of all competitive systems, including those that do not necessarily yield a saving of primary energy, provided that they benefit the community. This is in particular the case of two-energy systems, which often use resistance heating in conjunction with fossil-fuel steam generators.

And finally, the pursuit of an ambitious programme of research and development - for example, for industry, in such processes as the electrolysis of water, the electrification of refining furnaces, the use of plasmas, and so on.

This, in a few words, is our new strategy.

On the whole, in a difficult economic context, the desired course of development has got off to a good start: between 1973 and 1981, the share of electricity in French energy consumption rose from 22 % to 31 %.

CONCLUSION

The French nuclear power programme was launched to reduce our country's dependence on imported energy. The first stage is drawing to a close, since the production of electricity will soon become practically independent of imported fossil fuels.

We are now entering a second stage. The nuclear power programme will of course be continued to meet the natural growth of consumption. But this growth has been considerably slowed down by the world economic crisis.

We must therefore make a special effort to have users substitute electricity for imported fossil fuels. Regardless of the short- and medium-term fluctuations that can be observed in the oil market, we feel that it is essential for a country like our own to reduce in so far as possible its dependence on this source of energy; and I should like to emphasize in concluding that it is also a duty for those industrialized countries that can develop nuclear power to leave as much oil as possible to the developing countries.

SESSION 1 H.N. セトナ博士

NUCLEAR POWER DEVELOPMENT IN INDIA WITH SPECIAL REFERENCE TO REPROCESSING AND WASTE MANAGEMENT.

BY

H. N. SETHNA
Chairman, Atomic Energy Commission
Bombay.

INTRODUCTION

India has one of the largest deposits of thorium, but somewhat modest resources of uranium. Our strategy of nuclear power development has, therefore, envisaged installation of natural uranium reactors in the first phase; followed by fast breeder reactors in the second phase, using plutonium from the first phase reactors and using U^{238} or thorium as the blanket; followed eventually by reactor systems based on the U^{233} -thorium cycle. This strategy necessitated the development of reprocessing of spent fuel as an essential step of the nuclear fuel cycle. The importance of radioactive waste management with respect to the impact on environment was also recognised at the early stage and work on development of suitable treatment methods and safe disposal practices was initiated much ahead of the nuclear power programme. This has resulted in effective management schemes for radioactive wastes from all the stages of the nuclear fuel cycle including operation of power plants and fuel reprocessing facilities.

This paper deals with the development of technology for spent fuel reprocessing and radioactive waste management in India. A brief overview of the nuclear power programme has also been included.

2. NUCLEAR POWER PROGRAMME

India launched its nuclear power generation programme with the commencement of operation of the Tarapur Atomic Power Station in 1969. This consists of two boiling water reactor units of 210 MWe each. It was erected on a turn-key basis largely to prove the economic viability of nuclear power and to obtain experience in the operation and maintenance of nuclear power stations. However, the main thrust has been to pursue the development of natural uranium fuelled, pressurised heavy water reactors (PHWR) in the first phase. The purpose was to choose a system that could be fuelled from indigenous sources and whose major components could be manufactured within the country. Moreover, heavy water reactors have also the advantage of utilising fissile material in a most efficient manner. Accordingly a beginning was made with the construction of the second nuclear power station in Rajasthan consisting of two PHWR units of 220 MW(e) each. The first unit of this station was commissioned in 1972 and the second one became operational in 1980. Construction work on the third plant having two PHWR units of 235 MW(e) each at Kalpakkam, near Madras (South India) is nearly complete and the fourth plant at Narora in the north is under construction. Work has also been initiated on the fifth Atomic Power Station at Kakrapar in Gujarat (Western India). Design work is under way for larger units of 500 MW(e) capacity. The plan, as envisaged now, is to instal a capacity of about 10,000 MW(e) by the turn of the century.

The second phase of the nuclear power development programme will be in the area of Fast Breeder Reactors, which will utilise the plutonium produced in the thermal reactors. An experimental 50 MW(Th) Fast Breeder Test Reactor is under construction at Kalpakkam. Studies are also in progress for the design of a proto-type fast breeder reactor of 500 MW(e) capacity to be built by mid-1990s.

India has one of the largest thorium reserves in the world. The reasonably assured reserves are reported to be about 319,000 tonnes ThO_2. It is, therefore, natural that the development of nuclear power programme takes into account the utilisation of this vast reserve ultimately in the $uranium^{233}$ -thorium cycle.

3. REPROCESSING

With this strategy for the development and growth of nuclear power in view, the role of spent fuel reprocessing became evident. The reprocessing programme was launched with the setting up of the first demonstration plant at Trombay in 1964. This was designed to reprocess the aluminium clad natural uranium fuel from the 40 MW(Th) research reactor. For reprocessing of the oxide fuel from the Tarapur and Rajasthan reactors, another plant has been built at Tarapur. To cater to the needs of the 3rd nuclear power station at Kalpakkam and the fast breeder test reactor, design work is on hand for another plant to be located at Kalpakkam, near Madras. As a prelude to utilising thorium, a few aluminium-clad thorium and thoria rods were irradiated on an experimental basis and the irradiated fuel was reprocessed in a pilot facility at Trombay to separate uranium^{233}.

3.1 Trombay Plant:

The decision to set-up this plant was taken in 1958 and preliminary design was completed by January, 1961. This plant adopted the Purex flowsheet, using mechanically pulsed solvent extraction columns with 30% tributyl phosphate as solvent. Experiments with pulsed perforated plate columns were carried out to arrive at the design data. This was followed by finalisation of the process and equipment design, fabrication and installation of equipment and piping in the process cells, and the associated systems. The plant was commissioned in 1964 to reprocess spent fuel from the 40 MW(Th) research reactor, CIRUS. The metallic fuel elements, 3.4 m long, were of natural uranium with aluminium clad. For the head-end treatment chemical dejacketing was adopted, followed by dissolution of the fuel in concentrated nitric acid. The solvent extraction flowsheet comprised of a co-decontamination cycle, a partition cycle and two separate parallel cycles for the purification of uranium and plutonium. The reductant used in the partitioning stage was ferrous sulphamate solution in nitric acid medium. The final purification of plutonium nitrate solution was by ion exchange. A direct maintenance concept was adopted for this plant and this proved highly useful, as during operation many parts of the plant could be approached after decontamination as and when required in order to effect modifications to suit operational requirements. In view of the maintenance difficulties due to high radiation field, the use of mechanical pumps for transfer of solution was kept to a minimum and restricted to streams where metering was required. In all other cases, transfers were by steam jet syphon. For process instrumentation, pneumatic instruments were used employing air purge for density and level measurements. Column inter-phase control was achieved by regulating the flow of acquous stream through diaphragm control valves.

This plant was not only useful in generating trained manpower and expertise for future plants, achieved through special training courses, but it also helped in identifying areas for further research and development on various aspects of reprocessing. In particular, these included solvent degradation, developing of equipment and systems for achieving higher plant throughput and bringing about improvements in performance, representative sampling and analysis, on-line instrumentation and use of computerised Data Acquisition System (DAS) for process control and dynamic material accounting.

After successful operation for a number of years this plant was decommissioned and the equipment has been replaced with a view to extend the life of the plant and augment its capacity. The plant will be re-commissioned shortly. The decommissioning aspect is covered in some detail later in the paper.

3.2 Tarapur Plant:

With the advent of power reactors, a need arose for the construction of another plant for reprocessing zircaloy clad oxide fuel discharged from Tarapur and Rajasthan nuclear power stations. This plant, located at Tarapur in close proximity of the nuclear power station, has a nominal reprocessing capacity of 0.5 tonne HM per day.

~~nominal reprocessing capacity of 0.5 tonne HM per day.~~

While the basic process flowsheet (Fig. 1) followed in this plant is the same as in the Trombay plant, certain specific features were incorporated in this plant based on the operating experience of the Trombay Plant and taking into account the nature of the fuel. The chop leach method has been adopted for the head-end treatment. Pneumatically pulsed solvent extraction columns have been used in this plant as compared to mechanical pulsing, and the experience so far, has been good. Uranuous nitrate stabilised by hydrazine is used as the reductant for plutonium partition. Other engineering features of this plant include introduction of air-lift as a metering device for radioactive process solutions, use of thermo-syphon evaporators for evaporation of intercycle products, removal of entrained solvent in aqueous stream by use of diluent spray column, and interface control in the solvent extraction columns by regulating the aqueous flow from the column based on the air-lift principle. The conversion of plutonium to oxide is carried out by continuous exalate precipitation followed by continuous calcination. The de-nitration of radioactive liquid waste using formaldehyde is adopted with a view to reduce the waste column. Except for the head-end treatment stage, which has provision for remote maintenance of in-cell equipment, the concept used for the rest of the plant is again that of direct maintenance. The flowsheet conditions in the plant have been so chosen as to include recovery of neptunium from the uranium purification stage. [redacted].

3.3 Kalpakkam Plant:

To reprocess the spent fuel from the Madras nuclear power station, a third reprocessing plant is being designed, which will be located near the power station and which will have a nominal capacity of 0.5 t HM/ day. The design of the plant envisages the construction of a set of stand-by process cells so that the life span of the plant could be extended to match the expected life span of the power station. The plant will incorporate features with a view to standardising on a design which could be adopted in future plants, to effect reduction in cost and construction time. The plant would also have provision for introducing at an appropriate time, the spent fuel from the Fast Breeder Test Reactor. Development work is in progress at the fuel reprocessing development laboratory at Kalpakkam to realise the remote maintenance concept visualised for the reprocessing of the FBTR fuel. Studies on contractors with low residence time are also being carried out in this laboratory.

3.4 Irradiated Thorium Reprocessing:

As indicated earlier, utilisation of thorium for generation of power is one of the important objectives of the Indian nuclear power programme. As a prelude to achieve this, aluminium clad thorium metal and thoria fuel rods were irradiated on an experimental basis in the research reactor CIRUS and the irradiated fuel, after a sufficiently long cooling period, was reprocessed in the pilot plant facility at Trombay to separate $uranium^{233}$. The process operation included chemical de-jacketing in thermo-syphon type batch dissolver, followed by dissolution of the fuel in nitric acid in the presence of fluoride ions. Solvent extraction was carried out following the Thorex flowsheet, in a glass mixer-settler housed in glove box.

Mixing of the two phases was achieved by means of vacuum-cum-air pressure pulsing.

Experience gained in the successful completion of this technological study will be helpful in setting up industrial scale reprocessing plants for irradiated thorium when the need arises.

3.5 Decommissioning Experience:

Decommissioning of nuclear facilities is a topic which is receiving increasing attention, at present, in many countries. In India, valuable experience was gained in this area during the decommissioning of the Trombay plant. After a number of years of operation of this plant, it was considered desirable to decommission the plant for carrying out replacements to extend its life. This opoortunity was also utilised to increase the capacity of the plant to meet the additional reprocessing requirements on completion of the new 100 MW(Th) research reactor being built at Trombay alongside the existing reactor CIRUS. The entire decommissioning programme, which called for dismantling of a variety of equipment like extraction columns, evaporators, condensers, ion-exchange columns, storage vessels with associated piping, etc., was meticulously planned to keep the personnel radiation exposures within ICRP limits by training personnel on the type of operation involved and devising proper tools and equipment. Particular attention was paid to the control of wastes generated and its management.

The decommissioning procedure comprised of several sequential steps. The internal decontamination of equipment and piping was achieved using multiple decontamination routes and covering a maximum number of equipment in a single route so as to keep the resultant volume of radioactive liquid waste low. Following the internal decontamination of the equipment, the task of decontaminating the exterior surfaces of the equipment and piping and the interior surfaces of the cells was undertaken when the radiation fields were low to permit personnel entry, using protective gear. After dismantling and disposal of equipment and piping, high pressure water jets, steam, chemicals, pneumatic chippers and concreting were used, as appropriate to remove contamination or shield hot spots on cell surfaces. The success of the decommissioning operation could be gauged from the insignificantly low background levels of radiation field ultimately achieved and personnel exposure well within ICRP limits. The entire decommissioning and salvaging operations involved a dose of about 2000 man-rems, spread over about 3 years. The experience gained in this exercise has emphasised the importance of making provision for decommissioning at the design stage.

3.6 Spent Fuel Storage and Transportation:

With the growth of nuclear power generation envisaged in India and the strategy being followed for locating the power plants in various zones of the country, the need for interim storage and transportation of spent fuel will assume greater importance. Considerable experience has been gained in the storage of spent fuel, metal and oxide, at the reactor sites as well as at reprocessing plant. Limited experience has also been gained in the transportation of spent oxide fuel over long distances by road and rail, using casks weighing upto 70 tonnes, designed and fabricated in the country conforming to relevant IAEA regulations.

3.7 Techno-Economic Aspects:

As already indicated, the proposed nuclear power programme envisages an installed capacity of about 10,000 MW(e) by the turn of the century. This is sought to be achieved by building a series of nuclear power stations comprising each of 235 MW(e) reactor units initially, followed by 500 MW(e) units in various zones in the country.

The strategy for sizing and siting of reprocessing plants to cater to the above nuclear power programme may range from small plants of 100-200 tonnes per annum capacity located at nuclear power station sites, presently being followed, to large size industrial plants at an independent site serving many stations, at a later date. While in industrialised countries, large capacity centralised reprocessing plants may be favoured for achieving economies of scale and on other considerations, experience has shown that the optimum capacity of a reprocessing plant is essentially a function of the parameters specific to the country in which it is located. Prominent among them are the growth of spent fuel arising from the installed nuclear capacity, average capacity factors achievable over the useful life span of the plant, infrastructural constraints like transportation problems, and environmental considerations. Another factor relevant while considering the size of a plant is the rate at which technological improvements are being made, which otherwise might render a larger plant obsolescent. Though economies of scale should be applicable under conditions of optimum utilisation, considering the growth of installed capacity for nuclear power in India and considering transport conditions, smaller plants of 100-200 tonnes per annum capacity have been considered optimum for at least sometime to come. Even with these small plants, the capital cost and unit cost of reprocessing are comparable to the costs reported for large plants elsewhere. This is due to lower construction and labour costs, lower engineering and commissioning costs and in view of government financing.

To give an idea of the costs, the Trombay Plant, which was commissioned in 1964 cost about Rs. 35 million (equivalent to about US $ 3.5 million). The cost of refurbishing this plant, after decommissioning, with expansion in capacity, has come to Rs. 50 million ($ 5.0 million). The Tarapur plant, constructed during the 70's has cost about Rs. 120 million ($12 million). The cost of the Kalpakkam plant is estimated at Rs. 1000 million ($ 100 million). The annual operating cost with fixed charge at 6½% on capital and allowing for the straight-line depreciation (with life of plant components between 10 to 20 years) is expected to be about $ 15 million. Thus, the unit cost of reprocessing, at 80% capacity, excluding the cost of fuel transportation and waste management, will be about $ 190 per Kg of heavy metal. The reprocessing cost in the Tarapur plant is, of course, lower than this. This may be compared to the reported cost of $ 314-763 per Kg (based on 1977 prices) for plants of 300 tonnes per annum design capacity.

4. WASTE MANAGEMENT

One of the persistent criticisms against nuclear power has been that the nuclear industry is still to demonstrate its ability to safely isolate the high level radioactive wastes generated in the nuclear fuel cycle, from man's environment. The primary waste stream of concern is the first cycle raffinate of the purex process from the reprocessing plant. Though volumes are low (500-800 lit./Te of fuel reprocessed) specific activities are high (about 3500 Ci/1). Presently the general practice in all the countries has been to store the high level radioactive wastes in liquid form, in high integrity stainless steel tanks located in underground concrete vaults. However, liquid storage at best can only be a temporary measure. Its conversion into a suitable solid form as soon as practicable offers distinct advantages of handling, transport, storage and ultimate disposal. Further, it also minimises the degree of surveillance and monitoring requirements.

The presently accepted management concept involves solidification of the wastes into a solid form with desired characteristics and its containerisation, dissipation of significant fraction of decay heat in a controlled manner in an engineered containment and finally disposal in a repository located in deep geological media. One waste form, which has been extensively studied in many countries, including India, upto industrial scale and with actual wastes, is the vitreous mass obtained by incorporation of high level wastes in glass matrices with significant part of the work based on alkali-borosilicate systems. This matrix has flexibility to accommodate the diverse elements present in the waste. Upto about 25% waste oxides can be accommodated in the matrix without deleterious effects on its characteristics. The glass has the following typical characteristics:

Pouring Temperature	: 1050 - 1100°C
Density	: 2.5 - 3 gm/cm^3

Thermal conductivity (upto 500°C)	: 1.2 - 1.5 w/m°C
Leach rate by dynamic leaching method	: 10^{-6} gm/cm^2 -day

4.1 Waste Immobilisation Plant at Tarapur:

A semi-continuous pot glass process, involving calcination followed by melting in the processing vessel and subsequent casting of the glass in a storage container has been developed and is adopted in the Waste Immobilisation Plant at Tarapur. Preconcentrated waste solution and glass forming additives in the form of slurry are metered separately into the process vessel located in a multi-zone induction furnace. A simplified schematic of the process is presented in Figure-2. The process vessel is 325 mm o.d., 1.8 m long, made of inconel 690 incorporating a freeze valve pipe section which is heated by an independent zone of the furnace. The feed solutions are distributed along the central 25 mm o.d. tube section which also acts as a thermowell to measure the centre-line temperature at different points along the length of the vessel. The furnace temperature is initially maintained at 600°C. As the feeding is continued the liquid in the process vessel becomes concentrated and is subsequently converted into a calcine mass. The feed is stopped when the vessel is around 75% full with calcine. At this stage the furnace temperature is raised to around 1100 to 1200°C and the calcine product melts down. To achieve homogeneity, the glass is kept in the molten condition for about four to six hours. The molten glass is then drained into the storage container by operating the freeze valve section. The storage container is located in an annealing furnace programmed to adjust cooling rates based on the temperature of the product, to ensure that the product is cooled gradually so as to ensure its integrity and homogeneity. The storage container is subsequently sealed by remote welding and decontaminated. The storage container is 325 mm in dia., 0.75 m long and is constructed of stainless steel AISI type 304L. The total weight of the glass in the container is about 125 Kg., and heat release is about 1.75 KW. Two furnace units operate in a staggered operating cycle. The plant has a nominal capacity of 25 litres per hour with each of the furnace rated for production of 4 Kg., of glass in an hour.

Some important problems, which need to be kept in mind in designing such a plant are indicated below:-

i) Volatilisation of semi-volatile radionuclides such as ruthenium and cesium during the evaporation and calcination steps could post problems. This is tackled by control of the process conditions, like acidity, condensation of the volatile fraction and recycling it.

ii) Control of homogeneity of the glass and assurance that the glass cast into storage canister, retains its monolithic nature is very important. This is achieved by selection of proper glass composition, controlling the feed streams to the process and providing sufficient soaking time at the melting step. The glass after casting into the storage canister is cooled at a pre-determined rate using a programmable annealing furnace.

iii) The process, being semi-continuous one, involves a number of mechanical operations. It is essential that the waste transfer system, remote handling and maintenance system are of very high reliability. For active liquid transfers, multiple modes of transfers are provided. For control of feed, 2-stage air lift transfer is employed as the primary mechanism. Remote-head double-diaphragm pumps are also used for controlled and metered transfer. To enable remote operation and maintenance, remote handling equipment such as power manipulators, master slave manipulators and in-cell cranes, and remote viewing equipment such as shielding glass, CCTV and periscopes are provided in the cell.

For achieving the remote operation and maintenance of the process equipment, such equipment are grouped together on functional basis and housed within tubular structures serving as modules, complete with their own process services and instrumentation etc. Intermodular piping connectors and pipe jumpers which can be operated with manipulators and impact wrenches are provided. Equipment which may need replacement such as online instruments, heaters, filters, remote heads of the metering pumps, etc., are mounted on one phase of the module such that they can be removed and replaced with ease. One of the most critical modules where a number of operations are to be carried out on a routine basis is the furnace module. The furnace itself is mounted on a trolley, facilitating the removal and replacement of the process canister; such removals are expected to occur once in every 20 to 25 cycles. The welding of the storage canister is carried out using a specially developed welding unit and is based on pulsed TIG welding. The portable welding head is mounted over the canister lid where it gets positioned precisely by means of a locating pin mating with a hole machined to very close tolerance to the lid. An electric motor incorporated in the welding head enables the torch to move around the circumference of the lid. The entire welding operation is carried out automatically by a power supply system complete with automatic programming of welding current, arc starting, current pulsation and sequencing of external controls.

The Waste Immobilisation Plant at Tarapur is presently under commissioning trials and should go into active operation before the end of this year.

4.2 Interim Solid Storage:

It is recognised that engineered storage in near surface facilities would be required for conditioning of high level wastes prior to disposal. As mentioned earlier, this is primarily required to reduce the heat load in the waste form such that ultimate repository can be optimally loaded. This will also minimise deleterious thermal effects on the waste form. A number of concepts can be used for interim solid storage. Among them are water pools with extension of the spent fuel storage technology, air cooled vaults with forced or natural convective air cooling, and sealed casks stored on the surface. AVM plant at Marcoule uses forced air circulation system, while the Tarapur plant in India will employ air cooled vault with convective air circulation system. A schematic view of this facility is presented in Figure-3.

The facility is designed to store waste canisters produced over a period of about 20 years with provisions for continuous cooling, surveillance and monitoring. The canister is 324 mm outside diameter and 770 mm long and contains 45 litres of waste with a projected heat generation of about 1.75 KW. Two such canisters are enclosed in a secondary container and the container is totally sealed by remote welding the lid on, thus yielding a storage unit.

The storage units are arranged vertically on a triangular pitch of 825 x 825 mm. The cooling air enters through a screen to an inlet air-corridor and is distributed into the compartments through well designed ducts. The cooling system utilises the decay heat and a suitably designed stack to provide the driving force for the movement of air through the storage vault. The design of the vault ensures the balancing of all relevant parameters yielding the correct ventilation, stack height, inlet port parameters, storage unit array and filling pattern. The system will be self-regulating and can compensate for changes in heat load or weather conditions.

4.3 Ultimate Disposal:

Extensive efforts are directed in many countries towards development of disposal systems in geological formations. A number of concepts including mine tunnel repositories deep-hole repositories, etc., are being evaluated. Various host rocks, such as salt, shale, clay, granite and other hard rocks are under investigation to assess their suitability for the location of repositories. With the present technology many of these concepts appear feasible. Our efforts are presently primarily concentrated on location of suitable host rocks and sites for location of ultimate repositories, repository design and safety analysis.

4.4 Waste Management Costs:

As in case of reprocessing, the cost of management of the waste generated from reprocessing of spent fuel would depend on the technological and economic conditions prevailing in the country. In India, presently, the cost of management of high level radioactive wastes including the projected cost of disposal works out to about Rs. 720/- (US $ 72) per Kg of heavy metal reprocessed. The cost analysis again assumes $6\frac{1}{2}\%$ interest on capital and 20 years as average life of the plant. Research and development costs at 2 per cent of the capital investment have also been included.

The above cost works out to about 0.5 - 1.4 paise (0.5 - 1.4 mills) per KWh of electricity generated depending upon whether the fuel has come from the BWR or the PHWR. This indicates that the impact of waste management on cost of electricity generation is only marginal.

5. CONCLUSION

In conclusion, it can be said that the technological base for reprocessing of irradiated nuclear fuel and management of highly radioactive waste has been well established in India for successful implementation of the nuclear power programme. Research and development efforts are constantly directed towards strengthening this case. The need for specially trained manpower was recognised at the very early stage and intensive training courses are being organised regularly for the operating personnel.

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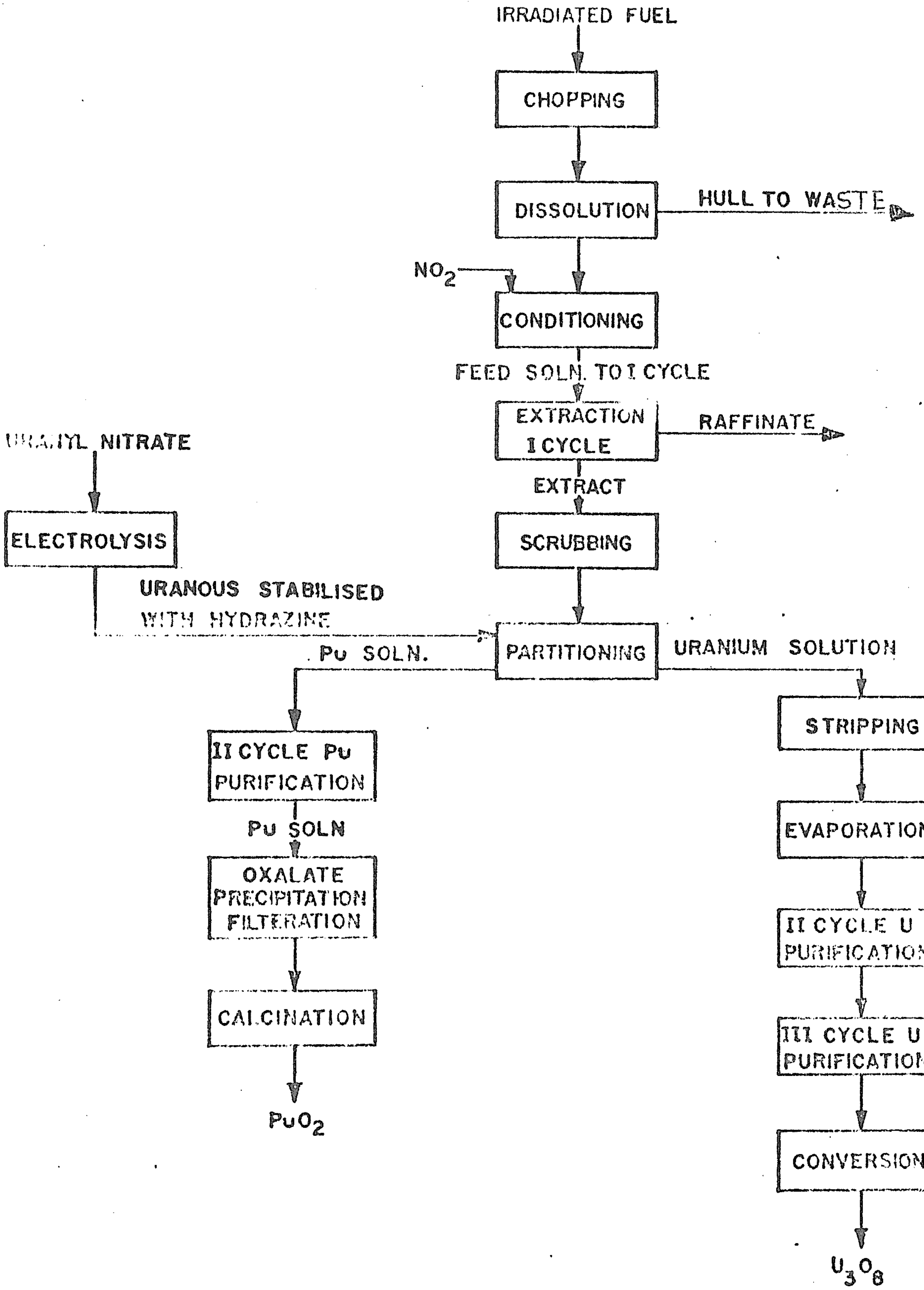

FIG.1. SEPARATION OF PLUTONIUM, URANIUM AND FISSION PRODUCTS.

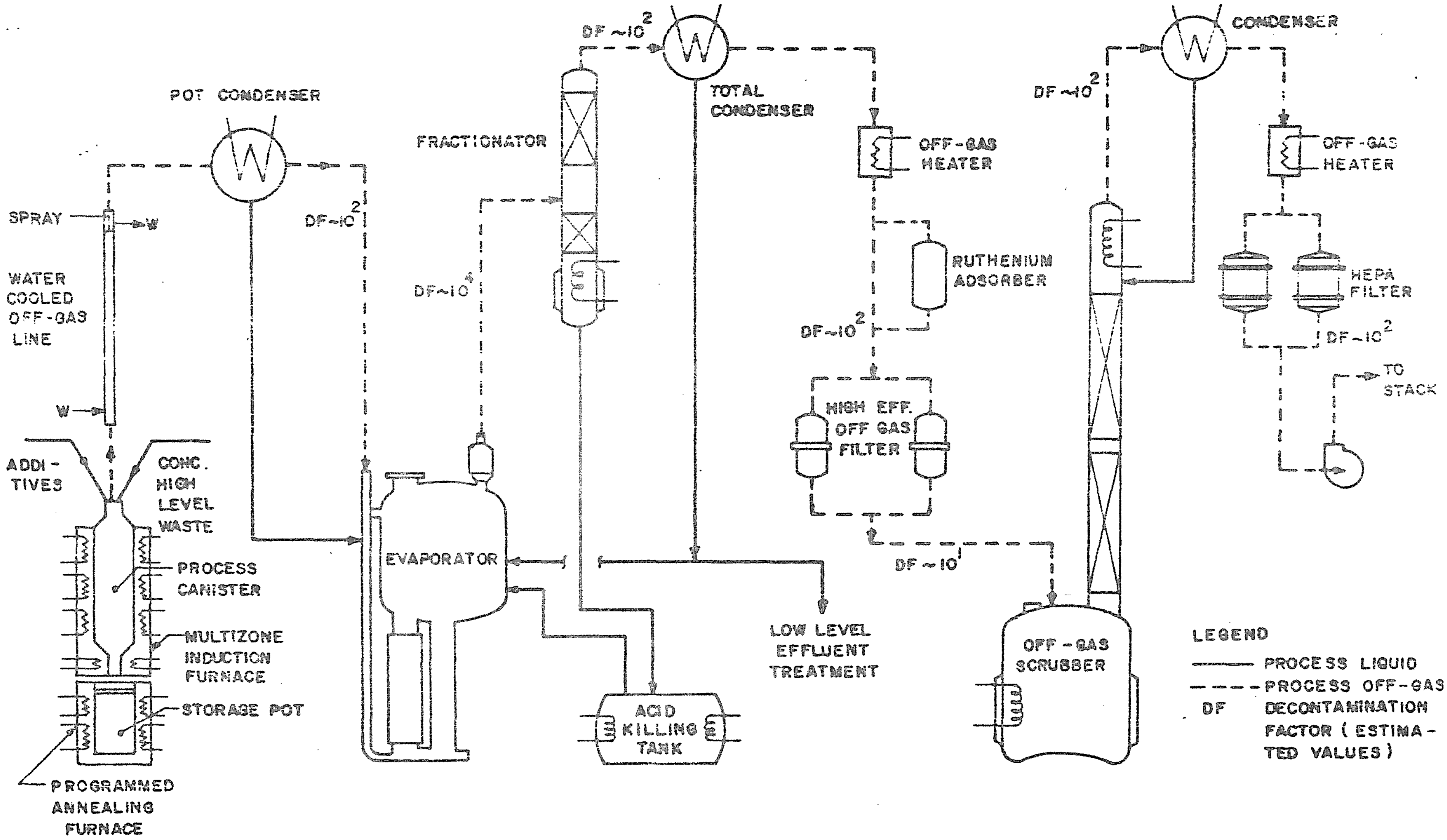

FIG. 2 SIMPLIFIED PROCESS SCHEMATIC
WASTE IMMOBILISATION PLANT, TARAPUR

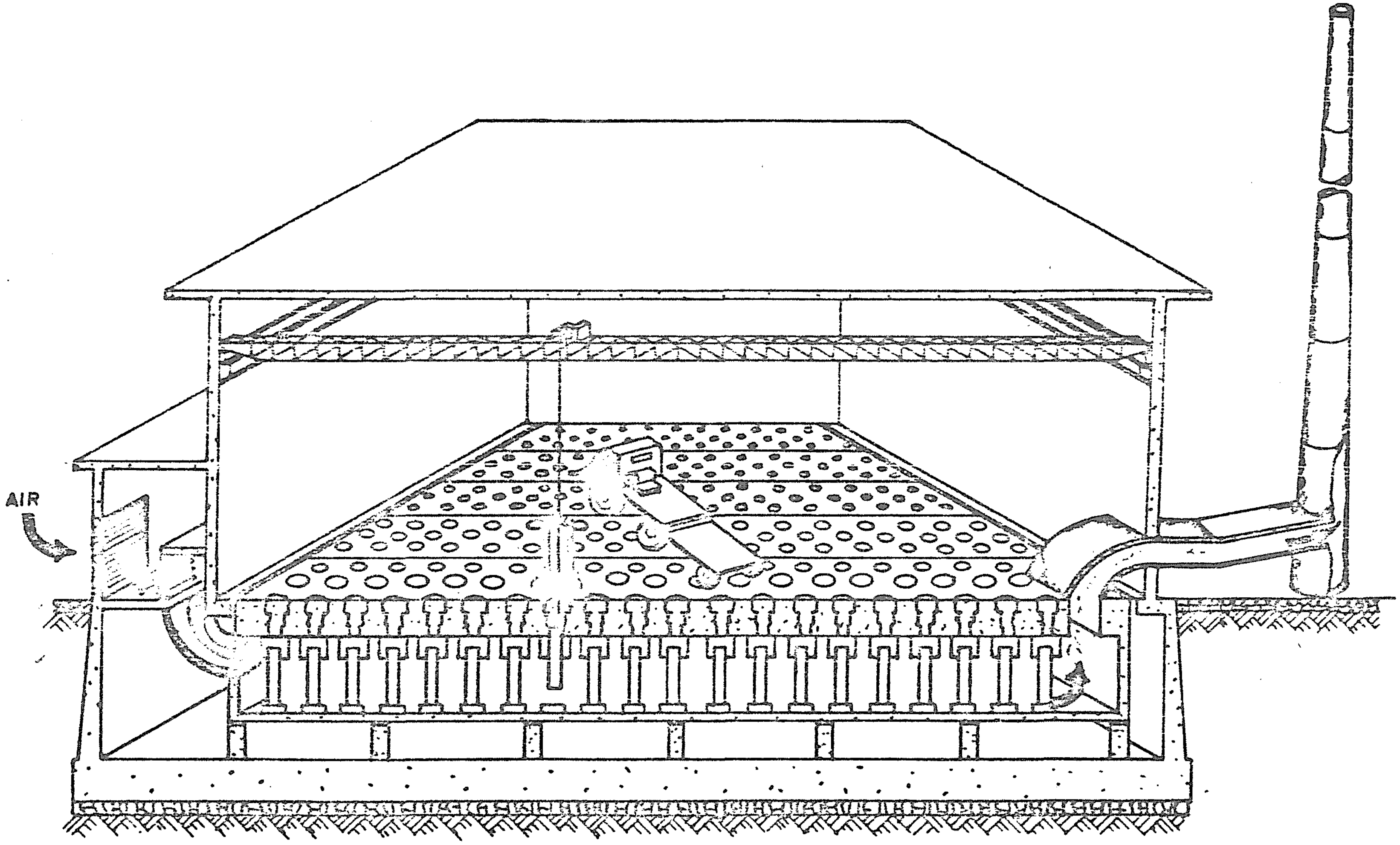

FIG.3 . SCHEMATIC VIEW OF AIR-COOLED STORAGE FACILITY AT TARAPUR

March 23

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JAPAN ATOMIC INDUSTRIAL FORUM

SIXTEENTH ANNUAL CONFERENCE

MARCH 23-25, 1983

TOKYO, JAPAN

U.S. ENERGY POLICY & INTERNATIONAL NUCLEAR DEVELOPMENTS

SHELBY T. BREWER
ASSISTANT SECRETARY FOR NUCLEAR ENERGY
UNITED STATES DEPARTMENT OF ENERGY

Introduction

I am very pleased to participate in this 16th Conference of the Japan Atomic Industrial Forum. I welcome this opportunity to take part in your discussion and to exchange ideas as we all seek solutions to our common problems.

The history of nuclear development in the United States has been one of international cooperative relationships. The Atoms for Peace program, begun in 1954, provided the groundwork for the concepts underlying the International Atomic Energy Agency, the Nuclear Nonproliferation Treaty, and the whole structure of peaceful international nuclear exchange. The basic philosophy of this approach is that the United States would provide technical information in nuclear programs--from the use of isotopes in medicine to the behavior of nuclear fuel in power reactors--to other countries in exchange for a guarantee that they would not attempt to obtain nuclear weapons or to pursue their development. Since the early beginnings of nuclear power development, our country has been at the forefront of nuclear fuel cycle and related technology advancements--enrichment, reprocessing, waste management, spent fuel handling, reactor safety, safeguards, and advanced breeder reactors. Many of our developments in these areas have been shared with our friends and allies through technology transfer arrangements. At our institutions and research facilities, we have provided training for thousands of nuclear scientists from around the world.

WE ARE PROUD OF THE U.S. CONTRIBUTION TO THE GLOBAL INTRODUCTION OF NUCLEAR TECHNOLOGY, AND WE ALSO RECONGNIZE AND APPRECIATE THE SIGNIFICANT CONTRIBUTIONS MADE BY OTHER NUCLEAR NATIONS. OUR TECHNOLOGICAL COLLABORATION, EXERCISED THROUGH BILATERAL AGREEMENTS AND INTERNATIONAL ORGANIZATIONS, HAS ENABLED GREAT STRIDES IN THE ECONOMIC AND SOCAL ADVANCEMENT OF OTHER COUNTRIES. THE REAGAN ADMINISTRATION STRONGLY ENDORSES THE PRINCIPLE OF INTERNATIONAL COMMITMENT TO PEACEFUL APPLICATIONS OF NUCLEAR POWER AND HAS ESTABLISHED NATIONAL ENERGY POLICIES TO CONTINUE AND REINFORCE IT.

OUR NEW SECRETARY OF ENERGY, DONALD HODEL, ARTICULATED OUR COUNTRY'S COMMITMENT TO THE PHILOSOPHY OF AN INTERNATIONAL ENERGY COMMUNITY AT HIS CONFIRMATION HEARING BEFORE THE UNITED STATES SENATE ON DECEMBER 1, 1982. HE SAID, "A PURPOSEFUL ENERGY POLICY IS CRUCIAL FOR THIS COUNTRY AND FOR THE REST OF THE WORLD. WHAT CONGRESS AND THE ADMINISTRATION DO ABOUT ENERGY HAS GLOBAL IMPLICATIONS, FOR ALTHOUGH WHAT WE DO IN THE UNITED STATES MAY CAUSE ONLY RIPPLES ON THE ENERGY SHORES OF OUR SOCIETY, IT MAY CAUSE TIDAL WAVES ON THE ENERGY SHORES OF OTHER NATIONS ESPECIALLY IN THE DEVELOPING COUNTRIES... IT IS MY INTENTION THAT THE DEPARTMENT OF ENERGY, WORKING CLOSELY WITH THE SECRETARY OF STATE AND THE NATIONAL SECURITY COUNCIL, CONTINUE ITS EFFORTS TO FORGE CLOSE COOPERATION WITH KEY ENERGY IMPORTING AND EXPORTING NATIONS ON A WIDE RANGE OF INTERNATIONAL ENERGY POLICY ISSUES."

AS THE U.S. AND OTHER COUNTRIES PURSUE ENERGY SECURITY THROUGH THE ESTABLISHMENT OF WISE ENERGY POLICIES AND THE DEVELOPMENT AND

DEPLOYMENT OF PROMISING TECHNOLOGIES, NO OPTION HAS A GREATER AND MORE CRUCIAL ROLE THAN NUCLEAR ENERGY.

STATUS OF NUCLEAR POWER IN THE UNITED STATES

NUCLEAR ENERGY CONTRIBUTES OVER 12 PERCENT OF THE COUNTRY'S TOTAL ELECTRICAL SUPPLY AND IN SOME REGIONS THE CONTRIBUTION IS SIGNIFICANTLY HIGHER (FIGURE 1). IT EMPLOYS OVER 300,000 PEOPLE, A LARGE PROPORTION OF THEM TECHNICALLY TRAINED OR HIGHLY SKILLED. BY 1990, AS ADDITIONAL PLANTS IN THE PIPELINE BEGIN OPERATION, THE NUCLEAR SHARE OF GENERATION WILL CLIMB TO OVER 20 PERCENT OF THE TOTAL (FIGURES 2 AND 3). THE IMPACT OF THIS GROWTH ON THE COUNTRY'S ECONOMY WILL BE SUBSTANTIAL. IT HAS BEEN ESTIMATED THAT NUCLEAR-PLANT CONSTRUCTION EXPENDITURES FOR THE REMAINDER OF THE DECADE SHOUL BE ABOUT $75 BILLION AND THAT THE ENSUING MARKET FOR SERVICING AND FUELING NUCLEAR PLANTS SHOULD PROVIDE ANOTHER $40 TO $60 BILLION WORTH OF BUSINESS.

OVER THE LAST DECADE, NUCLEAR ENERGY HAS OFFERED STEADY, RELIABLE POWER DURING SEVERE WEATHER CONDITIONS, LABOR DISPUTES AND, MOST IMPORTANTLY, FUEL SUPPLY INTERRUPTIONS. DESPITE THIS IMPRESSIVE PERFORMANCE, WE HAVE A SITUATION IN OUR DOMESTIC NUCLEAR MARKET WHEREIN NO NUCLEAR PLANTS HAVE BEEN ORDERED SINCE 1978 AND A STEADILY MOUNTING NUMBER OF PLANTS ARE BEING CANCELLED (FIGURE 4).
THE NUCLEAR INDUSTRY, WHICH WAS THRIVING AND EXPANDING IN THE EARLY 1970'S, HAS LOST ITS MOMENTUM IN OUR COUNTRY. INTERNATIONAL NUCLEAR PARTNERSHIPS HAVE BEEN DISRUPTED AND PUBLIC APPREHENSIONS HAVE INCREASED. AUTHORITATIVE ENERGY STUDIES HAVE ENVISIONED NUCLEAR

1981 Electrical Generation by Nuclear Power

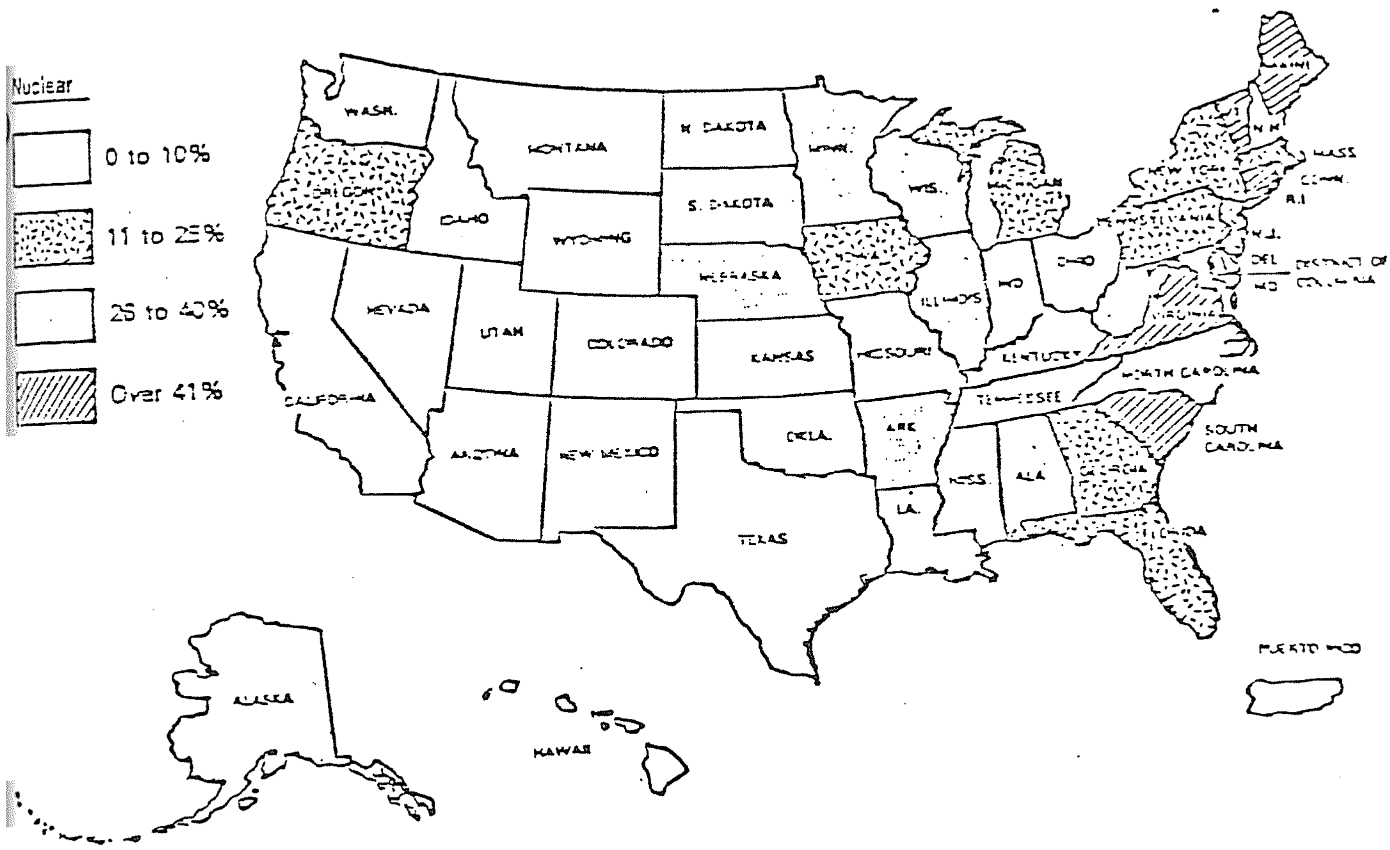


Figure 1

U.S. NUCLEAR PLANTS
SCHEDULE OF COMMERCIAL OPERATION
AS OF APRIL 1, 1982

	MWE Net		No. of Units	
Year	New	Cumulative	New	Cumulative
1980	1,819.0	53,068.0	2	72
1981	4,272.0	57,340.0	4	76
1982	4.226.0	61,566.0	4	80
1983	14,566.0	76,132.0	14	94
1984	15,241.4	91,373.0	14	108
1985	7,451.0	98,824.4	7	115
1986	13,778.8	112,603.2	12	127
1987	4,558.0	117,161.2	4	131
1988	2,365.0	119,526.2	2	133
1989	1,838.0	121,364.2	2	135
1990 on	3,700.0	125,064.2	3	138
Indefinite	24,416.4	149.480.6	21	159

Figure 2

ELECTRICITY PRODUCTION BY VARIOUS FUELS

(PERCENTAGES)

	Actual 9/81 — 8/82	Projected 1990	2000
	52.9	56.9	59.3
...ar	12.3	22.3	24.7
...o	13.1	10.2	9.3
...Technologies ...)	.2	.9	2.6
	7.4	2.8	1.3
...al Gas	14.0	6.2	2.9
...rts	—	.7	0

Figure 3

ANNUAL ORDERS AND CANCELLATIONS OF NUCLEAR GENERATING CAPACITY BY U.S. UTILITIES

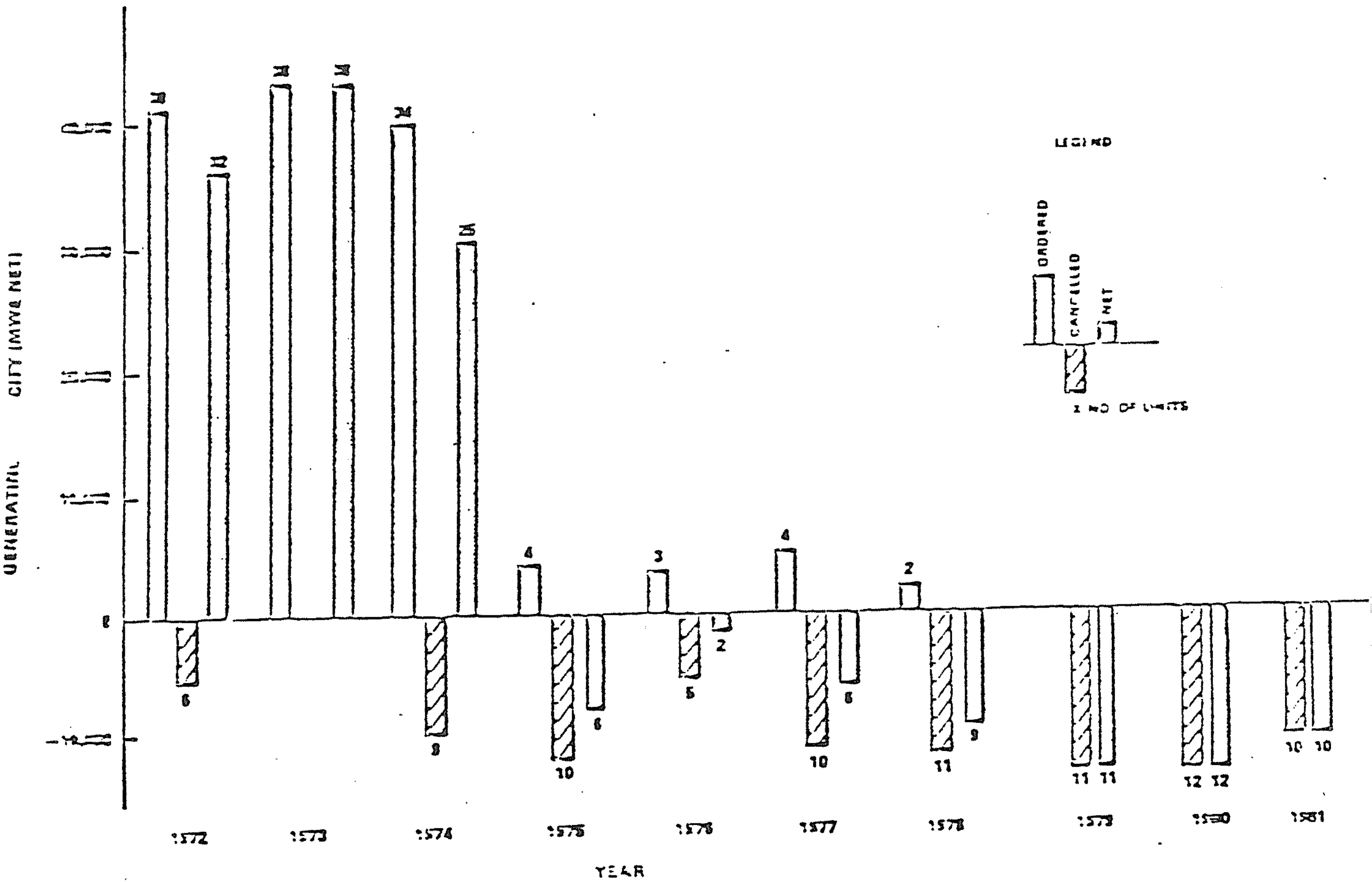
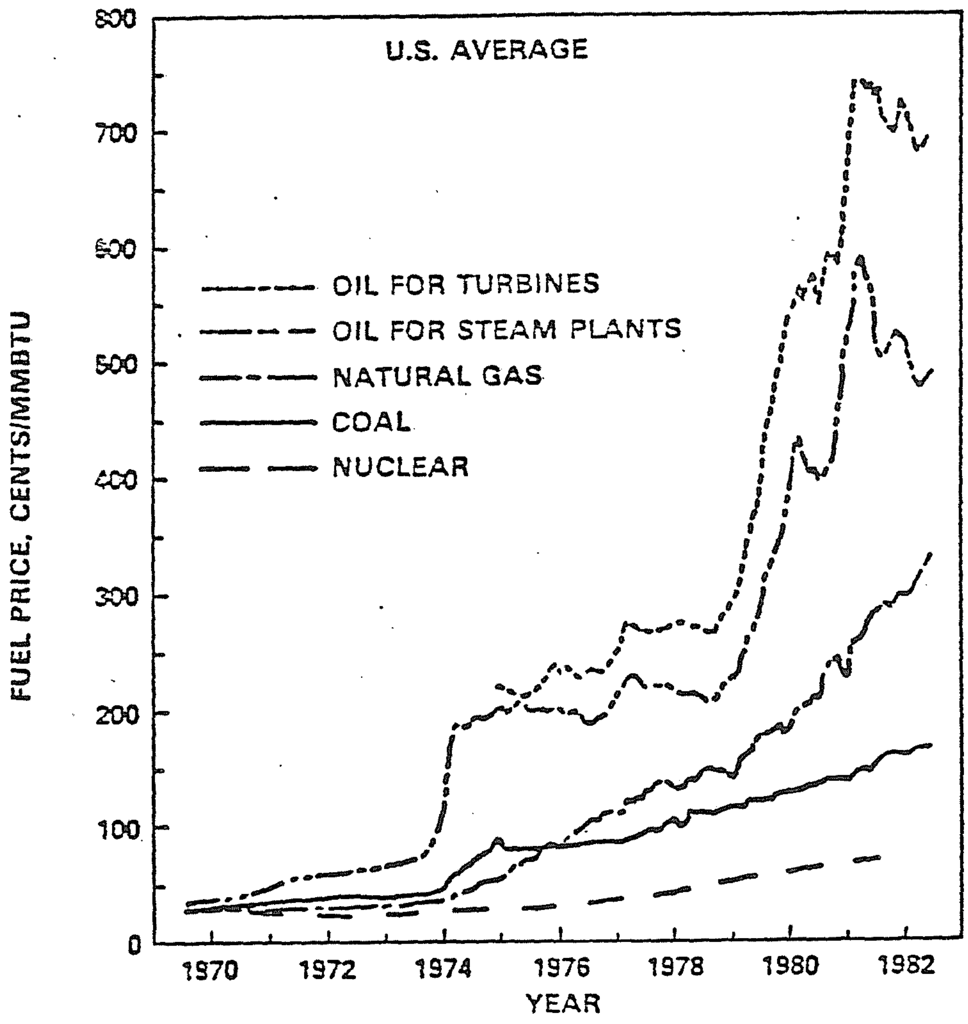


Figure 4

UTILITY FUEL COSTS



Source of this data?

Figure 5

ENERGY AS ONE OF THE TWO PRINCIPAL FUEL SOURCES, WITH COAL, THAT COULD SUPPORT EXPANDED U.S. ENERGY REQUIREMENTS AND REDUCE OUR DEPENDENCE ON FOREIGN OIL, BUT THE IMMEDIATE PROMISE AND FUTURE POTENTIAL OF THIS ABUNDANT ENERGY SOURCE HAVE BEEN SEVERELY THREATENED.

THE REASONS FOR THIS STAGNATION ARE INSTITUTIONAL RATHER THAN TECHNICAL. NUCLEAR POWER CONTINUES TO ENJOY A MASSIVE ADVANTAGE OVER OTHER SOURCES IN TERMS OF FUEL CYCLE COSTS (FIGURE 5). IT CONTINUES TO BE COMPETITIVE, IF NOT SLIGHTLY PREFERRED, IN TERMS OF TOTAL BUS-BAR GENERATING COSTS, INCLUDING PLANT CAPITAL, FUEL, AND OPERATING AND MAINTENANCE COSTS. NEVERTHELESS, NUCLEAR INVESTMENT HAS NOT BEEN AN INVITING PROSPECT FOR UTILITY EXECUTIVES OVER THE LAST SEVERAL YEARS. A LICENSING PROCESS THAT CONDONES EXCESSIVE, REDUNDANT INTERVENTION HAS AMPLIFIED NORMAL MARKET UNCERTAINTIES. LEAD TIMES FOR DESIGN, LICENSING AND CONSTRUCTION HAVE INCREASED TO AN ABSURD EXTENT. ALTHOUGH THE LICENSING PROCESS IS NOT THE SOLE REASON, NUCLEAR PLANTS NOW TAKE 10-14 YEARS TO SITE, DESIGN, LICENSE OR PERMIT, AND CONSTRUCT; A DECADE AGO SUCH ACTIVITIES COULD BE ACCOMPLISHED IN 5 TO 6 YEARS (FIGURE 6). SEVERAL COUNTRIES, INCLUDING SOME REPRESENTED AT THIS CONFERENCE, CAN STILL BRING A SAFE, RELIABLE PLANT ON LINE IN A REASONABLE PERIOD OF TIME. THE HESITATION OF THE U.S. UTILITIES, OR RATHER THEIR INVESTORS, TO PUT MONEY INTO A PLANT THAT HAS A LEADTIME OF 10 TO 14 YEARS IS UNDERSTANDABLE.

NUCLEAR POWER PLANT PROJECT LEAD TIMES

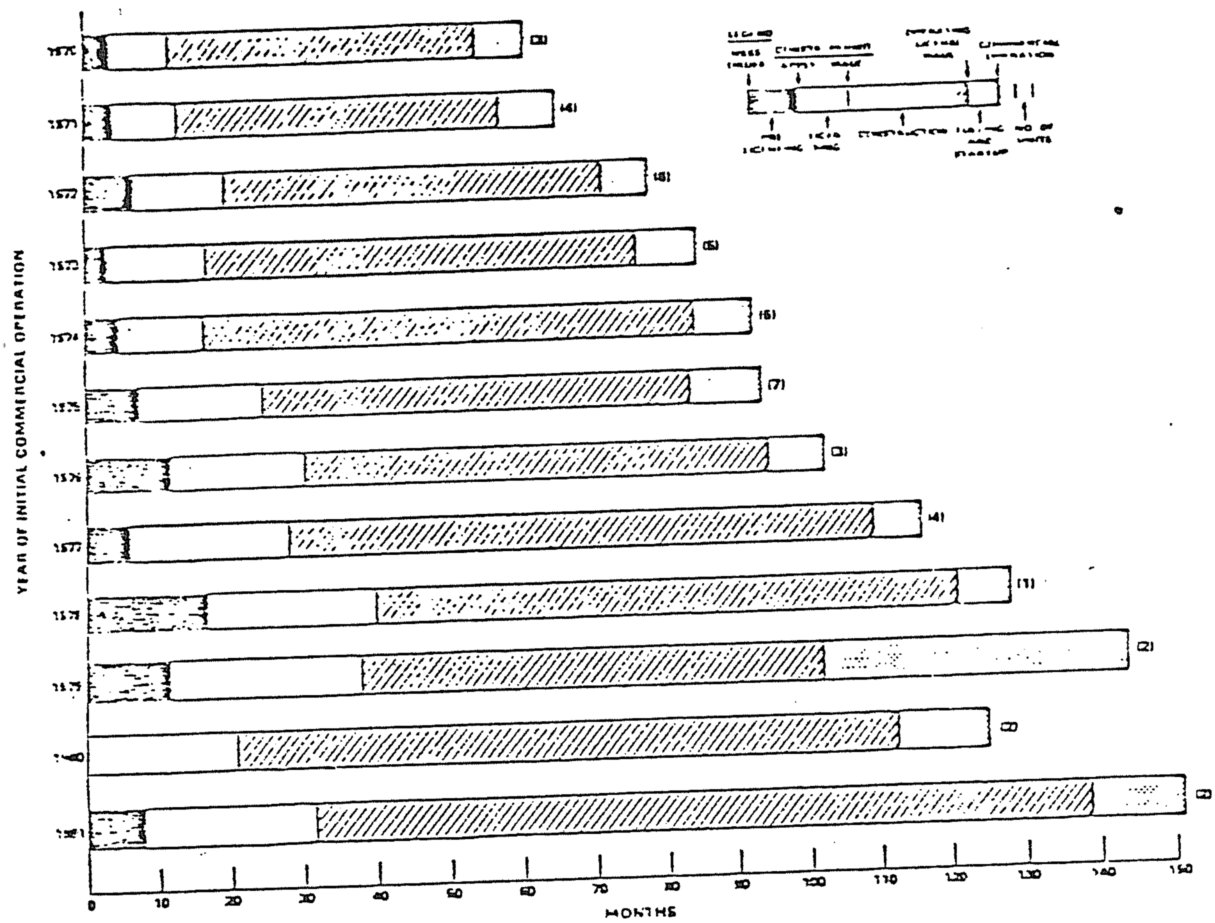


Figure 6

NUCLEAR POWER BY REMOVING UNNECESSARY REGULATORY AND INSTITUTIONAL IMPEDIMENTS THAT HAVE DEVELOPED OVER THE YEARS; BY FULFILLING ITS RESPONSIBILITIES FOR CERTAIN ELEMENTS OF THE FUEL CYCLE, SUCH AS HIGH-LEVEL WASTE DISPOSAL AND URANIUM ENRICHMENT; AND BY CONDUCTING HIGH-COST, HIGH-RISK, RESEARCH AND DEVELOPMENT THAT IS OF SIGNIFICANT BENEFIT TO THE NATION BUT BEYOND THE CAPABILITY OF THE PRIVATE SECTOR. ULTIMATELY, HOWEVER, IT IS THE RESPONSIBILITY OF INDUSTRY TO MAKE THE MARKET-PLACE DECISIONS FOR EXPANSION AND DEPLOYMENT.

ON OCTOBER 8, 1981, PRESIDENT REAGAN ISSUED A REVISED U.S. NUCLEAR POLICY THAT RECOGNIZES BOTH THE POTENTIAL OF NUCLEAR ENERGY AND THE IMPEDIMENTS CURRENTLY RESTRICTING ITS FULL USE IN OUR COUNTRY. ALTHOUGH THE CONSTRUCTION AND OPERATION OF NUCLEAR POWERPLANTS IS A PRIVATE SECTOR ACTIVITY IN OUR COUNTRY, THE FEDERAL GOVERNMENT PLAYED A KEY ROLE IN SHAPING THE NUCLEAR POWER INDUSTRY AND IS RESPONSIBLE, IN PART, FOR SOME OF THE CURRENT PROBLEMS FACING THE NUCLEAR INDUSTRY AND THE ELECTRIC UTILITIES TODAY. TO ADDRESS THESE PROBLEMS AND ALLOW NUCLEAR POWER TO COMPETE, FREE OF CONSTRAINT, IN THE MARKETPLACE, SEVERAL MAJOR GOVERNMENT POLICY INITIATIVES WERE ANNOUNCED. THEY INCLUDE:

- IMPROVEMENT IN THE NUCLEAR LICENSING PROCESS AND IN THE ENTIRE INSTITUTIONAL AND FINANCIAL ENVIRONMENT OF THE ELECTRIC UTILITIES;

- SWIFT ESTABLISHMENT OF A NUCLEAR WASTE DISPOSAL CAPABILITY;

- DEMONSTRATION OF BREEDER REACTOR TECHNOLOGY INCLUDING EXPEDITIOUS COMPLETION OF THE CLINCH RIVER BREEDER REACTOR; AND

- STABLE LONG-TERM POLICIES TO ENCOURAGE COMMERCIAL REPROCESSING.

THESE FOUR INITIATIVES CORRESPOND TO THE STRATEGY ELEMENTS THAT THE NUCLEAR PIONEERS ENVISIONED DECADES AGO AS NECESSARY FOR ACHIEVING THE FULL POTENTIAL OF FISSION ENERGY (FIGURE 7). THE DEGREE OF SUCCESS IN ACCOMPLISHING THEM WILL SUBSTANTIALLY DETERMINE THE FUTURE CONTRIBUTION THAT NUCLEAR POWER WILL MAKE TO ENERGY SECURITY IN THE UNITED STATES.

EARLIER IN 1981, PRESIDENT REAGAN HAD ANNOUNCED THE POLICY GOVERNING U.S. NONPROLIFERATION ACTIVITIES. HE IDENTIFIED "A STRONG AND DEPENDABLE UNITED STATES, VIBRANT ALLIANCES AND IMPROVED RELATIONS WITH OTHERS, AND A DEDICATION TO THOSE TASKS THAT ARE VITAL FOR A STABLE WORLD ORDER" AS VITAL TOOLS IN REDUCING THE RISKS OF NUCLEAR PROLIFERATION. FURTHER, HE PLEDGED PRIORITY ATTENTION TO RESTORING THE U.S. POSITION OF LEADERSHIP IN INTERNATIONAL NUCLEAR AFFAIRS. HE SAID, "THE UNITED STATES WILL COOPERATE WITH OTHER NATIONS IN THE PEACEFUL USES OF NUCLEAR ENERGY, INCLUDING CIVIL NUCLEAR PROGRAMS TO MEET THEIR ENERGY SECURITY NEEDS UNDER A REGIME OF ADEQUATE SAFEGUARDS AND CONTROLS. MANY FRIENDS AND ALLIES OF THE UNITED STATES HAVE A STRONG INTEREST IN NUCLEAR POWER AND HAVE, DURING RECENT YEARS, LOST CONFIDENCE IN THE ABILITY OF OUR NATION TO RECOGNIZE THEIR NEEDS. WE MUST REESTABLISH THIS NATION AS A PREDICTABLE AND RELIABLE PARTNER FOR PEACEFUL NUCLEAR COOPERATION UNDER ADEQUATE SAFEGUARDS. THIS IS ESSENTIAL TO OUR NONRPOLIFERATION GOALS. IF WE ARE NOT SUCH A PARTNER,

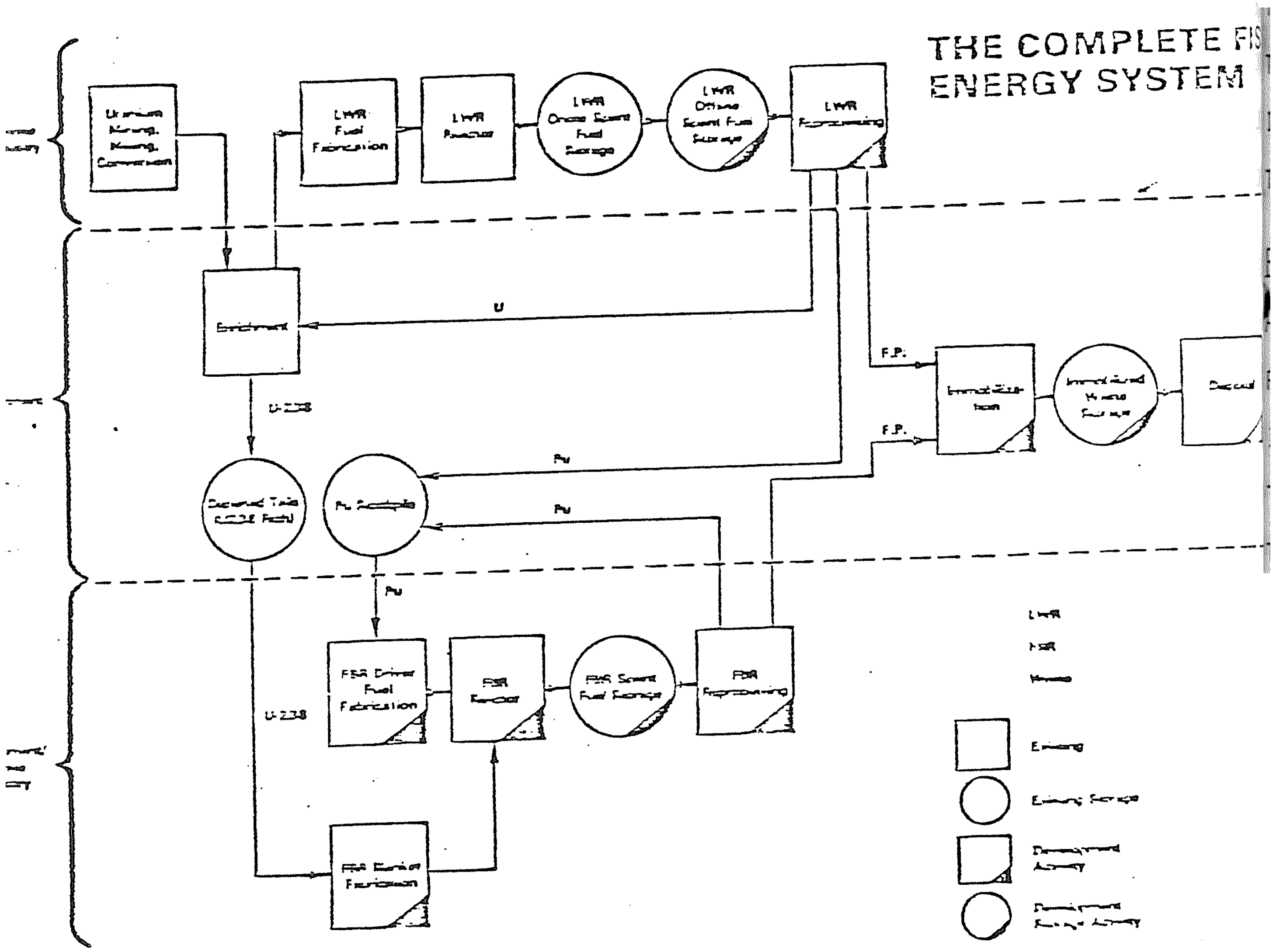

THE COMPLETE FIS
ENERGY SYSTEM
Uranium Mining, Milling, Conversion
LWR Fuel Fabrication
LWR Reactor
LWR Onsite Spent Fuel Storage
LWR Offsite Spent Fuel Storage
LWR Reprocessing
Enrichment
U
U-238
F.P.
F.P.
Pu
Pu
Pu
Pu Stockpile
FBR Driver Fuel Fabrication
FBR Reactor
FBR Spent Fuel Storage
FBR Reprocessing
U-238
FBR Blanket Fabrication
LWR
FBR
Existing

Figure 7

OTHER COUNTRIES WILL TEND TO GO THEIR OWN WAYS, AND OUR INFLUENCE WILL DIMINISH. THIS WOULD REDUCE OUR EFFECTIVENESS IN GAINING THE SUPPORT WE NEED TO DEAL WITH PROLIFERATION PROBLEMS."

THE REMAINDER OF THIS PAPER WILL DESCRIBE THE ACTIONS THAT HAVE BEEN TAKEN IN THE UNITED STATES TO IMPLEMENT THESE POLICY CHANGES AND WILL IDENTIFY WHAT REMAINS TO BE DONE. IT WILL ALSO DISCUSS THE IMPLICATIONS THAT OUR DOMESTIC STRATEGY HOLDS FOR INTERNATIONAL COOPERATION.

REGULATORY AND LICENSING REFORM

AS I STATED EARLIER, THE CURRENT PROCESS FOR LICENSING U.S. NUCLEAR PLANTS NO LONGER MEETS THE NEEDS OF THE PUBLIC, THE REGULATOR, OR THE INDUSTRY. ESTABLISHED AS A METHOD OF LICENSING NUCLEAR PLANTS WHEN THE TECHNOLOGY WAS DEVELOPMENTAL AND WHEN LICENSE APPLICATIONS WERE FEW, THE CURRENT PROCESS IS OUTMODED AND ILL-SUITED FOR REGULATING A MAJOR NATIONAL ENERGY SOURCE. FURTHER, IT IS NOT CLEAR THAT THE TOTALITY OF REGULATORY REQUIREMENTS, ADDED IN AN AD HOC AND PRESCRIPTIVE FASHION OVER THE YEARS, HAS LED TO AN INCREASE IN OPERATIONAL SAFETY OF NUCLEAR PLANTS. MANY ARGUE JUST THE OPPOSITE--COMPLEXITY AND EXCESSIVE ATTENTION TO POSTULATED LOW PROBABILITY EVENTS TEND TO RESULT IN PLANTS THAT MAY, IN FACT, BE LESS SAFE OPERATIONALLY.

AFTER CONSULTING EXTENSIVELY WITH INDUSTRY, REGULATORS, UTILITIES, THE SCIENTIFIC AND ACADEMIC COMMUNITY, NATIONAL AND STATE GOVERNMENTAL BODIES, AND PUBLIC INTEREST GROUPS, THE DEPARTMENT OF ENERGY HAS ARRIVED AT A SET OF RECOMMENDATIONS TO REFORM AND STREAMLINE THE REGULATORY AND LICENSING PROCESS. SOME OF THESE OBJECTIVES, WE BELIEVE, COULD BE ACCOMPLISHED THROUGH CHANGES IN THE ADMINISTRATIVE PROCEDURES OF THE

U.S. NUCLEAR REGULATORY COMMISSION. OTHERS WILL REQUIRE LEGISLATION, AND I AM PLEASED TO TELL YOU THAT THIS PAST FRIDAY, MARCH 18, WE SENT TO CONGRESS A COMPREHENSIVE LEGISLATIVE PROPOSAL.

WE BELIEVE ENACTMENT OF THESE MEASURES WOULD PROVIDE INCREASED BENEFITS TO THE PUBLIC, TO THE UTILITIES AND THEIR SUPPLY INDUSTRIES, AND TO THE REGULATORS. THE IMPLEMENTATION OF THESE REFORMS WILL HAVE SIGNIFICANCE TO TWO POPULATIONS OF PLANTS--THOSE CURRENTLY OPERATING OR IN THE CONSTRUCTION PIPELINE AND NEW PLANTS THAT THE NATION NEEDS TO BRING ON LINE IN THE FUTURE.

FIRST, WE ARE RECOMMENDING A MORE DISCIPLINED AND COHERENT PROCESS FOR BACKFITTING--THAT IS, A MORE RIGOROUS CRITERIA FOR DETERMINING WHETHER BACKFITS ARE NECESSARY OR COST-EFFECTIVE. SECONDLY, WE ARE RECOMMENDING A ONE-STEP LICENSING PROCESS THAT COULD SAVE SUBSTANTIAL CONSTRUCTION TIME BY PERMITTING EARLY COMPLETION OF PLANT DESIGN, AND ALLOWING THE NUCLEAR REGULATORY COMMISSION TO ISSUE A LICENSE THAT WOULD AUTHORIZE BOTH CONSTRUCTION AND OPERATION. WE BELIEVE A NATURAL ADJUNCT TO ONE-STEP LICENSING IS PREAPPROVAL OF SITES AND DESIGNS. THIS WOULD PERMIT UTILITIES TO SELECT FROM AND MATCH TOGETHER STANDARDIZED REACTOR DESIGNS AND PRE-APPROVED SITES. FINALLY, WE ARE RECOMMENDING MAJOR CHANGES IN THE HEARING PROCESS. OUR REVISIONS WOULD REORIENT THE FORMAL HEARINGS TOWARD CONSIDERATION OF IMPORTANT DISPUTED AREAS AND THOSE ISSUES THAT ARE CRITICAL TO FINAL LICENSING DECISIONS. THE PROCESS SHOULD NOT BE A FORUM TO EXPRESS RANDOM AND UNFOUNDED COMPLAINTS ABOUT NUCLEAR POWER, BUT RATHER A PROCEDURE FOR RESOLVING DISPUTES ON SPECIFIC ISSUES PERTINENT TO PUBLIC HEALTH AND SAFETY.

PROVIDING A REGULATORY PROCESS THAT OFFERS PREDICTABLE CRITERIA FOR TING, DESIGN AND CONSTRUCTION OF POWERPLANTS AND PREDICTABLE SCHEDULES R AUTHORIZING, CONSTRUCTING, AND OPERATING THESE PLANTS, SIGNIFICANT ANT CAPITAL COST SAVINGS WILL RESULT. THIS WOULD ENCOURAGE A SURGENCE OF NUCLEAR PLANT ORDERS AND LEAD TO SAVINGS IN CONSUMER ELECTRIC LLS AND, FROM A NATIONAL PERSPECTIVE, TO ASSURANCE OF DIVERSE ENERGY SUPPLY.

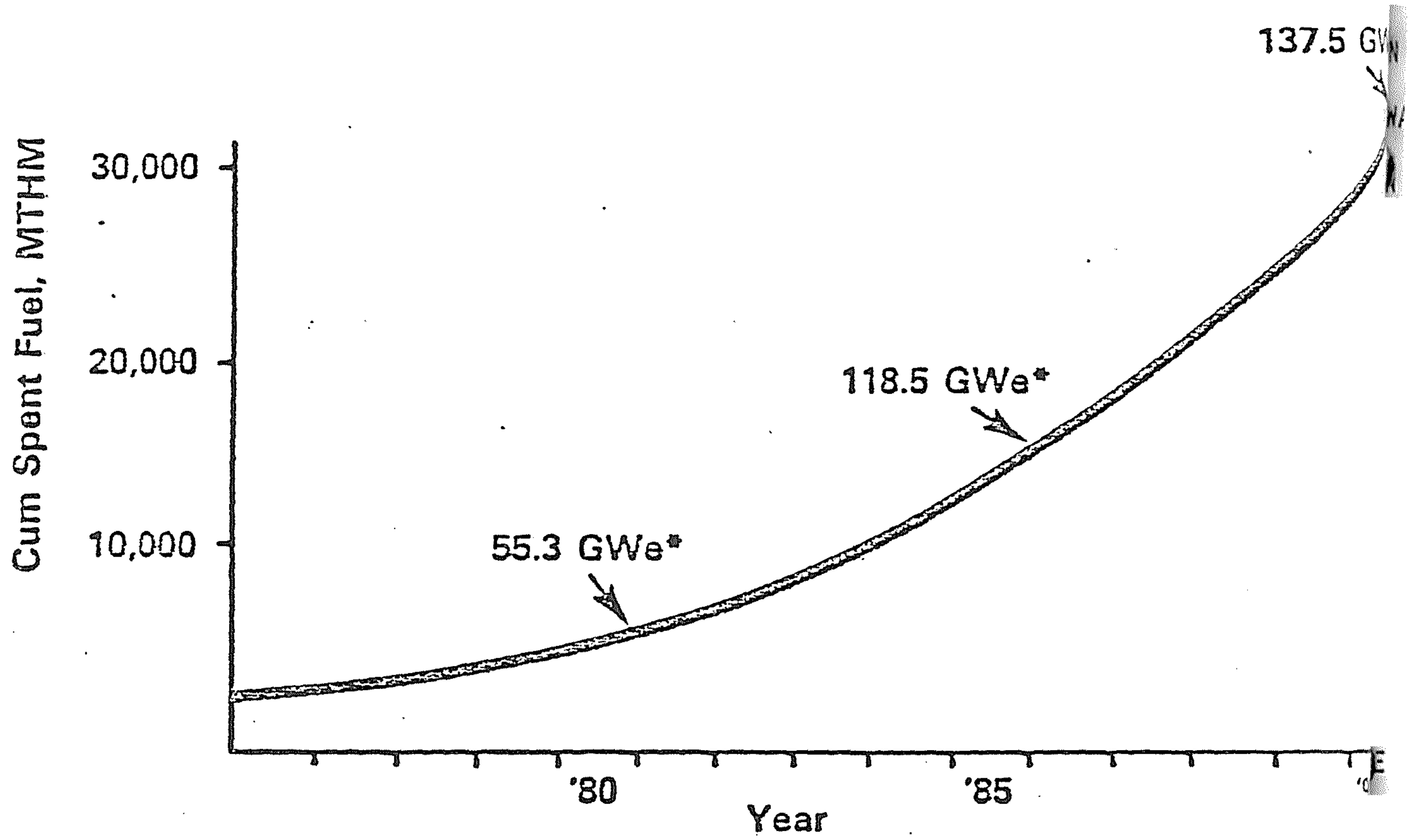
STE MANAGEMENT SOLUTION

OTHER AREA THAT IS ABSOLUTELY ESSENTIAL TO REVITALIZING NUCLEAR POWER THE UNITED STATES IS A SOLUTION TO THE NUCLEAR WASTE DISPOSAL PROBLEM. IS IS PROBABLY THE AMERICAN PUBLIC'S SINGLE GREATEST NUCLEAR CONCERN. IS ALSO A CONCERN OF THE UTILITIES WHO ARE CURRENTLY STORING SPENT EL IN POOLS AT THE REACTOR SITES, AS THE WASTE STORAGE CAPACITY FOR ME UTILITIES WILL BE EXHAUSTED IN SEVERAL YEARS (FIGURE 8). WHILE FFORTS ARE BEING MADE TO EXPAND THE AVAILABLE STORAGE SPACE, A PERMANENT OLUTION NEEDS TO BE DEPLOYED.

ECENTLY, OUR COUNTRY HAS MADE VERY SIGNIFICANT PROGRESS TOWARD RESOLVING HE WASTE DISPOSAL PROBLEM. ON JANUARY 7, PRESIDENT REAGAN SIGNED INTO W THE NUCLEAR WASTE POLICY ACT OF 1982. THE PROVISIONS OF THE ACT CLUDE ALL THE MAJOR ELEMENTS THAT THE PRESIDENT HAD EARLIER IDENTIFIED AS UCIAL TO A COHERENT NUCLEAR WASTE MANAGEMENT SYSTEM. SPECIFICALLY,

1) A SYSTEM OF FEES PAID BY UTILITIES TO FUND WASTE ACTIVITIES THAT WILL PERMIT THE FULL COST OF NUCLEAR POWER TO BE BORNE BY ITS BENEFICIARIES;
2) A METHOD FOR EXTENSIVE STATE PARTICIPATION IN THE SITING OF WASTE FACILITIES AND A MEANS FOR RESOLVING STATE OBJECTIONS;
3) A LIMITED, TEMPORARY FEDERAL STORAGE PROGRAM TO ASSIST UTILITIES WITH A SEVERE NEAR-TERM STORAGE PROBLEM;

DISCHARGED LWR SPENT FUEL ACCUMULATION



*Installed Nuclear Capacity

Figure 8

4) A strong commitment to permanent geologic disposal as the ultimate solution to the waste problem;

5) A study of monitored retrievable storage as an interim step toward permanent disposition, and

6) A clear distinction between the handling of civilian and defense wastes.

Passage of this landmark legislation is visible evidence that n the United States we have reoriented our waste management activities ay from a study mode and are now concentrating on actually deploying operational system on a mandated, legislated schedule. Our current metable for bringing the first repository on line calls for the near-erm nomination of five candidate sites. After the preparation of nvironmental assessments, three will be recommended for detailed haracterization. After extensive evaluation, the final selection f the site for the first repository will be submitted to the Nuclear egulatory Commission in 1987. Operation is scheduled to begin by 998. Schedules have also been established for a second repository nd a test and evaluation facility. With passage of this legislation, e believe our efforts to establish a national waste disposal system re substantially strengthened.

ommercial Reprocessing

third initiative announced by President Reagan is the reinstitution of ommercial reprocessing of spent nuclear fuel. Since the early days of uclear power development, it has been assumed that economics, the desire o conserve uranium resources, and waste management considerations would

DICTATE REPROCESSING OF SPENT FUEL (FIGURE 9). THREE U.S. COMMERCIAL REPROCESSING VENTURES HAVE FAILED, HOWEVER, AND TWO OF THOSE FAILURES ARE TRACEABLE TO UNSTABLE FEDERAL REGULATORY AND DEVELOPMENT POLICY. CONSEQUENTLY, THE PRESIDENT HAS DIRECTED THE DEPARTMENT OF ENERGY, IN CONSULTATION WITH OTHER GOVERNMENT ORGANIZATIONS AND INDUSTRY, TO TAKE STEPS TO CREATE A CLIMATE OF STABILITY IN WHICH REPROCESSING BY THE PRIVATE SECTOR CAN OCCUR. WHILE REPROCESSING HAS ADVANTAGES CLEARLY IN THE NATIONAL INTEREST, THE PRIVATE SECTOR IS UNDERSTANDABLY RELUCTANT TO MAKE ADDITIONAL REPROCESSING COMMITMENTS IN LIGHT OF THE EXPERIENCE TO DATE.

IN LINE WITH THE PRESIDENT'S DIRECTIVE, A DEPARTMENT OF ENERGY TASK FORCE HAS IDENTIFIED THREE MAJOR DETERRENTS TO COMMERCIAL INTEREST IN REPROCESSING. FIRST, INDUSTRY IS WARY OF THE PREVAILING REGULATORY UNCERTAINTIES. ALTHOUGH THE PRESIDENT HAS NOW CALLED FOR THE RESUMPTION OF COMMERCIAL REPROCESSING, UNCERTAINTIES HAVE YET TO BE RESOLVED BOTH FOR THE LICENSING OF A REPROCESSING FACILITY AND FOR THE REGULATION OF ITS OPERATION. A SECOND AND EQUALLY IMPORTANT BARRIER IS INDUSTRY'S UNCERTAINTY OVER THE STABILITY OF FEDERAL POLICY. THE 1977 DECISION TO DEFER REPROCESSING LEFT COMMERCIAL REPROCESSING INVESTORS IN DEBT TO THE TUNE OF HUNDREDS OF MILLIONS OF DOLLARS. CURRENT POTENTIAL INVESTORS ARE UNDERSTANDABLY CONCERNED THAT SUCH A COSTLY EXPERIENCE COULD BE REPEATED. THE THIRD AREA OF UNCERTAINTY LIES IN THE ECONOMICS OF REPROCESSING. NEAR-TERM MARKETS FOR REPROCESSING SERVICES, THE VALUE OF THE RECOVERED URANIUM AND PLUTONIUM, THE COSTS FOR HANDLING AND DISPOSING OF THE RADIOACTIVE REPROCESSING WASTES, AND THE CONSTRUCTION AND OPERATION COSTS OF THE PLANTS THEMSELVES ARE ALL CONSIDERATIONS THAT WILL DETERMINE THE TIMING OF A REPROCESSING COMMITMENT.

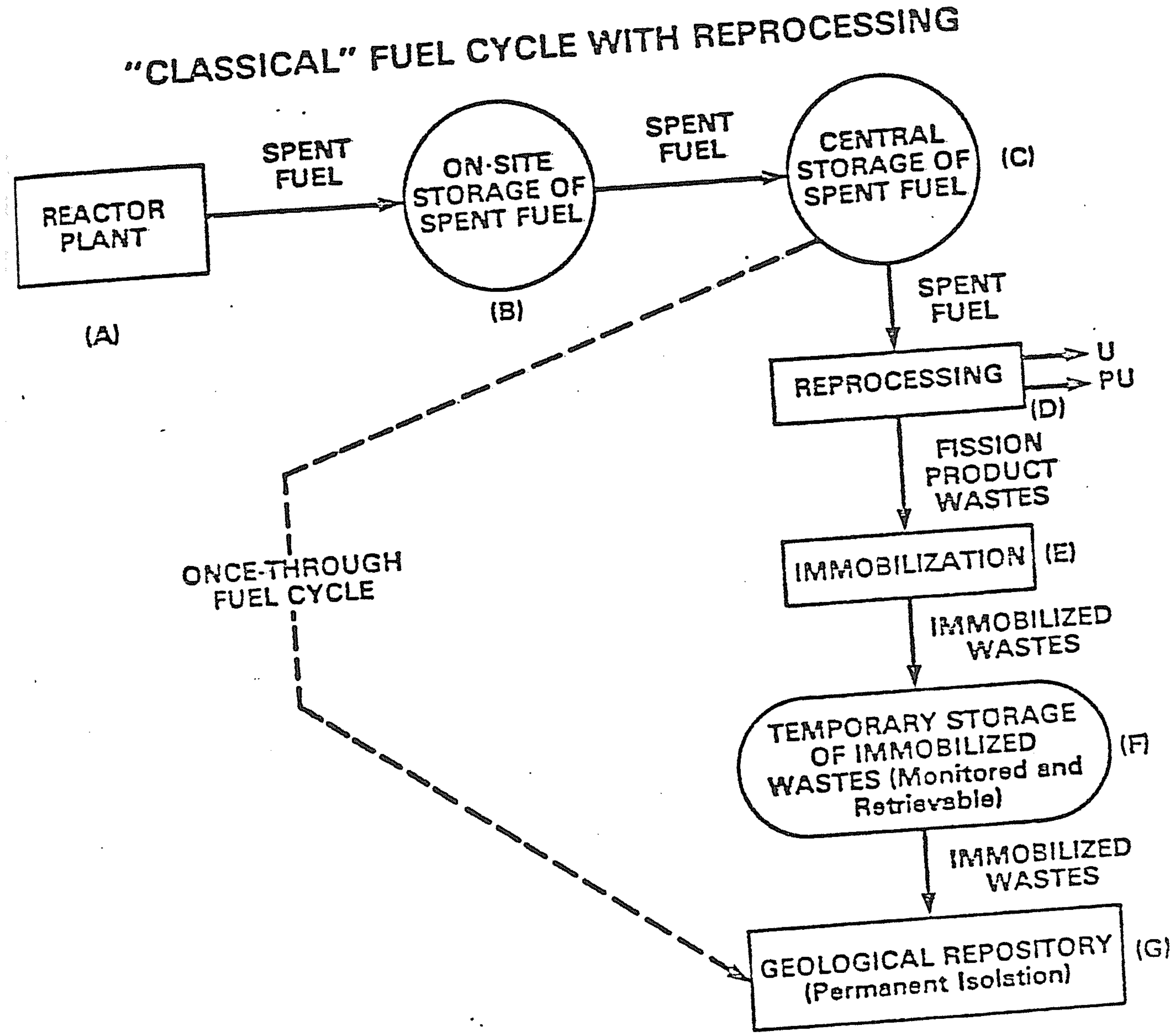

"CLASSICAL" FUEL CYCLE WITH REPROCESSING
REACTOR PLANT
(A)
SPENT FUEL
ON-SITE STORAGE OF SPENT FUEL
(B)
SPENT FUEL
CENTRAL STORAGE OF SPENT FUEL
(C)
SPENT FUEL
REPROCESSING
(D)
U
PU
FISSION PRODUCT WASTES
IMMOBILIZATION
(E)
IMMOBILIZED WASTES
TEMPORARY STORAGE OF IMMOBILIZED WASTES (Monitored and Retrievable)
(F)
IMMOBILIZED WASTES
GEOLOGICAL REPOSITORY (Permanent Isolation)
(G)
ONCE-THROUGH FUEL CYCLE

Figure 9

UNTIL THESE UNCERTAINTIES ARE ALLEVIATED, IT IS UNLIKELY THAT COMMERCIAL REPROCESSING VENTURES WILL EMERGE IN THE UNITED STATES.

AGGRESSIVE BREEDER DEVELOPMENT

THE FOURTH ELEMENT OF OUR NUCLEAR POLICY IS THE CONTINUED DEVELOPMENT AND DEMONSTRATION OF THE BREEDER REACTOR SYSTEM. THE SURGE OF UTILITY ORDERS FOR LIGHT WATER REACTORS IN THE EARLY 1960'S LED U.S. DEVELOPERS TO ASSUME THAT THE FIRST GENERATION TECHNOLOGY WAS MATURE AND THAT EMPHASIS COULD BE SHIFTED TO DEVELOPMENT OF THE NEXT GENERATION OF REACTORS, THE BREEDER. AFTER INVESTIGATING AND EVALUATING SEVERAL BREEDER TECHNOLOGIES, IT WAS DECIDED THAT THE LIQUID METAL FAST BREEDER REACTOR (LMFBR) TECHNOLOGY HAD THE BEST CHARACTERISTICS FOR PROVIDING A SAFE, ECONOMIC AND ESSENTIALLY UNLIMITED SUPPLY OF ENERGY OVER THE LONG TERM. THE DEVELOPMENT STRATEGY AT THAT TIME PROJECTED THAT THE LMFBR WOULD EVENTUALLY BECOME THE PREDOMINANT REACTOR SYSTEM, AND TO BRING IT TO THE POINT OF UTILITY COMMERCIALIZATION, THE GOVERNMENT WOULD CONDUCT A PROGRAM OF RESEARCH AND DEVELOPMENT CENTERED AROUND A SEQUENCE OF PROGRESSIVELY LARGER AND MORE TECHNICALLY SOPHISTICATED DEMONSTRATION PLANTS.

DESPITE COMPELLING ARGUMENTS FOR EXPEDITIOUSLY COMPLETING THE DEVELOPME OF THE BREEDER, THE PATH HAS NOT BEEN SMOOTH IN THE UNITED STATES. AFT BEING HAILED AS THE ANSWER TO ALL OF OUR ENERGY PROBLEMS IN THE EARLY D OF THE TECHNOLOGY, A REACTIONARY PHASE OF ANTI-NUCLEAR SENTIMENT EMERGE IN THE MID-1970'S, WITH THE BREEDER--PARTICULARLY THE 375 MWE CLINCH

IVER BREEDER REACTOR (CRBR) DEMONSTRATION PROJECT--AS ITS FOCAL POINT. CONTINUOUS POLITICAL DEBATE, WHICH CULMINATED IN THE 1977 DECISION PRESIDENT CARTER TO DEFER BREEDER DEMONSTRATION AND CANCEL CONRUCTION OF CRBR, SEVERELY IMPACTED THE PROGRAM. AS A RESULT, THE NSTRUCTION SCHEDULE WAS DELAYED, SIGNIFICANTLY ESCALATING THE COSTS.

TH THE ELECTION OF PRESIDENT REAGAN, THE TIDE OF BREEDER FORTUNES TURNED ICE MORE. IN ADDITION TO AFFIRMATION OF THE TECHNOLOGY, THE NEW POLICY ENTIFIES A FEDERAL GOVERNMENT ROLE IN BREEDER DEVELOPMENT BASED ON THE OTENTIAL LONG-TERM BENEFIT TO U.S. ENERGY SECURITY AND THE INABILITY F INDUSTRY TO SHOULDER ALONE THE INHERENT HIGH DEVELOPMENT COST AND NITIAL TECHNICAL DEVELOPMENT RISKS. ACCORDINGLY, BREEDER EFFORTS HAVE EEN DIRECTED TOWARD AN AGGRESSIVE PROGRAM OF ACCOMPLISHMENT DESIGNED O HAVE THE TECHNOLOGY READY WHEN ECONOMIC FACTORS SIGNAL THE NEED FOR OMMERCIAL BREEDER INTRODUCTION.

MAJOR THRUST OF OUR EFFORT HAS BEEN TO REORIENT AND STREAMLINE THE LINCH RIVER PROJECT, WITH THE RESULT THAT WE HAVE ACCELERATED THE ONSTRUCTION SCHEDULE BY ABOUT 2 YEARS. AT PRESENT, THE PROJECT DESIGN S ABOUT 90 PERCENT COMPLETE, OVER 70 PERCENT OF THE MAJOR EQUIPMENT ND COMPONENTS HAVE BEEN DELIVERED OR ARE ON ORDER, LICENSING ACTIVITY S PROCEEDING AS EXPECTED, AND SITE PREPARATION IS WELL UNDER WAY. THIS ONTH, AN ELECTRIC UTILITY TASK FORCE REPORTED TO CONGRESS ON POSSIBLE AYS TO INCREASE PRIVATE FINANCIAL SUPPORT FOR THE CLINCH RIVER PROJECT. HE TASK FORCE CONCLUDED THAT THERE IS SUBSTANTIAL MARKET VALUE FOR HE PROJECT AND THE ELECTRICITY IT WILL PRODUCE, OVER AND ABOVE THE ROJECT'S RESEARCH AND DEVELOPMENT VALUE.

WE PLAN TO BRING CLINCH RIVER ON LINE BY 1989. ITS PURPOSE IS TO PROVE THE OPERATIONAL CAPABILITY OF AN INTERMEDIATE-SIZE PLANT AND TO ENABLE THE RESEARCH AND DEVELOPMENT NECESSARY TO ADVANCE TO A FULL-SIZE COMMERCIAL PLANT. THE NEXT STEP AFTER CRBR WILL BE A LARGE-SCALE PROTOTYPE BREEDER THAT WILL PROVIDE SPECIFIC INFORMATION ABOUT COMMERCIAL-SIZE OPERATION AND ECONOMICS. ALL ELEMENTS OF THE NUCLEAR COMMUNITY--GOVERNMENT, UTILITIES AND INDUSTRY--WILL COOPERATE IN THE DESIGN AND DEVELOPMENT OF THE PROTOTYPE PLANT; CONSTRUCTION FUNDING IS EXPECTED TO COME LARGELY FROM THE PRIVATE SECTOR.

OUR RETURN TO ACTIVE, AGGRESSIVE PARTICIPATION IN THE AREAS OF REPROCES AND BREEDER DEVELOPMENT HAS SUBSTANTIAL IMPLICATIONS FOR THE FIFTH AND FINAL PRESIDENTIAL DIRECTIVE THAT I WILL DISCUSS: THE REESTABLISHMENT THE UNITED STATES AS A RELIABLE SUPPLIER OF NUCLEAR SERVICES ABROAD.

<u>REESTABLISHMENT OF THE UNITED STATES AS A RELIABLE SUPPLIER OF NUCLEAR SERVICES</u>

THIS ADMINISTRATION HAS RECOGNIZED THE NEED TO REEXAMINE OUR INTERNATI NUCLEAR POLICIES IN ORDER TO COMBINE SUCCESSFULLY OUR NONPROLIFERATION OBJECTIVES, OUR COROLLARY INTENT TO PROVIDE TECHNICAL ASSISTANCE TO COUNTRIES DISAVOWING NUCLEAR WEAPONS PROGRAMS, AND OUR DESIRE TO REMAI A LEADER IN WORLDWIDE DEVELOPMENT OF NUCLEAR POWER. WE BELIEVE THESE GOALS ARE COMPATIBLE AND MUTUALLY SUPPORTIVE. OUR COMMITMENT TO RESTR THE SPREAD OF NUCLEAR WEAPONS REMAINS STEADFAST. WE ARE STRONG ADVOCA OF THE NUCLEAR NONPROLIFERATION TREATY AND THE APPLICATION OF FULL-SCO SAFEGUARDS WHERE APPROPRIATE. WITHIN THIS FRAMEWORK, HOWEVER, WE SEE ROOM FOR SEVERAL POLICY CHANGES THAT COULD AID IN REESTABLISHING THE UNITED STATES AS A RELIABLE SUPPLIER.

RST, AS PREVIOUSLY DISCUSSED, WE BELIEVE A STRONG DOMESTIC NUCLEAR OGRAM IS ESSENTIAL TO OUR ABILITY TO PARTICIPATE IN BILATERAL AND TERNATIONAL COOPERATIVE NUCLEAR TECHNICAL EXCHANGE AND, THEREFORE, TO E ACHIEVEMENT OF OUR NONPROLIFERATION GOALS. ACCORDINGLY, WE ARE TURNING TO AGGRESSIVE DEVELOPMENT OF THE BREEDER AND ITS SUPPORTING EL CYCLE. WE ARE ALSO ENCOURAGING A RETURN TO COMMERCIAL REPROCESSING. R REENTRY INTO ADVANCED NUCLEAR ACTIVITIES WILL REINFORCE OUR POSITION F INTERNATIONAL AUTHORITY IN TECHNOLOGY DEVELOPMENT--A POSITION FROM HICH WE CAN BETTER INFLUENCE WORLDWIDE DECISIONS ON SAFEGUARDS AND APONS NONPROLIFERATION.

ECONDLY, WE SEEK TO COOPERATE WITH OTHER COUNTRIES THAT ARE ENGAGED N RESEARCH AND DEVELOPMENT OF NUCLEAR TECHNOLOGIES IN PURSUIT OF AFE, RELIABLE AND ECONOMIC NUCLEAR POWER. THE RESTORATION OF GOOD ORKING PARTNERSHIPS WITH COUNTRIES THAT HAVE CREDIBLE NONPROLIFERATION REDENTIALS IS A PRIORITY GOAL OF THE UNITED STATES.

INALLY, WE INTEND TO ADD PREDICTABILITY AND RELIABILITY TO OUR EXPORT OLICIES. INSTANCES, DURING THE PREVIOUS ADMINISTRATION, OF UNILATERAL OLICY CHANGES AND CHANGES IN OUR EXPORT REQUIREMENTS HAVE BEEN COUNTER-RODUCTIVE TO U.S. TRADE OBJECTIVES. HOWEVER, IN CONSIDERING THESE OLICY SHIFTS, IT SHOULD BE BORNE IN MIND THAT NUCLEAR POWER--A HIGH ECHNOLOGY DEVELOPMENT WHICH INFLUENCES THE DAILY ACTIVITIES OF LARGE UMBERS OF PEOPLE--HAS BEEN INSERTED INTO THE COMMERCIAL REGIME IN FEW SHORT DECADES. IT WOULD BE HIGHLY UNREALISTIC TO EXPECT THIS O OCCUR SMOOTHLY AND WITHOUT INCIDENT. REVIEWING OUR NUCLEAR POLICIES VER THE PERSPECTIVE OF 30 YEARS REVEALS AN OVERALL PATTERN OF RELATIVE CONSTANCY.

THE REAGAN ADMINISTRATION POLICY IS TO SEEK WAYS TO ENHANCE OUR FUEL CYCLE SERVICES TO CUSTOMER COUNTRIES WITHIN A FRAMEWORK OF MUTUALLY ACCEPTABLE NONPROLIFERATION MEASURES. AN ASSURED FUEL SUPPLY AND EQUITABLE AND COMPETITIVE FINANCIAL ARRANGEMENTS ARE LEGITIMATE EXPECTATIONS OF USER NATIONS. IN THE AREA OF URANIUM ENRICHMENT, WE BELIEVE A KEY TO MARKET STRENGTH LIES IN FULL DEVELOPMENT AND USE OF ADVANCED TECHNOLOGIES SUCH AS THE CENTRIFUGE. CONSEQUENTLY, WE HAVE UNDER CONSTRUCTION A GAS CENTRIFUGE PLANT THAT CAN ENRICH URANIUM MORE EFFICIENTLY AND MORE ECONOMICALLY THAN THE GASEOUS DIFFUSION PLANTS THAT ARE CURRENTLY IN USE. ADVANCED CENTRIFUGE DEVELOPMENT, AND BEYOND THAT ADVANCED ISOTOPE SEPARATION, SHOULD BRING EVEN GREATER EFFICIENCY AND ECONOMY TO U.S. ENRICHMENT CAPABILITY.

SUMMARY OF FUTURE NUCLEAR ENERGY PROSPECTS IN THE UNITED STATES

IMPLEMENTATION OF THE REAGAN ADMINISTRATION POLICY INITIATIVES SHOULD IMPROVE SUBSTANTIALLY THE PROSPECTS FOR EXPANDED USE OF NUCLEAR POWER IN THE FUTURE. WITH THE REVIVAL OF THE ECONOMY, THE COROLLARY INCREASED DEMAND FOR ENERGY, AND THE RETURN OF REALISTIC, EFFICIENT PLANT LEADTIMES, IT IS REASONABLE TO ASSUME THAT UTILITY NUCLEAR INVESTMENT WILL BE FORTHCOMING. AN ADDITIONAL INCENTIVE FOR INVESTMENT IS THE NEW NATIONAL SYSTEM FOR NUCLEAR WASTE DISPOSAL, WITH THE FRAMEWORK THAT HAS JUST BEEN ESTABLISHED. RECOGNIZING THAT THERE IS A MAJOR POTENTIAL FOR NEW NUCLEAR PLANT AND SERVICE ORDERS FROM OTHER NATIONS, THE ADMINISTRATION'S COMMITMENT TO ADD PREDICTABILITY AND CERTAINTY TO EXPOR

LICIES SHOULD MEASURABLY ENHANCE BOTH U.S. TRADE INTERESTS AND NPROLIFERATION OBJECTIVES. AND THE AGGRESSIVE, COOPERATIVE VELOPMENT OF ADVANCED NUCLEAR TECHNOLOGIES WILL DEMONSTRATE, TH AT HOME AND ABROAD, THAT THE UNITED STATES HAS A LONG-TERM MMITMENT TO NUCLEAR ENERGY.

ROUGH PRUDENT, TIMELY DEVELOPMENT OF NUCLEAR POWER, THE WORLD VILIAN NUCLEAR COMMUNITY HAS THE OPPORTUNITY TO MAKE A SIGNIFICANT NTRIBUTION TO WORLDWIDE ENERGY SUPPLY, ECONOMIC WELL BEING, AND MAN PROGRESS. THE UNITED STATES IS PREPARED TO BE A PARTNER IN AT INTERNATIONAL UNDERTAKING.

§2 W.マーシャル博士

FINAL VERSION

SIR WALTER MARSHALL'S PAPER TO JAIF CONFERENCE - MARCH 1983

In this session of the conference we are going to discuss the prospects for the production of electricity using fast breeder reactors. Many people are ready to agree that these reactors promise to be the most efficient source of energy in the next century but that the immediate prospects for commercial exploitation of this type of reactor are modest. We therefore need to consider what policies we ought to adopt to keep making progress on this subject and to make sure that the technology is available in a viable and commercial form when we need it.

We can only examine the problems of the future by making sure we have learnt the lessons of the past. We should, therefore, spend a little time looking at the history of fast reactors. This history is an international story with contributions from many different countries but, of course, I am more familiar with the history of the fast reactor project in my own country so I hope you will forgive me if I look at the history from a UK point of view.

Going back many years I find that the first written mention of a fast reactor in the UK occurred on 2 July 1946 at Harwell and because of its historical significance, let me read to you an extract from the Minutes of the Power Committee held at the Harwell Research Establishment on that day:

> "In piles designed for power it is important that δ should be positive in order that each pile may be self-supporting, but very small values of δ are acceptable. In such a pile one may regard the thorium (or uranium 238) as the fuel and the fissile materials as a catalyst. Another kind of pile which might sometimes be required is a so called breeder pile, the object of which is to increase the amount of fissile material available. In such a pile obviously one wants δ to be significantly greater than zero, otherwise the whole operation would be extravagant."

I am quite sure that there are even earlier references to fast reactors in the United States and I believe there are probably references to the idea in France also in 1946. We are therefore dealing with a subject which is both international and approximately 37 years old.

At a relatively early date scientists in many countries decided that, since the fast reactor did not need a neutron moderator and because economics favoured a fuel highly concentrated in fissile material, it would be best to go for a reactor with a high energy density which demanded cooling by liquid sodium. Alternative coolants have been examined; helium, carbon dioxide, steam and even light water but overwhelmingly the world effort has concentrated on the sodium cooled fast reactor.

This thinking led naturally to the concept of a small reactor core fuelled with plutonium, surrounded by a blanket made from depleted uranium 238. Early thinking on the use of metallic fuels was replaced by a concentration on oxide fuels.

I do not want to discuss the technology of fast reactors in any detail today. I have given you this very brief account of it simply to demonst that the technical thinking in all countries has proceeded very much by consensus and agreement. Indeed, the only technical points which divide experts nowadays is whether the loop or pool type reactor design will prove to be the best in the long run. In effect, therefore there are no technical disagreements amongst the experts at all and, in addition, although some scientists will speak about the economics of fast reactors with great optimism and others with great pessimism, they do not in reality disagree very much because we all agree that fast reactors will be needed in significant quantities sometime in the first part of the next century.

However, despite this agreement amongst scientists on technical and economic factors, the prospects for fast reactors look different in each country. That must therefore be because of institutional problems, political problems or accidents of history. I shall review this situation as I see it today and I shall come to the conclusion that we need a kind of international collaboration; not to gain commercial advantage, energy independence or national prestige but simply to give help to one another to overcome institutional and other barriers to the successful deployment of an extremely important technology.

Let me begin at the beginning.

The earlier pioneers of nuclear energy throughout the world and certainly Sir John Cockcroft and the British team analysed the need for fast reactors in a very simple way. They pointed out that uranium came as a mixture of two isotopes; uranium 235 and uranium 238 and that any thermal reactor would have to be operated on a fuel which contained both isotopes. The uranium 235 would produce fission products and the uranium 238 would absorb neutrons and produce plutonium. They therefore argued with simple, straightforward rigour that the production of electricity by nuclear fission automatically meant the production of radioactive fission products, which were a waste product, and of plutonium. If the plutonium has a use, such as in fast reactors, it was a valuable by-product and if it did not have a use it was, by definition, a waste product. Sir John Cockcroft argued that it was not acceptable to have plutonium produced as a waste product and it was essential, therefore, to begin research upon its use as a fuel in fast reactors. We see from this that even in those early days the scientists recognised that the use of fast reactors was an essential consequence of having nuclear energy at all and I think that basic and simple argument remains true although, of course, I am also conscious of the possible merits of incinerating plutonium in thermal reactors.

However, coming back to the thinking of the early pioneers, they thought that uranium was a scarce and valuable mineral. They therefore deduced thermal reactors would rapidly burn up the uranium 235 resources in the world. They therefore saw an urgency to get on with fast reactors so that we could both burn plutonium and breed more plutonium. In effect they saw thermal reactors as a brief prelude lasting only a few decades before fast reactors dominated the production of nuclear electricity. This thinking gave a very early emphasis to the breeding characteristics of fast reactors. In the thinking of those days it was necessary that fast reactors produce a large excess of plutonium to enable an expansion of the electricity industry to take place. With hindsight we see that thinking is wrong. Uranium is not as scarce as the early pioneers thought. Thermal reactors can serve us for a much longer period. Furthermore, some aspects of the reactor technology proved more difficult than we expected and the prospects for the economic introduction of fast reactors was therefore receding as this thinking took place. However, the essential need for fast reactors remains as true now as it always was. Even on present day estimates the world's uranium resources, estimated to be about 10^7 tonnes, have a capability of yielding 4×10^{21} J of heat from thermal reactors. Fast reactors could increase this heat capability to 2×10^{23} J which is more than the total contribution from all fossil reserves of coal, oil and gas put together. Therefore it still remains true that fast reactors should be a major source of energy for the 21st Century. What then has held up the progress of fast reactors?

In the United States the problems seem to be entirely institutional and political and influenced by the plentiful uranium in the United States. The United States has the largest R & D programme on fast reactors of any country but it does not have an easy focus for that work because the Clinch River project has neither been approved nor disapproved. To use medical analogy, "it is on a life support system". That neither helps the confidence of American scientists working on fast reactors nor does it set a good example for Governments of other countries to follow. It seems to me that the early success of light water reactors in the United States permitted our American colleagues to ignore the back-end of the fuel cycle, so now the prospect of a fuel cycle for fast reactors faces institutional difficulties and problems of public acceptability which are difficult to overcome. The early American plans to use plutonium in thermal reactors recycle and the veto of those plans by President Ford and President Carter have not given a good introduction to the use of plutonium in commercial nuclear power in the United States. The problems of launching this technology have been compounded by a series of reorganisations in Washington. We have seen changes from AEC to ERDA to the Department of Energy and now, perhaps (or perhaps not) to something else. It must make careful thinking about the future more difficult. When all this is added to the public relations problems created by the accident at Three Mile Island and, by the nature of the regulatory process in the United States, I think we can see why fast reactors are making slow progress in that country. This is of great concern to many of us in other countries and we wish our American colleagues all possible success in seeing their way through these problems.

The position in France is almost the exact reverse. They made an early and firm commitment to fast reactors. We look forward to the early operation of Super Phenix and we are all awaiting with some anticipation the announcement of further fast reactor plants in France. It is not possible for me to exaggerate the admiration I have for the French programme but, if anything, they have been too successful. They have succeeded in developing an excellent technology rather earlier than it is actually needed at least in an international context.

The position in Germany for many years has been confused because of political arguments concerning the future of the Kalkar reactor but those problems now seem to be solved and we look forward to hearing about German progress later today. Italy is taking an active part in Super Phenix being built in France and later perhaps the next German reactor to be built - no doubt they will build their own fast reactor some time in the future.

In Japan there is an active and growing role for fast reactor development with the experimental JOYO 75 MWth reactor, now operational, and plans for a 300 MWe prototype MONJU are far advanced.

India, USSR and other countries all have active fast reactor programmes but I do not have time to talk about those today.

Let me now say some words about the position in the United Kingdom.

My country made a very early commitment to nuclear power and introduced the gas cooled MAGNOX reactors at a time when other countries looked upon nuclear power as only a research idea. We did that because, in the United Kingdom, we had plenty of coal but it was very expensive. We had no oil and no gas. We knew there was no prospect of major finds of oil or gas onshore or offshore in the North Sea because the geologists told us with such confidence that this could not be. However, the geologists of that time were wrong and now we know that there are copious supplies of natural gas and oil offshore in the North Sea. The United Kingdom has therefore unexpectedly found itself to be a country rich in fossil fuel resources and while this is undoubtedly a great blessing for the country as a whole, it means that we do not need nuclear power with the same urgency that we envisaged some decades ago. Nevertheless, successive British Governments have made a firm commitment to the use of nuclear power and the present administration have launced a project to build the PWR alongside the gas cooled thermal reactors which have been traditional in my country.

The British Government has also given careful consideration to its policy on fast reactors. I explained earlier that, in my opinion, any programme on nuclear power must lead eventually to the fast reactor and the British Government has firmly stated that that is its own view but they do not now see fast reactors as an urgent matter. In our circumstances I think that is a reasonable conclusion. My Government has therefore made a firm commitment to the need for a continuing programme of research, development and demonstration on fast reactors in the United Kingdom and a declaration that we see this technology as an excellent topic for international collaboration. We see the need for a large demonstration reactor to be built in the United Kingdom in the foreseeable future so that we will gain the experience we feel is essential to launch a commerical programme of fast reactors early next Century but we do not see the timing of this programme as a sensitive matter.

This brief statement of the position in various countries makes the wisdom of international collaboration look self-evident and obvious and I look forward to hearing statements by other speakers today on how they see the position on fast reactors and how they view the prospects of international collaboration.

However, assuming there is a wide consensus that we should have international collaboration on this subject, what are the elements which should form part of that collaboration? Let me give you my personal opinion on that. We must start with the comment that the safety characteristics of a fast reactor are qualitatively different from those of a thermal reactor because a re-arrangement of fuel could lead to a prompt, critical reaction. The prospects of a Bethe-Tait incident in a fast reactor absorbed the attention of many early studies on fast reactor safety but recent experiments on the prototype fast reactor at Dounreay, the Phenix reactor in France and the fast flux test facility in the United States have given most of us great confidence about the safety of the fast reactor. A great deal of work needs to be done and many arguments will have to be prepared for our safety and licensing authorities but, in my opinion, the arguments about fast reactor safety look very secure. It would be a great advantage to get international agreement on safety goals and safety standards for this technology and this will require close collaboration between the research laboratories and the licensing bodies of all the countries involved.

In all sodium cooled fast reactors it is essential to transfer heat from the sodium to water to make steam. This sodium to water steam generat[or] is, in my opinion, the most important component to be developed by research in the future. Many experts have many different ideas about the most appropriate design of this component. We need to encourage all ideas on the subject so that the best choice emerges as soon as possible. Until this very important technological point is settled, no country can make firm plans for the large scale use of commercial fast reactors.

The fast reactor is vitally dependent upon the fuel cycle which serves it, and I cannot stress too strongly the importance of this point which is sometimes forgotten because people are familiar with the technology of thermal reactors. For thermal reactors the connection between the reactor operation and the fuel cycle is much less. There are several very important steps in the fast reactor fuel cycle. The first is the fabrication of the plutonium bearing fuel. Next there is the fabrication of the blanket containing uranium 238. After the operation of the reactor the fuel must be removed from the reactor, cooled for approximately a year and then reprocessed to separate the fission products, the remaining uranium and the unburnt plutonium. The uranium and the plutonium together with some freshly depleted uranium is then returned to the fabrication plant. It is absolutely essential that the fast reactor fuel cycle should operate efficiently and reliably and economically, otherwise the fast reactor is obliged to close down, or will be expensive to operate. The reprocessing of highly irradiated fast reactor fuel and the fabrication of the plutonium into a fresh charge of fuel has been successfully demonstrated both at Dounreay and in France. However, before we can move ahead with complete confidence, we will need to satisfy ourselves that commercial plants of sizes large enough to be economic will work with the same efficiency and reliability as the prototype plants that are presently existing.

It is not immediately clear to me what the ratio in numbers should be between fast reactors and fast reactor fuel plants. That is something that will be decided by experience in the future. However, for the moment, let me guess that the best ratio might be one fuel cycle plant to five reactors. This immediately poses a problem. We cannot have a single fast reactor which is commercially viable because the fuel cycle plant to serve it would be too expensive. We need to have about five reactors as a prior condition for economic operation. Here then is a challenge for international collaboration.

All countries planning to use fast reactors in the next Century will need to build a large demonstration reactor. As a first step in that process, common sense says that we ought to pool resources on the fuel cycle site. Thus for example, we might have five reactors in five countries all being served by one fuel cycle plant in one country. However, although that might be the most economical approach, national pride and the wish of many countries to be as independent as possible, may well make it impossible to establish such a close form of international collaboration. In my view, this joint approach to the fast reactor fuel cycle poses a most interesting and challenging institutional restraint on the development of fast reactors in the future. Let us all hope we can find a common sense way to move forward on this vital matter.

There is another institutional step forward which personally, I think would be very important and that is to have a cross investment of finance between the electricity utility operating fast reactors in various countries. Ideally, for example, the British utilities should make an investment in fast reactor systems in France, United States, Japan etc. and the utilities in those countries should make an investment in fast reactor systems in the UK. It is this type of commitment and involvement which, in my opinion, will be the most powerful agent for rationalisation of the R & D programme, component development and harmonisation of safety rules and an economic approach to the fuel cycle. Of course, such cross investment would need the consent and approval of Governments. In principle, we should explore this idea very seriously. I am, of course, happy to acknowledge that the Super Phenix project in France has set a splendid example of this idea because it involves the investment of several countries primarily Germany and Italy in a fast reactor in France. We should all learn from that experience.

I mentioned earlier the importance of the fast reactor fuel cycle. There is a particular item in that which requires a special emphasis. The expense of the fuel cycle per unit of electricity produced can be greatly reduced if a high burn up for the fuel can be achieved. We therefore, need an intensive research and development programme on improving fast reactor fuel. At the Dounreay reactor, some of the fuel is now approaching 10% burn-up with out a sign of failure. I recommend, therefore, that we should set ourselves the target of producing, and then demonstrating, fuel up to 15% burn up or even higher. Some years ago many people felt that the problems of fast neutron irradiation damage were so severe that the burn up of fast reactor fuel would be very limited. The mere fact that I am able, today, to mention a target at these still higher burn up figures is a tribute to the materials research which has been conducted on this subject over the last decade or so.

Finally, I would like to consider the role of Governments in future international collaboration. Of course, they will need to give overall approval for anything that it is decided to do but in addition, to that they will have to take a special responsibility for reaching agreements on the non-proliferation policies to be used in handling the plutonium cycle. Some very important discussions on this took place in the INFCE discussions which were initiated by President Carter a few years ago and in those discussions the importance of the IAEA was strongly emphasised. In my view it is extremely important that countries should work together on this matter.

These then are the elements which will need discussion in any international collaboration on fast reactors in the future. This is a very important subject which I have been able to discuss only briefly and approximately. No doubt, other people will have different views. I look forward to hearing those. We need all the good ideas we can get. In conclusion may I make one further comment of a philosophical kind. In the past we have seen two kinds of successful international collaboration. One concerns pure research or research which is so far away from commercial exploitation that collaboration and exchange of ideas can take place without being inhibited by ideas of commerical exploitation. As examples of those I can quote you research on high energy physics, on astro-physics and on fusion research. We also find it easy to set up international collaboration of a purely commerical kind when the application of the research is immediate and short term eg the licensing of light water reactors from America several years ago into all our various countries. However, so far as I know, we have never yet succeeded in setting up close international collaboration on a topic which has had an intermediate position between those two extremes. Nevertheless, that is what we need to do for fast reactors. The technology is not at the basic research level, neither is it ready for commercial licensing. The way forward on this important subject is, therefore, an important challenge for us all. I am quite sure that in this whole subject, Japan has a very important role to play and it has been a great privilege for me to give this lecture here in Tokyo today. Thank you very much for your patience in listening to me.

W Marshall
17/3/83

JAIF SESSION 2

Fast Breeder Reactors as a guaranty for the future

G. RENON - R. CARLE - M. ROZENHOLC

In every country, the choice of an energy policy taking into account the local conditions implies the setting up of complex logistics systems and heavy investments whose lead times reach or exceed 10 years after the decision time. Consequently, those decisions cannot be taken with respect to short term fluctuations. On the contrary, they have to take into account the long term trands of the energy market to achieve a continuous and consistent policy.

That means essentially that we have to plan to-day for an economic recovery out of the current crisis which is dommageable to all the countries but even more to developing countries. The only way to achieve this goal is to restore economic growth, Despite the heavy investments in energy conservation a new economic growth will inevitably increase the energy consumption in particular in those developing countries which consume very little energy to-day but have high demographic growth rates. To be able to meet the demands of those countries, and assure them access to the easy to use energy sources like oil, less of it will be available for industrialized countries.

Also, in the long run, oil will have to be restricted to very specific uses like transportation.

As a consequence it is already necessary to draw more heavily on other energy sources like coal and nuclear.

The latter is the best bet to reduce the energy dependence upon oil of many countries in particular those with little or limited indigeneous resources like Japon or France.

This independance factor both political and economical, together with the benefic effect on the balance of paiment and the lower cost of nuclear electricity explains why the thermal reactor-programs are continuing in many countries and are even picking-up again in many others.

However, beyond these programs, the next step, the fast breeder, must be prepared. Fast breeders appear to be, from the technical point of view, a logical continuation of thermal reactors since they use the plutonium produced by the latter and make the best out of depleted uranium stockpiled in huge amounts at the enrichment plants. This would allow and even greater independance form the international energy market.

As a matter of fact, in several advanced countries, fast breeders are, to day, reaching industrial maturity and are developed in many others. I would like here to stress especially the strong dedication of Japan to the development of this reactor line.

More generally speaking all the countries with a significant thermal reactor program have kept the fast breeder option open.

I would like here to recall quickly the French example. The situation to-day in France is the result of a logical, progressive and continuous effort over the last twenty years. It is characterized by three important milestones.

Firstly, the RAPSODIE reactor was built between 1962 and 1966. It enabled us to verify our design ideas and was a very valuable irradiation tool. As an example, a burn-up of 220 000MWd/t, was achieved on a fuel assembly in 1981. This explains why this reactor led us to develop very quickly the industrial type fuel for commercial reactors. As you know, RAPSODIE has now been shut down due to a minute sodium leak in the primary circuit. We considered that the goals being achieved it was not worthwhile to carry out the repairs.

Several countries in the world have also achieved the equivalent of the Rapsodie step, in particular Japan with the JOYO reactor.

The next step was the PHENIX reactor (equivalent of Japan's MONJU) built between 1968 and 1973. It allowed to demonstrate that the availibility of FBRs compared favorably with that of other power plants. At the end of 1982, PHENIX had produced 11 billion KWh and the maximum burn-up reached 100 000 MWd/t. Also, PHENIX has shown the multiple advantages of the pool design in particular when we had to modify successively three intermediate heat exchangers. This last year, three identical defects on the steam generators have confirmed that the operators cope very well with sodium-water reactions which otherwise look so awesome to the non-specialist. This minor problem enabled us to improve the operation of the plant.

The third step, SUPERPHENIX, is now under completion at Creys-Malville. The construction is carried out in a European frame since electricity producers of Germany, Italy and France will own the plant and since the construction involves the industry of the three countries. Up to now, no major difficulty appeared and as of to-day the commissionning is foreseen for next year. It is worldwhile to mention that construction cost and schedule were maintained within normal shifts compared to the forecasts which is a good achievement for a prototype.

In parallel, fuel fabrication and reprocessing facilities have been developped. The fuel fabrication shop at Cadarache, whose capacity is over 20 t/year has finished manufacturing the first core of SUPERPHENIX under totally industrial conditions. The specific fast breeder fuel reprocessing facility, SAP/TOR 5t/year, will start-up in 1984. It will allow us to evaluate, at an industrial stage, the merits of the solutions choosen for the head-end due to the particular aspects of the fast breeder reprocessing in this area. The chosen solutions rely essentially on the non-active experiments carried out for several years at the Industrial Prototype Department at Marcoule.

All those industrial programs for reactors and fuel cycle facilities have been carried out with the support of intensive R & D in each area including of course safety. In the latter as an example, France and Germany have gathered Japan and all the other FBR developping countries around the CABRI reactor specialised in fuel accident investigation. By the way, at the 1982 Lyon conference on FBR safety it was sidely recognized that FBRS are as safe as PWRs.

.../...

To prepare commercial penetration of the FBR, industrial structures have already been set-up in France, and consultation is maintained between the different actors like the electricity producer EDF, the NSSS maker, NOVATOME, the conventional island supplier ALSTHOM-ATLANTIQUE, COGEMA in charge of the fuel cycle and CEA.

Of course, we are not yet at the commercial stage and the time for it will depend very much upon outside factors like uranium price, and inside factors like reactor construction cost and fuel cycle cost.

Hence, there are still problems to be solved. First, as I said the problem of the cost. Already to-day, the cost of the SUPERPHENIX KWh compares quite well with that of the most modern coal fired stations. However, it is still significantly higher than that of the PWR KWh generated in France, especially in this period of low uranium prices. One of the reasons is of course the absence of a series effect on an isolated prototype compared to the PWR which is commercialized in series.

So the french partners have taken as their prime goal to reduce the cost. Already, new design features based on the experience gathered during the construction at Creys-Malville will allow to drop the cost very significantly through a reduction of 30% in the total steel weight used.

On the other hand, in the fuel cycle area, despite the fact that the PHENIX fuel cycle has been closed, using small scale facilities, it is now necessary to close the SUPERPHENIX cycle with typical commercial size facilities. The SAP/TOR facility with a capacity of 5 T/year will be an important step along this path which has been followed by very few of our partners so far. The important thing is to gather enough valuable experience to be able, when the time comes, to launch an industrial unit, sufficiently large to yield representative costs.

During this FBR industrialization period, it will be necessary to extend to the FBRs the good public acceptance of nuclear energy in France. This can only be achieved by a very large effort of information focused on the technical specificities of the FBR. This effort has already been started and we think we are on the right track judging after the low success the last demonstrations against SUPERPHENIX have had.

Glancing at the technological development programs which remain to be carried out, and the cost reduction to be achieved we are led to believe that the Fast Neutron Reactors will reach the commercial stage shortly after the year 2000. At that time they should produce a KWh roughly at the same cost as the PWRs. This relies on the assumption that the extraction cost of uranium is going to increase as it has already, that the uranium demand is going to increase due to late comers in the nuclear field and picking-up of the programs in developed countries. Under those assumptions, it will become clear that FBRs are the only technology available to-day able to insure that the development of the use of electricity can continue at a predictable and low cost independently of the energy market tensions whose little elasticity is well known.

The time frame being set that way, it involves a certain number of intermediary decisions to be taken in particular about a follow-up to SUPERPHENIX, CEA, EDF and the involved industry are carrying out the necessary studies for the government to be in a position, with all the information on hand, to launch the next step in 1986. This date takes into account the fact that by then, a significant operational experience of SUPERPHENIX and of the reprocessing facility SAP/TOR will be available and be an input to the decision taking process. Also, the decision should not bepostponed too much to avoid the loss of construction expertise accumulated with SUPERPHENIX.

So far I have, been very french centered but many other countries have contributed to the common effort. The success we have experienced so far is partly due to the fact that we have recognized very carly that international cooperation is the best way to optimise cost and effort. This idea translated itself into several R&D and industrial agreements between the european partners (France, Italy, Germany, Belgium, Netherlands). These agreements were very satisfactory.

The management of those agreements is adapted to the particular cooperation area involved.

For instance, regarding research and development to ensure a maximum flexibility, working groups have been created in several research domains, like, nuclear fuel, sodium technology, core physics and computer codes, safety, components, materials evaluation for design. Within those groups, the specialists meet several times a year to exchange completely the information generated by each party. The consistency of the whole program is assured by a Liaison Committee which meets twice a year at top level.

This cooperation allows us to harmonize more and more the R&D efforts among the partners so that they become more and more complementary.

In the industrial field another system has been set up, taking into account the specific nature of each class of component and the capabilities of the local industry. For this reason, for SUPERPHENIX, companies of different countries have teamed-up for the manufacturing of certain components like for example STEIN-INDUSTRIE (France) and BREDA/TOSI (Italy) for the inter mediate heat exchanger, NEYRPIC and FIAT for control rod mechanisms, JEUMONT SCHNEIDER with FIAT for the pumps. As a whole, the fabrication has been split between the different countries according to their shares in SUPERPHENIX.

NOVATOME and NIRA supply the installed NSSS jointly. The engineering of the project was carried out under NOVATOME by a team including NIRA.

As far as utilities are concerned, it was already common practice in Europe to have cross-participations between utilities. This was, in the nuclear field the case between Germany, Belgium and France for the Fessenheim, Chooz and Tihange plants.

With SUPERPHENIX, we went a step further since the owner of the reactor is NERSA, a joint venture between (EDF 51 %, ENEL 33 %, SBK 16 %).

Further to this good cooperation, we think that it is time to enlarge this international cooperation to all countries engaged in the development of FBR's and having gathered construction experience. More ambitious objectives could then be reached at a lower cost. Teaming the efforts would allow to clear more easily the most costly milestones which are the construction of advanced prototypes for both reactor and fuel cycle facilities. Basing this effort on the experience gathered during the construction of the units under completion will give a good assurance of success, both from the technical and the economical points of view. The french partners (electricity producer, engineering and R&D entitics) are thinking about different formulas which could be profitable for all the interested countries.

As a final conclusion, we thing that FBRs should in the future take a share in the production of electricity. They will become more and more economically competitive due to uranium price increases and reduction of reactor investiment and fuel cycle cost as a result of the R&D programs. More over since their operation is practically independent of the cost evolution of energetic material, they appear to be an insurance against the difficulties which can arise as the past has shown, from desorganization of the international trade.

SESSION 2 F. カラーK)

BREEDER PROGRAM IN THE UNITED STATES

by

Floyd Culler, President
Electric Power Research Institute

The current availability and price of natural uranium has given time to develop good breeder plants but it does not lessen the need to eventually establish a breeder power industry that uses the breeder material which is accumulating at the existing nuclear plants around the world. To attain a self-sustaining fuel supply in an economimally viable electricity generating industry for the 21st century is the goal of the United States. Our approach is to develop reliable components; obtain experience in the U.S. with the Clinch River reator plant, FFTF, and our old work horse pilot plant EBR-II; and develop a large-scale prototype plant that will lead to competitive breeder plants for the utility industry. Deployment of these plants can begin by the year 2000 or before. We are aware of the excellent work being accomplished in your countries and believe that safe and economical breeder plants and fuel facilities will benefit mankind around the world. We want to work with all of you who have goals similar to ours.

I. Clinch River Breeder Reactor Plant

You are familiar with the CRBR design concept and the fact that it is a joint project of the U.S. Department of Energy, Commonwealth Edison Co., Tennessee Valley Authority, and the Project Management Corporation which represents about 700 utilities. The plant design is 90% complete. The supporting research and development program is about 97% complete. Equipment delivered and on-order is approximately $750 million. Project expenditure to date is $1.4 billion and the estimated cost is $3.6 billion. When completed the plant will occupy 100 acres of a 1,364 acre site near Oak Ridge, Tennessee. The Tennessee Valley Authority will be the operator. Westinghouse Electric Company is the lead reactor manufacturer, Burns & Roe is the architect engineer, and Stone and Webster is the construction general contractor.

The U.S. Nuclear Regulatory Commission issued a revision to the Site Suitability Report in June of 1982 and the final supplement to the Environment Statement was issued in November 1982. Environmental hearings have been completed. The Project Management Office expects to receive the Construction Permit from NRC before the end of this year. If the Construction Permit is delayed, it is planned that a Limited Work Authorization will be obtained by November.

A contract for site preparation was awarded to the Perini Corporation on August 20 and work started September 22, 1982. The U.S. Congress authorized a $192 million funding level for fiscal year 1983 (ending October 1st) specifying that these funds are not to be used for new major equipment orders or for construction of safety-related permanent structures. This restriction has not significantly affected the planned procurement activities nor the site preparation work. The President's FY84 budget request to Congress on January 31st contains $270 million for CRBR. However, efforts are under way to work out an agreement between the utilities and the government for long-term funding. The objective is to avoid the uncertainties of piecemeal funding year by year that has been the case in the past.

A full-scale CRBR hockey stick steam generator is being tested at the Energy Technology Engineering Center (ETEC) in Southern California. The test loop has 70 MW thermal capability. There are nine such units in the Clinch River design, two evaporators and one superheater per loop and three loops. The full-scale (33,500 gpm) CRBR prototype pump has been tested for 5500 hours at the ETEC laboratory. These tests include performance tests, thermal transients, and endurance runs at both high- and low-temperatures. The pump has been removed and cleaned. Presently, the pump is being reassembled with the addition of anticonvection baffles and another impeller. The next set of tests are scheduled for completion in June.

In addition to the steam generator, the CRBR natural draft heat exchanger is scheduled for testing at the Energy Technology Engineering Center. The heat exchanger unit is part of the CRBR decay heat removal system. Other tests are being conducted at ETEC such as The Self-Actuated Shutdown System and those to qualify small sodium valves and rupture discs.

II. Fuel Cycle

As has been long recognized by those directly involved in breeder reactor development, the commercial application of breeder reactors requires closure of the nuclear fuel cycle and a coupling of breeder reactors and light water reactors in a synergistic economy. I'm happy to report that there is slow but major progress in the U.S. in several important areas. Perhaps the development of most lasting significance is the passage, in the final hours of the 96th Congress, of the Waste Policy Act. It contains many important provisions, some of them of critical importance to the nuclear industry, and to the breeder reactor. While time does not permit a detailed discussion of the WPA of 1983, a few key provisions should be highlighted here.

- o The United States government is made responsible for storage, transportation and disposal of spent nuclear fuel beginning in 1998; the utility industry must pay a 1 mil/kWh surcharge beginning, April 7, 1983 on electricity generated in nuclear plants. This tax will raise $14 billion by the year 2000 and over $24 billion by around 2030. (The fee is adjustable, but is a one time fee). There is an elaborate and complete series of schedules and milestones in the Act leading to nomination by the President of a site for a first repository in 1987, and licensing of the first repository for construction by 1989, and provisions for nomination and licensing of a second repository; all of this leading to operation of a repository by January 1998.

- o There are provisions for a backup program, a Monitored Retrievable Storage (MRS) program to provide storage of spent fuel and a schedule leading to a decision prior to 1985 on whether MRS will be an integral part of the program.

- o You may be aware of the mandate within the Act for a cooperative international program to provide "technical assistance to non-nuclear weapons states in the field of spent fuel storage and disposal."

The act is notable for some of the matters it omits. No where is the term reprocessing, a necessary element for breeder reactor implementation, mentioned. But there are several provisions of the act that will encourage preservation of fuel resource values and eventually encourage reprocessing. For example:

- o Spent fuel or high-level waste may be disposed in a repository. Spent fuel must be indefinitely retrievable, while separated high level waste may be permanently disposed.

- o The act requires that the government take title to spent fuel, and liquid or solid high level waste.

- o The implementation of the Act will permit utilities to reprocess fuel and turnover the waste to the government, on a basis such that the cost of waste disposal is prepaid by the 1 mil/kWh tax.

These and other provisions may accommodate either a government or a private sector venture in reprocessing.

For example, alternate business structures to operate the Barnwell Nuclear Fuel Reprocessing Plant at Barnwell, So. Carolina are being evaluated. Various business organizations are being considered including operation as a nonprofit R&D corporation, or operation by a private company as a leased facility from the U.S. government. However, there are unique requirements in the Waste Policy Act relating to the use of Barnwell, and concerns by the government of South Carolina that make it difficult to predict the precise future scenario. Unique provisions of the Act coupled with nonprofit corporation status could permit fees as low as $250/kg to be realistic for reprocessing services.

Similarly, there are encouraging developments at the facilities being built in conjunction with the FFTF on the Hanford reservation in the state of Washington. An important facility, the Fuels and Materials Examination Facility (FMEF), is approaching contruction completion and is located in close proximity to the FFTF. The FMEF accommodates fuel cycle activities directly supporting FFTF and other elements of the U.S. breeder reactor program. The two most important activities are the Secure Automated Fabrication (SAF) Project and the Breeder Reprocessing Engineering Test (BRET) Project. The SAF Project is a fully automated and remotized fabrication line for mixed-oxide fuel, with a throughput capacity of 6,000 kg per year (U + Pu). The SAF line will be operational in 1986. The BRET Project will provide the capability for reprocessing breeder reactor fuel at a rate of 100 kg per day, and will serve as a pilot plant for development of advanced reprocessing equipment and process technology. The BRET Project is a joint project involving HEDL and the Oak Ridge National Laboratory. The work includes engineering of remote process equipment that can be maintained, head end equipment that might be used to remove the spent pellets from their tubes and assemblies, emission control of off-gases, and finding solutions to other generic problems.

Pending BRET completion in 1990, FFTF spent fuel will be stored in the adjacent, recently completed Fuel Storage Facility (FSF). Closure of the breeder fuel cycle within the co-located FFTF/FMEF complex will provide a demonstration of an important part of LMFBR technology.

III. The Base LMFBR R&D Program

The total DOE breeder budget for FY1983 is $550 million and $603 million is required for FY1984. Of these budgets, $192 and $270 million are earmarked for CRBR leaving $358 and $333 million for other programs. The fuel cycle and waste management work is funded separately. The mission of the LMFBR base program is to develop the requisite technology to the point where the private sector is able to support construction and operation of economical, safe, and reliable liquid metal fast breeder reactor plants. The program is carried out through generation of new concepts, identification, and resolution of critical technical problems inherent in such designs, computer code work to predict performance, the conduct of R&D to verify behavior predictions, and testing of components and integrated concepts as models to verify problem solutions and successful performance predictions. Some of the highlights are:

- The large leak sodium-water reaction testing series will be completed, using a prototypical CRBR steam generator tube bundle. So far analytical predictions of wasting effects are verified showing that reliable fast response leak protection systems are needed.

- Acceptable hydraulic performance characteristics have been demonstrated in water tests of a 1/3-scale model of the 85,000 gpm intermediate system sodium pump designed for large plants.

- The 70 MW (th) model steam generator, based on the large helical tube steam generator design, has been assembled and eventually will be tested at ETEC.

- A seven tube model steam generator has been built and tested. This model is based on the Westinghouse double-wall tube large steam generator design. Acceptable thermal and hydraulic characteristics were verified. Assembly of the 70 MW (th) double-wall steam generator model will be initiated in 1984.

- Assembly of the 85,000 gpm, two stage, primary sodium pump test article is under way. The unit will be tested in water first and eventually tests in sodium will be conducted beginning in 1985.

IV. Fast Flux Test Facility and EBR-II

The programs conducted at FFTF and EBR-II are important parts of the Base Program due to the irradiationn tests, special experiments, and operations experience obtained by operating these reactor plants and their associated facilities. FFTF completed its first operating cycle and first refueling and is now in its second operating period with many experiments installed.

Development of core component technology, through testing of prototypic components in FFTF, continues to accelerate on a broad front, building on 19 years of effective operations and testing experience in EBR-II. EBR-II core height is only 14 inches; FFTF can test full height and larger tube bundles. The goals of the core components program are to develop highly reliable, long-lifetime components which will enable improved plant performance and reduced fuel cycle costs. The FFTF core is highly instrumented and provides a good environment for fuel assemblies, blanket assemblies, and reflector/shield pieces. The standard FFTF driver fuel assemblies are thoroughly characterized and a comprehensive program is under way to evaluate the performance of the driver fuel beyond design lifetimes. Selected assemblies are discharged at the end of each operating cycle to assess performance with increasing burnup. In-process measurements are also made to characterize core restraint effects. In addition, an extensive program for development of advanced fuel, blanket, and absorber assemblies is in progress; more than 50 full-scale test assemblies are presently installed in the core.

No significant failures have yet been observed in FFTF core components. One gas leak from a fuel pin was detected at an early stage in an experimental fuel assembly, demonstrating the very high sensitivity of the FFTF gas tagging system (pioneered at EBR-II) for failed element detection and location. In addition to the detection and location of the fuel pin gas leak, a number of other tag gas releases were detected and located by the gas monitoring system. The source was leaks from pressurized capsules in MOTA. Eleven of these capsules were expected to fail in Cycle 2 but later in the cycle. All fuel, blanket, and absorber assemblies in FFTF are uniquely gas tagged; this system will be particularly important in future operations as a number of assemblies are deliberately taken to and beyond cladding breach to establish failure statistics and characterize failed pin behavior.

The FFTF is also equipped with a number of specially instrumented open core positions for experiments which are providing extensive in-core performance data. Presently installed in the core are three fuels and absorber experiments for continuous monitoring of assembly thermal-hydraulic performance; also in operation is a special materials test assembly which provides active control of irradiation temperature over the range 400-450°C ((750-1400°F).

Planning is under way for the activation of a fully independent closed loop in one of the eight instrumented test positions. The closed loop will permit the conduct of a variety of fuels and safety tests (e.g., run-beyond-cladding breach, operational transient, flow blockage, etc.) without interfering with normal core functioning. The test assemblies in the closed loop can be of power reactor size components.

The standard FFTF driver fuel will reach the goal burnup level of 80,000 MWD/MTM (peak) at the end of Cycle 3, later this year. A series of prototypic second-generation fuel assemblies now in the core are scheduled to attain a goal burnup of 125,000-135,000 MWD/MTM (peak) by the end of next year. The first of a series of third-generation fuel assemblies will be inserted at the start of Cycle 3, with a burnup goal in the range 150,000-250,000 MWD/MTM. Parallel development efforts on long-life blanket and absorber assemblies are in progress. By the end of this decade, it is expected that the state of core component technology will be fully supported of commercial-scale breeder reactor plants.

In EBR-II we had no opportunity to monitor buildup of radioactivity in primary loop cells because the primary sodium systems is contained in the primary tank. FFTF provides an opportunity to monitor the cells beginning while they are new, the loops are clean, and ^{22}Na is quite low. The following account appeared in "FFTF in Review" (a monthly newsletter).

An important requirement for any type of reactor system design is the ability to perform on-line maintenance on its heat transport system. In FFTF, each of the three cells containing a primary pump and an intermediate heat exchanger is separated from the reactor cavity by a shielded pipeway containing isolation valves on both the inlet and the outlet piping. By design, the equipment in one of the three loops can be shut down to permit access for maintenance while the other two loops remain in operation.

But, the feasibility of such "two-loop operation" and "one-loop maintenance" depends in large part on the radiation levels that maintenance personnel would experience during repairs. For this reason, radiation measurements were made in one of the heat transport system cells following Cycle 1.

Radiation in an FFTF heat transport system cell is expected to come from three major sources: long-lived ^{22}Na isotope, plateout of corrosion products, and deposition of fission products following operation with breached fuel. The specific activity of ^{22}Na is measured routinely using small samples of primary sodium, and its growth is in reasonable agreement with design prediction. As the reactor has not operated with breached fuel, fission products are not now a radiation source. Therfore, the major uncertainty in the dose rate is associatd with the plateout of corrosion products.

Six weeks following reactor shutdown, two types of radiation measurements were made in the heat transport system cells and in the isolation valve pipeway. First, gamma-ray dose rates were measured by lowering an ionization chamber into the cells at five different locations through periscope penetrations. Second, gamma-ray spectrum measurments were made through three different surveillance holes. The results were in fair agreement with predictions. Manganese was predicted to preferentially plate out on cold leg components. ^{60}Co was not detected. The important thing is that similar measurements (to more precisely establish the time-dependent buildup of ^{22}Na and corrosion products as a function of operating history) are planned during future reactor shutdowns.

~~during future reactor outages.~~ This program of measurements will not only provide direcct dose rate information in the FFTF heat transport system cells, but will also provide better bases for predicting conditions in future reactors and for evaluating the effects of any remedial actions taken to reduce radiation levels.

V EBR-II

Since 1965, the EBR-II has been the workhorse for the U.S. fuel and and materials steady-state irradiations as well as our pilot breeder power plant. The FFTF has now taken over much of this burden and has released the EBR-II for what is called operational reliability testing. This program has two broad categories: (1) off-normal fuel performance testing and (2) operational transient testing. The Japanese PNC and the U.S. DOE have a contract to cooperate in this area adn to share the costs. This work was initiated in 1982 and is scheduled to continue into 1986 or 1987.

An important part of this program will be the "run-beyond-clad-breech experiments." As you know, mixed oxides swell slowly when exposed to the primary sodium. A clad breech that starts as a crack in a fuel tube can expand as the oxides swell due to exposure to the flowing coolant. The run-beyond-breech experiments will detemrine the behavior of a fuel tube bundle after a crack occurs in a tube containing irradiated fuel that is not located and removed in a short time. The transport of fuel particles and fission products out through the crack will be monitored. The effects of changes of power, shutdowns, and startups will be determined.

Other experiments will simulate operational transients and determine the effects of duty cycles that are expected in the life of fuel in a commercial breeder plant with long burnup goals. Operational safety testing will be conducted to benchmark shutdown heat removal without site power. The adequacy of natural convection flow will be demonstrated and the results will be used to check the pertinent computer codes. Additional experiments will be conducted to validate analytical models used in computer codes, to study severe events and. The plan is to ultimately test the response of mixed oxide fuel to sodium boiling at the decay heat level.

The plan is to explore the man-machine interface using EBR-II. This does not mean "human factors" but refers to developing and testing computer-based techniques [to au]gment the operators during plant upsets. Also, on-line monitoring would detect degradation of a safety-related measurement and predict by on-line computer analyses of other parameters what the degraded measurement should be. The computer would not take the place of a properly trained operator but would be his tool to augment his ability to judge and diagnose what is happening during off-normal situations.

The ZPPR facility at the EBR-II site is being used for zero power experimental studies of heterogeneous cores of the type planned for CRBR and large breeder plants. ZPPR has a 14-ft table and is well adapted for studies of large breeder cores.

VI. Large-Scale Prototype Reactor

As previously mentioned, the U.S. breeder program includes a large-scale prototype breeder plant (LSPB) as the logical next step to follow the Clinch River intermediate-size plant. This large plant is to emphasize total cost of pwoer, i.e., particular attention is focused on developing a design concept that is less complicated, easy to construct, and potentially less costly. It is realized that the prototype will incur developmental and first-of-a-kind costs that will make it more costly than a light water reactor plant or an equivalent coal plant. However, the objective is to make the LSPB prototype of 1,000 MW (e) commerical breeders to follow, that will be economically vaiable at the turn-of-the-century.

To do this, safety issues are addressed early and solutions will be incorporated in the concept at the beginning. These solutions must be consistent with the basic philosophy that the design must be less complicated and easy to construct as well as safe. Also, maintainability is addressed from the outset in developing the concept. By applying design criteria that specify fewer components and less complicated systems, there can be more room for maintenance and ready access where maintenance has to be performed without making buildings larger and more costly. In fact, it is believed that the amount of reinforced concrete can be drastically reduced.

The conceptual design work stresses the need to reduce the exposures of operating and maintenance personnel to radioactivity as compared to post and current situations in nuclear power plants. The approach can be to design around (i.e., eliminate) the needs for operations that would otherwise have to be performed in spaces where radioactivity would buildup. It appears that commercial breeders can be considerably better than current LWRs are with respect to doses to plant personnel and yet not add to the costs to accomplish this goal.

Competitive overall cost of power is the ultimate goal and this means that spent fuel from LWRs and from breeders must be reprocessed economically. Also, the refabrication of the plutonium and depleted uranium into reliable breeder fuel and blanket assemblies must be economical. These are real challenges and are recognized as important parts of the innovative engineering and development that have to be accomplished. These tasks are equally important with the development of a superior breeder plant design concept and the details of engineering and building that prototype breeder.

The needs of the large-scale prototype breeder will serve to focus our future R&D and the efforts to develop an institutional structure that will support breeder plants and their fuel cycle.

VII Consolidated Management Office (CoMO)

The U.S. government and private industry are cooperating to establish institutional and financial arrangements, and to develop plans for proceeding with the design, construction, and operation of a large breeder plant. Ultimately, the effort is expected to include participation of other countries. An agreement between the Department of Energy and the Electric Power Research Institute (EPRI) to cooperate on the large-scale prototype breeder effort was executed last year.

A consolidated management office called CoMO has been established to consolidate the efforts of the U.S. Department of Energy, U.S. utilities/EPRI, reactor manufacturers, and architect engineering companies directed toward the many facets of developing the Large-Scale Prototype Breeder (LSPB) and its fuel cycle. CoMO is to perform two primary functions: (1) technical integration of the LSPB program activities and (2) direct the effort to establish international cooperation on the program. EPRI has taken the lead for the U.S. utilities and has established this consolidated management office in Naperville, Illinois near Chicago.

The Department of Energy has delegated to CoMO the responsibility for technical direction and surveillance of the LSPB contractors who are under contract to DOE for plant design efforts. One of the contributions of CoMO is to obtain and integrate the requirements of the end users (the utilities) into the engineering and development of the LSPB. As a major step toward this, an LMFBR Utility Steering Committee has been set up to give guidance to CoMO including requirements and policy direction. This committee is made up of senior executives from the U.S. utilities that have a long history of interest in liquid metal cooled fast breeder reactors. Engineers from these utilities will be an important part of the CoMO working staff.

In view of the similar goals that we, the various countries, have for attaining breeder power plants and the use of our fissile material assets contained in spent fuel assemblies, it seems advantageous for all to organize some sort of formal cooperation that would reduce duplication of R&D and other costly activities. The amount of money, talented personnel, and costly facilities needed to develop truly safe and economical plants ~~is~~ are very large. It should be possible to organize a cooperative program to make use of the existing facilities and qualified personnel in each of our countries such that the work is divided up and the results are shared. Obviously, there would be many problems to work out among us but the savings could be large if such a collaborative program can be established. CoMO is charged with the responsibility to explore these possibilities and to promote the establishing of a formal collaborative program. In addition to the possible savings mentioned, there could be another significant advantage to a strong international collaboration. There are some people in each of our countries who are strongly opposed to breeders, not realizing that society will certainly need such power plants in the future. If we can work together and present a well thought-out unified program, it should be easier to continue to win a majority of the legislators, administrators, and the general public to support our breeder programs.

Introductory Statement for the Panel Discussion of Session 2

Development Strategy of Fast Breeder Reactors

Background

More than a decade had passed after the end of the Second World War, when the Federal Republic of Germany began to give government support to research and development in the field of nuclear energy. Following some preparatory work, a first nuclear programme was drafted in 1957/1958. Its main objective was to make up the scientific and technological lead taken by other countries, above all the United States, and to set up an efficient nuclear industry within the shortest time possible.

The members of the German Atomic Commission, who prepared the first nuclear programme, assumed at the time "... that, after a certain interim period, electrical power from nuclear energy would be generated mainly by means of so-called fast breeder reactors..."

The nuclear R & D work of the fifties and sixties was characterized by activities in search of the most approriate reactor technology. As far as the first-generation reactors operating with thermal neutrons were concerned, the search relatively soon focused on today's commercial light-water reactors. The world's first nuclear power plant with more than one thousand Megawatt of electrical power built in the Federal Republic of Germany is operated with an extremely successful type of reactor: three nuclear power plants of this order of magnitude - Biblis B, Unterweser Nuclear Power Station and Biblis A - achieved a worldwide lead in annual power generation in 1982. In the field of fast breeder reactors, the Federal Republic of Germany, like all the other countries, chose liquid sodium to serve as a coolant, a decision based on extensive investigations and discussions of the various means of reactor cooling.

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Once this decision had been taken, a strategy for the development and commercialization of breeder reactors was speedily drafted, which, for the most part, is still valid today except for its schedule. This strategy has two principal features: on the one hand, German activities in all areas of breeder technology have been designed with a view to setting up a complete breeder system; on the other hand, extensive international cooperation and industrial collaboration are intended to reduce development costs and minimize the investment costs respectively.

Technological constraints and an international exchange of ideas led to a concentration of breeder development on the same technology in all industrialized countries, thus largely facilitating cooperation in the past and in the future.

Technological development

Of course, the development of the breeder towards its commercialization, like that of any other large-scale plant, passes through several phases during which experimental facilities of increasing size are built. Subsequent to the operation of a first experimental zero-power facility called SNEAK, a first sodium-cooled nuclear power plant (KNK) was commissioned at the Karlsruhe Nuclear Research Centre in 1973, which still had a thermal reactor core. Its main purpose was to test sodium as a coolant. In 1977 it was equipped with a fast reactor core of 20 Megawatt of power output. This experimental power plant called KNK II is used above all for the development of fuel elements for future plants of a larger size. The long history of operation with practically no accidents demonstrates the operational safety of sodium-cooled fast reactors and the high quality of the fuel elements, which have reached a burn-up rate of as much as 100,000 MWd/to.

In 1972 the first partial construction licence was granted for the SNR 300 prototype nuclear power station. It is a loop-type

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power plant and is to go into operation in 1985. Its operator is SBK, the German-Belgian-Netherlands Fast Breeder Nuclear Power Plant Company.

The expected period for construction of the SNR 300 was seven years at the time when the contract was awarded, but is now thirteen years. The costs increased from an original DM 1.5 thousand million to DM 6.5 thousand million. The smaller part of these cost increases and delays in schedule was caused by technological problems, the majority, however, is to be attributed to the licencing procedure. Since the German nuclear licencing procedure does not provide for any special rules for experimental and prototype plants, the SNR 300 had to meet the same criteria that are applied to commercial nuclear power plants. This frequently resulted in additional requirements being imposed by the licencing authorities even during construction. For instance, a requirement imposed after the contract had been awarded was the ability to control the effects of a Bethe-Tait accident with a maximum excursion of up to 370 MWs. Considerable cost increases and delays were the natural consequences. A similar outcome resulted from the requirements imposed during construction to upgrade the reactor to resist the impact of high-speed military aircraft and earthquakes of an intensity unusual in Germany. In addition, the requirements as to the quality and quantity of documentation, tests and expert opinions were increased during construction. Present efforts to streamline and simplify the licencing procedure also aim at modifying those special features of the German licencing procedure in such a way that it will again be possible to establish reliable schedules and calculations for prototype power plants, too.

...

In September 1982 the final construction licence was granted for the SNR 300. Any further substantial requirements are not to be expected. It should, therefore, be possible to adhere to the present cost and time schedule.

The SNR 300, like the Phénix in France, is the predecessor of a commercial-size nuclear breeder power plant. The next consistent step in the German breeder development will be the SNR 2, a power plant which has been envisaged for some time now and which will have a gross electrical output of 1,300 Megawatt. Preliminary definition work for the SNR 2 is under way; it will require a decision on whether to use a loop concept as in the case of the SNR 300 or the pool concept selected for Superphénix. Design work could start in 1984, meaning that construction could then begin at the end of the eighties. Since in the Federal Republic of Germany, the utilities are responsible for the design, construction and operation of power plants, it is, above all, the utilities (who are interested in the breeder as a means of power generation) who will have to provide most of the funds, and who will have to make the decision on the next steps to be taken. An agreement concluded back in 1971 between the Electricité de France (EdF), the Italian Ente Nazionale per l'Energia Elettrica (ENEL) and the German Rheinisch-Westfälisches Elektrizitätswerk (REW) provides for joint EdF and ENEL participation of 49 % in the SNR 2.

Reprocessing

The fuel cycle is an important and integral part of breeder technology. The fuel cycle cost makes up a considerable portion of the power generation costs in the case of breeders. The technological organization of the nuclear fuel cycle largely determines the breeding rate and the time required from the beginning of breeder commercialization to achieving independence of imported nuclear fuel. Although the Purex process, which proved its value for LWRs, can, in principle, also be used for the reprocessing of spent fuel from breeders, substantial modifications will have to be made not only because of technical differences between the breeder and the LWR cycles, but also because the safety and safeguards requirements are different in the case of the breeder.

At the Karlsruhe Nuclear Research Centre, a breeder fuel reprocessing facility of laboratory scale is being operated. Preliminary design work is under way for a semi-industrial facility. So far, the beginning of construction work has not been envisaged. Since the fuel elements of the SNR 300 and of the small experimental KNK II power plant will be reprocessed in France, the construction of a German breeder fuel reprocessing facility is not a matter of urgency.

International cooperation

The endeavours to create a broad basis for the breeder development and to minimize costs resulted in the conclusion of agreements and arrangements even at an early stage, e.g. in 1983 when German work was incorporated in EURATOM's nuclear breeder programme, further in the German-Belgian-Netherlands R & D agreement of 1967 and, above all, in the Fast Breeder Convention of 1971 concerning the construction of two demonstration plants of commercial size in France and in the Federal Republic of Germany. In 1976, the German-French cooperation agreement was signed in Nice and was followed by detailed arrangements between all German and French parties concerned, including the associate partners Belgium, the Netherlands and Italy. These agreements provid for comprehensive R & D cooperation and commercialization of knowhow by the joint firm of SERENA.

Under this agreement, the biggest German utility (Rheinisch-Westfälisches Elektrizitätswerk), together with its Belgian and Netherlands partners, participates in the French Superphénix. On the other hand, the French and Italian utilities EdF and ENEL respectively will, as I said before, participate in the German SNR 2.

...

The powerful West European group that has thus been established is linked by cooperation agreements in particular with PNC in Japan and the US Department of Energy. Conversations with the United Kingdom on closer cooperation are being conducted.

The fuel elements from the KNK II experimental plant and from the SNR 300 will be reprocessed in France.

Future development strategy

All countries which carry on breeder development work agree that the time required to reach the phase of eventual commercialization will be longer than anticipated. This re-assessment takes account of both general aspects of world politics and world economy and special developments in power engineering and in the power supply industry. We should make good use of the additional time in order to establish broader and more extensive international cooperation. Such cooperation can help us all to optimize the breeder system in terms of technology and economics and to make more effective use of the limited government resources available. It can also help to achieve the necessary technical progress and to obtain experience with a smaller number of demonstration plants. My government is therefore very keen to extend and develop the existing close cooperation of the Federal Republic of Germany with France, Belgium, the Netherlands and Italy to include further partners as well.

Cooperation should, however, by no means be confined to Europe. Together with our European partners, we seek to intensify our existing cooperation with Japan and the United States. The similarity of technologies and future problems offers a great opportunity for us to seize.

Any substantial improvement of the security of power supply by means of breeder reactors can be achieved only if nuclear energy makes a considerable contribution to power generation. Hence the decision on the commercialization of the breeder will in the last analysis depend also on how the utilization of nuclear energy develops throughout the world. The high standard

...

of safety, the low level of environmental pollution and the economical operation of nuclear power plants achieved in most industrialized countries induces us to believe that nuclear energy will become the most important source of energy, particularly in the base load sector.

The question of when the fast breeder reactors will be ready for commercialization will to a large extent depend on progress made with regard to the economical operation of large breeder reactors and the associated fuel cycle facilities. The political evaluation of the gain in supply security to be achieved by breeder reactor systems will also play a major part in this connection. Last but not least, the environmental impact of all types of power generation will be used as a yardstick for their acceptance. In this respect, nuclear power on the whole offers clear benefits compared with coal or oil-fired power plants. As a result, it can probably be expected that breeders will be quite successful in the market.

International cooperation can accelerate this process considerably. In addition, it can and must establish the necessary broad-based confidence for public acceptance of this technology, which at present still meets with emotional rather than rational objections.

§3 キム氏本論文

International Cooperation

AT 16TH JAIF ANNUAL MEETING

MARCH 23 - 25

SUN CHANG KIM

DIRECTOR AND VICE PRESIDENT

KOREA ELECTRIC POWER CORPORATION

SEOUL, REPUBLIC OF KOREA

Mr. Chairman, Ladies and Gentlemen ;

I am very pleased to be here this afternoon to share my thought of international cooperation with you. For your better understanding, I would like to present briefly nuclear needs in Korea and status of international cooperation activities undertaken primarily by Korea Electric Power Corporation (KEPCO) which is solely responsible for executing entire nuclear power program before explaining my views on "how international cooperation between developing and advanced countries should be pursued.

Nuclear Needs in Korea

Nuclear industries have remained sluggish mainly because of the prolonged recession throughout the world. Nevertheless, Korea is one of the countries which continue to develop nuclear energies in a positive manner. The major reason is that Korea does not have enough indigenous energy resources to meet the national demand.

Even though oil price currently seems to be declining, it is believed that this tendency is a passing phenomenon. As for the countries which retain only poor energy resources, like Korea, I think that the utilization of nuclear energy should be increased more than before in view of securing stable energy supply sources.

Since 1978 we have successfully operated Korea Nuclear Unit No. One(1) plant of which capacity is 587 MWe and its operating capacity factor is progressively improving. Two other plants are going to be in commercial operation near future and now in various start-up testing stages.

Six units of 950 MWe are under construction. The total nuclear power will reach 9.4 GWe which represents 39.7% of total installed electric capacity in the year 1991.

Status of International Cooperation Activities

Until now, we have been trying to strengthen cooperational relationship with foreign organizations on the basis of peaceful uses of nuclear energy. As result of this effort, we have been able to resolve many problems encountered during implementing Korea nuclear projects.

The international cooperation activities in KEPCO could be classified into three(3) types ; Technical information exchange program with five countries, Engineer dispatching program with two countries and participation in foreign organization with two countries.

1. Technical Information exchange program with ;

   a. Ontario Hydro, Canada

   b. Taiwan Power Company, Republic of China

c. Comision Nacional de Energia Atomica of Argentina

d. Belgian utilities with Belgium

e. Electric power development Co., Japan.

2. Engineer dispatching program with ;

   a. Taiwan Power Company, Republic of China

   b. Kyushu Electric Power Company, Japan

   c. Overseas Electrical Industry Survey Institute, Japan

3. Participation in foreign organizations with ;

   a. Atomic Industrial Forum, U.S.A

   b. Institute of Nuclear Power Operations/Nuclear Safety Analysis Center, U.S.A

   c. Westinghouse Owners Group, U.S.A

   d. Information Center on Nuclear Standards, U.S.A

   e. Canadian Nuclear Association (CNA), Canada

<u>My views on International Nuclear Cooperation</u>

Although there has been significant benefit resulted from the beforementioned cooperation arrangement, we also have realized that certain limitations exist in sharing practical experience and technology mainly due to the difficulties of rapid communication, great geographical distance and different way of thinking by the different cultural circumstances between the participated countries.

In view of Korean experiences with international cooperation activities, I can say that the most effective cooperation have been possible with Japan and the Republic of China because these three countries are neighbourhood each other.

As previously stated, oil price seems to be declining due to the world economic recession and energy conservation policy. However, it will not last long in existance.

More Asian countries are expected to take an effort to develop nuclear industry in future. And it will be very feasible to establish an international organization in Asia-Region to be beneficial for participating countries, because there are great similarities in customes, cultures and philosophy as well as geographical closeness among the countries in this region.

In the United States, the leading country of nuclear industry, nuclear projects lost their economic merits thesedays because of the increase of construction cost which resulted from delay of schedule, complicated licensing procedures and high interest rates. Although there is a tendency to take certain steps to improve licensing procedure within US Regulatory Authorities, it will require considerable time and effort to materialize the improvement.

On the contrary, another leading country in this side of earth, Japan has had over twenty-years experiences in nuclear power industry and is believed to be mature enough in view of financial and technical ability to support cooperation activities in Asian Region.

Considering this matter, it is very desirable to maintain closer cooperative relationship between countries in Asia-Zone. Accordingly, I would like to suggest a kind of regional cooperative organization be formulated consisting of industrial bodies such as ATOMIC INDUSTRY FORUMS or utilities of participating countries.

The regional nuclear organization which should be named by participating countries' consent, is expected to deal with the following areas ;

- Waste disposal
- Plant information exchange
- Front & Back-end fuel cycle
- Radiation Emergency Preparedness
- Any other areas of member's interest

It is also suggested that any planned meetings of the foregoing groups be held in sequence.

My thanks for your attention.

Table/Status of International Cooperation in KEPCO

Organization	Nation	Type of Cooperation	Effective Date
Taiwan Power Co. (TPC)	Republic of China	* Agreement for Cooperation in the area of Resources and Technology - Scope of Cooperation . New Technology . Securing of energy resources . Planning, construction and operation of nuclear power plants	1980. 11.
		* Agreement for personnel exchange program for training	1976. 6
Overseas Electrical Industry Survey	Japan	* Agreement for Technical Cooperation - Scope of Cooperation . Despatch of Trainees . Invitation to specialists . Exchange of Management and Technical Information	1979. 5
Electric Power Development Co. (EPDC)	Japan	* Agreement for Mutual Cooperation on Energy and Technology	1979. 12
Kyushu Electric Power Co.	Japan	* Agreement for Personnel Exchange Program	1969. 1

Organization	Nation	Type of Cooperation	EffectiveDate
Comision National De Energia Atomica (CNEA)	Argentina	* Agreement for Technological and Scientific Cooperation - Scope of Cooperation . Network requirement studies . Construction and start-up of Nuclear Plants . Safety and Protection . Training and Development of Personnel	1980. 2
Ontario Hydro	Canada	* Agreement for Technical Cooperation - Scope of Cooperation . Transfer of project management system . Design and Engineering . Commissioning, operation and maintenance . Any other fields of mutual interest	1981. 3
Belgian Utilities	Belgium	* Agreement for Technical Cooperation - Scope of Cooperation . Energy policy . Construction, operation and maintenance of power plants . Radiation control in nuclear power plants	1982. 11
Atomic Industrial Forum (AIF)	U.S.A	* Participation as membership	1980. 1

Organization	Nation	Type of Cooperation	Effective Date
Information Center on Nuclear Standards (ICONS)	U. S. A.	* Participation as membership	1975. 12
Institute of Nuclear Power Operations (INPO) and EPRI/NSAC	U. S. A.	* Participation as membership	1983. 2
Westinghouse Owners Group (WOG)	U. S. A.	* Participation as membership	1980. 6
Canadian Nuclear Association (CNA)	Canada	* Participation as membership	1974. 5

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§3 I. バドラン博士

INTERNATIONAL CO-OPERATION IN NUCLEAR ENERGY AN EGYPTIAN VIEW

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Presented to

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Tokyo, Japan

ARAB REPUBLIC OF EGYPT
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INTERNATIONAL CO-OPERATION IN NUCLEAR ENERGY
AN EGYPTIAN VIEW

ABSTRACT

The interplay of many dominating variables today has a decisive effect on survival. The most dominant variables are : the unavoidable growth in population, food and energy needs. The world's depletable energy resources nearing their end compell resorting to alternative long-lived durable energy resources and conserving oil consumption for premium uses. Search for alternatives unquestionably leads to the identification of nuclear power as the most economic long-term possible resource. Disparities existing among nations of the world today should not be viewed as impediments to this cause. For nuclear power generation to flourish, unifying interests can be a promoting factor, to mention: uranium deposits, advanced nuclear technology, financial resources, production of goods based on processing through new technologies, manpower, and finally the growing needs. All these do not belong to one nation, one region, or one economic structure. Egypt endorsed the non-proliferation treaty and started its nuclear energy programme to meet its growing energy demand through the year 2000. Concurrently manpower training is underway in a number of 30 year old institutions. A New Framework for International Co-operation in Nuclear Energy is proposed to encampus: "World Campaign" for Public Awareness; establishing a "World Trust Fund" to finance nuclear energy projects; establishing "Nuclear Science and Technology Training Institutes"; enhancing Research and Development in: fuel cycle, size of commercial nuclear power plants; unified electric grid in neighboring countries; waste disposal; other peaceful applications; and establishing an "International Order of Conduct". In addition, the role of IAEA should be strengthened.

INTRODUCTION

On behalf of the Government of the Arab Republic of Egypt, it gives me great honor to address this distinguished meeting on a subject of paramount importance to all of us .. it is indeed the subject related to our own survival.

Man NOW should be alarmed that the very issue of survival is at stake and that only through the efficient and just utilization of world resources .... survival for all, is possible.

Energy is the crucial issue of today. Unfortunately, nature has complicated the situation by providing energy in various forms. Some are fast depletable, some are slowly depletable and some are renewable. Some are ready utilizable, but most need further processing.

Until very recently, the world has concentrated on the use of depletable forms of fuel. Through a mixture of limited perception, indifference, and injudicious exploitation of resources, this turned sometimes into shear abuse.

In the meantime, conflicts between nations and pressing needs stimulated research and development in all aspects of science and technology. Added to that, there are the disparities among the nations of today. There are the rich and there are the poor ... there are the technologically advanced ... and there are the slow developing.

Moreover, the industrialized nations had the immeasurable advantage of having been able to complete their industrial transformation in an era of cheap energy, especially oil. The developing countries, on the other hand, will have to go through this experience in an era of relatively high energy prices.

For this diversified and complicated situation we are here today to discuss the present and future prospects of Nuclear Industry which is reaching the age of maturity and to present and exchange views on a new Framework for International Co-operation.

2. WORLD ENERGY CONSUMPTION AND REQUIREMENT

Analysis of the trends in the world energy consumption and future requirements leads to the following conclusions:

2.1 Average world energy consumption and electricity production between 1950-80 increased at annual rates of 5% and 7.5%, respectively.

2.2 The world energy demand will at least double its present level by the year 2000.

2.3 The present share of electrical energy of the total primary energy consumption is about 25% and may increase to about 40% by the year 2000.

2.4 At present the electricity produced by nuclear power plants is about 8% of the total electricity generated in the world. By the year 2000 the nuclear share is estimated to increase to about 20 to 25%.

Global Energy Demand Through the Year 2000

Demand on oil by the 4.5 billion people of the world today will probably continue to increase until 1995 at which time consumption will be at a critical situation regarding the limits of oil resources. Gas will continue to have its stable situation as a source of energy inspite of the difficulties of transport. The availability of huge resources of coal will allow it to meet a large part of the world energy demand. Renewable sources of energy such as solar, wind, tidal, geothermal and biomass are at the very early stages of industrial development and their contribution to the total energy supply is not expected to be more than 5-10% by the year 2000. Regarding electricity production, their contribution is not expected to reach any significant value by the end of the century. Thus it can be seen that the increase in world energy demand will not be met without a major contribution from nuclear power. The balance of electricity generation, would be mainly supplemented by coal and hydropower. Nuclear power has proven its competitiveness versus oil-fired plants, even with oil prices of $29/barrel,nuclear power, even with the extra cost due to more sophisticated safety requirements, is still competitive.

However, utilization of nuclear power is challenged by questions concerning reactor safety, environmental hazards, waste disposal, and the proliferation of nuclear weapons. On the other hand, the current view favors the safety record and the minimal environmental prevailing effects. Even with the most optimistic assumptions, in the absence of a nuclear programme, a country can still acquire the capability to procure nuclear explosives. Here, of course, comes the value and role of International Control.

3. <u>DEVELOPING COUNTRIES IN THE GLOBAL ENERGY CONTEXT</u>

The developing countries constitute an increasingly important component of the global energy scene. With three quarters of the world's population, they account for one-quarter of total energy consumption in spite of being the largest suppliers of petroleum, and have over 2/3 of the world's probable resources of oil and gas. While the developed countries which represent some 27% of the world population at present, consume more than 75% of the world energy. Thus, the average per capita consumption in industrial countries is more than eight times higher than that of the developing countries. With this apparant disparity, it can be seen that in the developing countries the expected rate of growth of demand for electricial energy will undoubtedely be higher than the corresponding rates in industrial countries.

The developing world searching for economic growth faces major challenges: pressures due to population increase, shortage of capital, lack of appropriate technologies, institutional and cultural barriers, and lack of effective energy management. Accordingly, an adequate and least expensive supply of electrical energy is becoming a basic requisite in the developing countries.

The low prices existing before 1974 induced developing countries to rely for 60% of their requirements on petroleum which few of them produce. While only 26 countries satisfy their needs or export, about 90 comprising the large majority of the population of the Third World, must import increasing quantities of petroleum. Their oil imports exceeding US$65 billion in 1980, aggravated by the rising prices of capital goods, added to the limitation of their exports and led to serious disturbance in their balance of payment.

In order to solve this crisis, it is felt imperative for developing countries to give priority to develop their energy resources and encourage the use of renewable resource technologies, especially for rural applications.

For this reason, some developing countries with large modern systems, however , are already using nuclear energy and many others are expected to use it before the end of the century.

The installed nuclear capacity in these developing countries in 1981 was 4.0 Gigawatt electric. By the year 2000, the developing countries total installed nuclear capacity is expected to reach between 51.5 and 78.0 Gigawatt electric.

Commercial reactors are available only in relatively large capacities which in the past has limited the number of countries which could use nuclear power in a balanced system.

The large majority of developing countries are facing an energy crisis which affects all aspects of their development plans. A response to this crisis would require:

- Very high investment in energy production.
- The re-orientation of development plans to take account of energy as a scarce and expensive component of the production.
- Energy conservation.
- A massive effort to ensure that the minimal requirements needed by the rural and urban development is to be met in the next two decades.

For all these reasons, the developing countries search to have financial and technical support which they need to expand their energy output.

4. EGYPT'S SITUATION

Egypt, as most members of the developing world club, has a rapidly increasing population with an ever-increasing demand for energy for accomplishing its social and economic development plan under relatively limited indigenous energy resources.

Up till the mid seventies energy activities in Egypt were handled on the production side by two ministries: the Ministry of Petroleum and the Ministry of Electricity and Energy. The alarming acceleration of energy consumption since the mid seventies, together with the global energy problems over the past few years, have created a strong recognition of the need for overall energy planning and co-ordination. A Supreme Council for Energy was established as the principal responsible body for policy and planning of major issues regarding energy. The Council's Chairman is the Deputy Prime Minister for Production and Minister of Petroleum and the rapporteur is the Minister of Electricity and Energy. The Council also includes in its membership the Ministers of Industry, Irrigation,Transport and Communcations, Housing and Reconstruction, Finance, Planning as well as the President of the Academy of Scientific Research and Technology and three selected scientists.

The Government has recently formulated a National Strategy for the Utilization and Development of New and Renewable Sources of Energy.

Egypt has several institutions working in the nuclear field. The Atomic Energy Authority, comprising about 3000 workers and established in 1955, is the research and development organization in fields related to the peaceful uses of nuclear energy. It is also the body responsible by an act issued in 1960 for the regulatory and safety aspects of nuclear reactors. Priority of the Research and Development programme is given among others to the strengthening of the infrastructure required for the implementation of the nuclear power programme and for maximizing national participation. Emphasis is made on the fuel cycle, nuclear instrumentation and control, regulatory, health and safety aspects and other related areas.

For the implementation of the nuclear power programme, the Nuclear Power Plants Authority was established in 1977. During the same year the Nuclear Material Corporation was established to deal with the exploration and extraction of nuclear materials, particularly uranium.

Egypt's energy policy is directed to the realization of economic and social development goals and objectives. This calls for securing energy supplies and optimal utilization of all available energy sources, promotion of effective conservation of energy, reduced dependence on oil, maximizing the use of available hydropower, shift to coal and gas, and the use of nuclear power.

The unified power system in Egypt interconnects all generating stations whether hydro or thermal. The unified grid supplies electrical energy to domestic, agricultural and industrial consumers through a network of transmission lines.

The total installed capacity at present is about 4700 Megawatt. It consists of a major hydro block at Aswan in Upper Egypt with a capacity of 2440 Megawatt and oil and gas-fired plants with a total capacity of 2260 Megawatt.The utilizable firm hydro block capacity, however, is controlled by the variable requirements of irrigation and Nile navigation system through the year.

The annual growth rate of energy consumption is rather high reaching 12.6% average over the past 20 years. The annual growth rate of peak load has been even higher reaching for example 14.5% between 1979 to 1980. These high rates are due to the combined effects of population growth, rural electrification, and the growing industrial and agricultural programmes.

Egypt's principal indigenous energy resources are, oil, natural gas, and hydropower. There are also limited coal deposits in Sinai and some potential uranium deposits in the Red Sea region and in Upper Egypt. Egypt's present annual production of oil and gas is 32 million tons of oil equivalent. The country's estimated proven oil reserves total about 400 million tons of which 90% is in the Gulf of Suez.

Potential hydro electric power resources are limited to the Nile Barrages and the Qattara Depression project which, if fully developed, would bring the total hydro energy to about 15.8 billion Kilowatt hour by the year 2000 which would cover only 15% of the expected energy needs at that time. Full utilization of the assumed available non-associated and associated gas increases its contribution to cover 13% of the total energy supply-requirement by the end of the century.

On the basis of various careful studies and detailed assessments of alternative options of power generation, it was found that nuclear power is expected to take a big share in covering power need. The size and extent of the nuclear programme would reach about 38 to 40% of the total power generation in the year 2000, which corresponds to about 8000 Migawatt electric, installed in eight nuclear units.

It is recognized that the realization of such a programme would require extensive efforts and special requirements in several areas. These include the development of necessary manpower, upgrading the present physical infrastructure, conclusion of necessary bilateral and international agreements to secure reliable sources of supply for nuclear equipment and fuel, adequate financing, and assurance of safety and public acceptance. Financing of the above requires massive investment which the Government is currently allocating from oil revenues despite the drop in world market oil price.

An extensive programme of manpower training is underway to face the responsibilities of the nuclear power programme. Co-operation with the IAEA, and several countries with whom bilaterial co-operation agreements is signed, is made use of for this training programme.

For the time being radioactive waste disposal does not constitute a major problem in Egypt, and will not be the case in the near future. However, preparing a well-trained team of workers capable of solving the present and future problems in this field appears to be a must. We are confident that through the extensive efforts made allover the world, the problem of long-range disposal of radioactive waste would ultimately find satisfactory solutions from which choices would be made suiting economic, national and international policies. In Egypt, the excellent degree of conservation, over thousands of years in the tombs of the Ancient Egyptians, is perhaps a historic message that long-term storage, in suitable geological formations, would become feasible afterall.

Egypt has concluded several bilateral agreements for co-operation in the field of peaceful applications of nuclear energy since the start of the programme for such applications as early as 1955. Bilaterial agreements of co-operation were concluded with the USSR, Norway, India, Yugoslavia and Italy. Co-operation with the IAEA was found to be of great help in providing the required services and technical assistance in many areas.

In order to show the good will and to assure the world of its peaceful intent in using nuclear power, Egypt ratified the Non-Proliferation Treaty in February 1981. This step encouraged the nuclear exporting countries, namely France, The United States, Federal Republic of Germany and Canada to sign nuclear co-operation agreements with Egypt which will allow for the transfer of nuclear technology, procurement of equipment and materials. Also Memoranda of Understanding were signed with the United Kingdom and Sweden for co-operation in the nuclear fields particularly in the areas of safety and training. Added to these, an agreement for the transfer of nuclear material was signed with Austrialia.

The Government is undertaking all the above measures while domestic energy prices are heavily subsidized. The Government is currently working on a plan by which suitable efforts and arrangements are being made to the best benefit of the consumers and at the same time with maximum gain to the national economy.

5. PROPOSAL: A NEW FRAMEWORK FOR INTERNATIONAL CO-OPERATION

At the outset, it should be recognized that within the arbitrary classification of rich or poor, developed or developing, First, Second or Third World and irrespective of their economic structure, the countries of the World have one common goal, i.e. their socio-economic development. Nowadays the survival of man, is resting on a balanced tripod of interaction among Man, Information, and Energy. Any unbalance in one or more of these three pivots will undoubtedly lead to pathological economy and hence failure in the process of development. Therefore, it is high time to get together to consider a new framework for international co-operation in the field of nuclear energy. It is believed that no one country, no one region, and no one economic structure can possess all the necessary supports for long-term economic growth.

EGYPT'S VIEW

Concentrating now on nuclear energy, an order of international co-operation, as viewed by Egypt and perhaps can be taken for other developing nations, would necessarily focus on the following aspects:

5.1 Campaign for Public Awareness

It is necessary to create an audible appeal and world-wide awareness of the value and necessity of "Nuclear Power for Peaceful Utilization". In particular, it would be wise and perhaps essential to embark on an organized campaign sponsored by national and international organizations under various forums, like this distinguished meeting, which is geared to removing the trailing unfavorable connotations which still adhere to the minds of many people.

5.2 Needed Financial Resources

As large investments are needed for construction of nuclear power plants, it will be useful for the world financing agencies, the developed nations, the various aid programmes, and the oil-rich developing countries to join hand-in-hand to establish a "WORLD TRUST FUND" or "NUCLEAR ENERGY ACCOUNT" to finance these projects. Drawing rights will, of course, be established according to some agreed mechanism, all oriented to the benefit of mankind.

5.3 Manpower Training

As nuclear technology is highly specialized, it would be necessary to ensure the availability of well-trained and skilled scientists, engineers and technicians as well as managers, from all and serving all countries. This would necessitate the establishment of "NUCLEAR SCIENCE AND TECHNOLOGY TRAINING INSTITUTES" in various regions of the World. Qualified instructors from the countries with the appropriate know-how would be drawn upon to implement the various required training programmes and be of help for permanent check and control.

5.4 Research and Development

In parallel with the above efforts, Research and Development should continue with emphasis on:

- Technology modification to the fuel cycle.
- Technology adaptation geared to reducing the minimum economic size of commercial nuclear plants.
- Studies of unified electric grids in small neighboring countries whose individual grids, financial resources and infrastructure cannot afford or sustain the present minimum size of commercial nuclear power plants.
- Development of other peaceful applications, e.g., desalination, process heating, ..etc.
- Research on waste diposal.

5.5. International Order of Conduct

Inspite of the attitude against universalization of nuclear know-how, the issue should be looked upon from the angle that any action is a calculated risk from the humanistic point of view. Difficulties are bound to exist between the would-be suppliers and recipients whether at the negotiation stage or during the fuel supply and nuclear servicing cycle. For these difficulties to be overcome, or perhaps avoided, ALL should adhere to an agreed "ORDER OF CONDUCT" to be DRAWN UP, SPONSORED, and PROTECTED by world organizations such as the UNITED NATIONS.

We propose that the Governments represented in this distinguished meeting join in sponsoring and supporting a proposal to the UN General Assembly to adopt a resolution covering all the aspects concerning the topics of contractual nature, assurance of supply, guarantees against proliferation of nuclear weapons, and perhaps economic sanctions against dissinters.

Specialized Agencies, like the IAEA, should be strengthened and perhaps their mandate expanded to cover some of the proposed responsibilities.

In conclusion, it should be remembered that a world without such international orders may get lost in a state where there will be no winners ... and perhaps no survivors.

International Atomic Energy Agency
Vienna, Austria

NEW FRAMEWORK FOR INTERNATIONAL NUCLEAR CO-OPERATION

B.A. Semenov
Deputy Director General
Head of the Department of Nuclear Energy and Safety

NEW FRAMEWORK FOR INTERNATIONAL NUCLEAR CO-OPERATION

B.A. Semenov
Deputy Director General
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International Atomic Energy Agency, Vienna, Austria.

A B S T R A C T

To better understand what is meant by "new framework", one should define more clearly the "old framework", discuss its successes and limitations.

The history of development of international co-operation in utilization of nuclear energy for peaceful purposes is shortly reviewed.

For the purpose of further discussion, which is limited to international co-operation with developing countries, the latter are conditionally divided into three subgroups: those at the stage of introducing nuclear power (about ten countries); those utilizing nuclear energy in other than power fields (40 - 50 countries), and those which have little interest so far in nuclear energy (all the others - more than 80 countries). The interests of the two first groups are discussed: The importance of international co-operation and specifically of the IAEA technical assistance programme for developing countries in various fields of nuclear energy applications is stressed and some figures are presented. Special emphasis is given to the first, the smallest group of developing countries, about to enter the "nuclear power group", the interests of which mainly require establishing the "new framework".

The present situation and prospects of nuclear power development in these countries are reviewed.

The role of international co-operation and of the IAEA in particular in assessing the necessity of nuclear power in developing countries and in assisting them in preparations for introduction (energy planning, manpower development, siting, safety, manuals, codes and guides, training courses, missions, etc.) are reviewed.

Then the long-term problems of assurances of supply for nuclear power programmes in developing countries are discussed in direct relationship with the problem of non-proliferation.

The linkage between non-proliferation obligations of NNWSs, party to NPT, and their expectations (according to Article IV of the NPT) for unimpeded access to peaceful nuclear technology, in particular in light of some collective and unilateral measures by supplier countries and the results of the INFCE study are discussed.

The IAEA statutory functions and practical activities in the field of assurances of supply are reviewed, with special reference to the work of the Committee on Assurance of Supply (CAS).

It is suggested that one should not damage the existing well functioning "old framework" of international co-operation but rather to establish the "new framework" on its basis, to be directed towards meeting emerging requirements of developing countries entering the "nuclear power group". The inherent linkage between assurances of supply and non-proliferation requirements is stressed.

The possibility of further harmonization of nuclear export policies is mentioned.

The actual situation with front end and back end services is reviewed and desirability of multinational or regional fuel cycle facilities is stated.

In conclusion, the importance of international co-operation in the past as well as in the future to solve newly emerging problems is underlined.

I believe that in order better to understand what is meant by a "new framework" for international nuclear co-operation, one should define clearly the existing or "old" framework, and discuss its successes and limitations. Only in this way can we sensibly and systematically assess the need for a new framework.

After approximately ten years of secrecy in the history of nuclear development, when military considerations tended to be dominant, the world witnessed in the middle of the 50's a boom in release of nuclear information which clearly showed the great peaceful potential of nuclear energy.

In December 1954, the IXth Session of the United Nations General Assembly adopted a significant resolution on international co-operation in the peaceful utilization of nuclear energy. Also in 1954, the Atoms for Peace Programme launched by the USA and the USSR programme on "Assistance to foreign countries in the creation of nuclear research centres" led to the start of wide utilization of nuclear technology in a number of countries, though not yet nuclear electricity generation.

In 1957 the IAEA started its activities to

> " ... seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world. It shall ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose."

International co-operation in peaceful nuclear energy now has almost thirty years of history in many fields and forms, but for the purpose of our discussion, I would like to limit myself to that associated with the developing countries of the Third World, since this is a major factor to the ongoing efforts to create a "new framework of international nuclear co-operation".

Nuclear science and technology are exceptional in the wide range of their possible peaceful uses. If they are employed to produce electrical power, the investments involved will be of the order of one billion dollars or more per power plant. If used as radioisotope or radiation technique in medical or agricultural research, in studies of water resources, or in various industrial applications, the investments involved are relatively small. But even the use of nuclear science and radiation techniques requires a scientific infrastructure: trained personnel and sophisticated equipment - that many developing countries do not yet have.

For the purpose of this talk, I propose to divide the developing countries into three groups:

(1) developing countries that have introduced or have decided (or plan) to introduce nuclear power;

(2) developing countries that make use of nuclear science and isotope or irradiation techniques, and

(3) developing countries for which nuclear science and technology have little practical interest at present.

There are less than a dozen countries in the first group, actually committed to nuclear power; and because of the cost of a nuclear power plant, the size of their national grids, infrastructure and manpower requirements, it is unlikely that this number will be more than doubled by the end of the century. However, the interests of this particular group of developing countries are dominating the problems of the transfer of nuclear power technology, or of the assurances of supply, and we will come back to this problem a bit later.

There are some 40 - 50 developing countries in the second category (including all countries of the first group), about 25 of them operating small research reactors.

There are some very good and some less successful examples of bilateral and multilateral and international co-operation within this second group of countries, including the successful Agency's technical assistance programme in general, and the Regional Co-operation Agreement (RCA) for Asia in particular. Since 1958, the IAEA has provided development assistance worth approximately US$ 150 million. The main objective of the Agency's technical co-operation programmes is to support the efforts made by recipient countries to apply nuclear technology more efficiently and safely. Individual projects are designed to strengthen the developing countries' self-reliance and also, in many cases, to promote collaboration among various national institutes and countries.

With these goals in mind, the Agency has developed several means of providing co-operative help. Assistance has been provided in the form of individual training, training courses, expert and consultant services, and equipment.

More than 7500 persons have been trained in subjects related to nuclear technology through awards of fellowships, and a further 3500 through participation in training courses and study tours. More than 2500 experts have been sent to developing countries as advisors and training course lecturers. In addition, equipment worth approximately US $ 55 million has been made available in the framework of technical co-operation projects. Programming for technical co-operation projects is carried out jointly by the Agency and the developing countries, usually on an annual basis. Some 700 projects have been completed during the last five years, and another 500 are now in progress.

Resources made available to the Agency's technical co-operation programmes have increased at an annual rate of about 18% over the last 14 years. Counting all sources of funds, they totalled nearly US $ 30 million in 1982.

With the expansion of nuclear technology it has recently become possible to tackle some development problems on a regional scale. Networks in many specialized fields could be established, linking industries, educational institutes and research centres with common interests. Such a network has already been initiated within the framework of the Regional Co-operative Agreement (RCA) in the Asia and Pacific region where established industries are adopting the use of isotope and radiation technology. Regional co-operation under the RCA is now being studied as a possible model for a similar plan in Latin America.

In future, the Agency could catalyse a growing number of development projects for which major inputs would be provided by the developing countries themselves.

It can be expected that the trends towards regional co-operation and multi-year projects will become stronger over the years. Combined with the Agency's traditional activities in technical co-operation, these forms of development assistance will provide a valuable contribution to further strengthen the nuclear infrastructure of developing countries.

However, the transfer of know-how and equipment in this type of co-operation does not cause any special problems, besides that of assuring adequate financing.

There are still many countries in the third group, most of whom are not Members of the Agency, although 20 - 25 are. For countries in this group the problems of nuclear technology and even of nuclear science transfer currently hold very little interest. For the time being, the Agency's responsibility in relation to these countries is to be continually alive to the possibility of nuclear techniques being suitable to assist them in their economic and social development, in such areas as health, agriculture and water resources; and to be ready to provide them with some basic education and training in nuclear science and the use of relevant nuclear techniques.

Therefore, to understand the substance of today's problems of nuclear co-operation, we should come back and consider problems facing those developing countries which have started or plan to start introducing nuclear power.

It is well understood that any shortage of energy in developing countries will hamper any further development, any improvement of the standard of living. It would, therefore, seem that nuclear power, independently of possible variations in the oil prices, would be an obvious solution within the framework of an otimized energy supply system.

Yet, in reality, as I already mentioned, only seven developing countries of the Third World now have thirteen nuclear power plants with total capacity of 6200 MWe in operation. Twenty-four plants with 16 000 MWe are under construction in these seven, plus three additional countries. At most, four developing countries have plants in the planning stage.

However, nuclear power is being quite justifiably considered as a viable electricity supply option in many developing countries, particularly in long-term perspective. And, although generally the world economy and energy situation have substantially changed, even recent projections for nuclear power introduction in developing countries (INFCE projection by year 2000: 165 - 211 GWe; IAEA 1983 projection: 70 - 120 GWe*/), the problem of meeting the interests of the increasing number of developing countries entering the nuclear power field exists and will be getting more urgent with the passage of time if it is not solved.

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*/ including 20 - 30 GWe in CPE countries

The introduction of nuclear power in a developing country entails a set of problems and considerations which are specific to nuclear; international co-operation and the IAEA in particular are, we believe, important contributors in solving some of them.

For example, in response to the special problems of nuclear power introduction, the IAEA recently published a "Guidebook on the Introduction of Nuclear Power", providing up-to-date information and guidance to decision makers, planners, managers and professional staff on the work that has to be undertaken in preparing for and introducing of nuclear power in a developing country.

The technical complexities and unique safety requirements of a nuclear power programme as well as the economic penalty of unreliable operation, make it imperative that highly qualified manpower be available at the beginning of the programme. To provide developing countries with more detailed information on the manpower requirements, the IAEA has published a "Guidebook on Manpower Development for Nuclear Power". In 1975 the IAEA started a training course programme aimed at the transfer of experience in all aspects of a nuclear power programme planning, project execution and power plant operation. So far, more than 1300 participants from about 50 developing countries have been trained.

Another important part of the IAEA technical assistance programme for developing countries are IAEA fellowships for on-the-job training in on-going nuclear power projects and related areas. In 1982, the IAEA awarded about 160 fellowships in fields related to nuclear power.

In addition, the IAEA increasingly sends missions to Member States to advise on and assist in planning and implementing co-ordinated manpower development and training for national nuclear power programmes.

Our experience clearly indicates that those developing countries that are at the very early stage of a nuclear power programme require very broad scope assistance. Such assistance can normally be provided both by bilateral and multilateral co-operation in which international organizations can have an important role.

Another important aspect is the international co-operation in nuclear safety and related aspects. Because of the international character of safety problems, international bodies already provide developing countries (as well as some developed) with the invaluable basis for nuclear power plant safety. I mean, for instance, the ICRP dose limitation system or the IAEA Radiation Protection and Nuclear Safety Standards Programme (NUSS). The latter has made available an internationally agreed set of codes of practice and safety guides for thermal nuclear power plants in the field of governmental organizations (for nuclear power implementation), siting, design, operation and quality assurance. These documents already play an important role as a fundamental basis for the transfer of nuclear technology including safety experience, from developed to developing countries.

In addition to this training and regulatory activity, the Agency has for many years been organizing missions on siting, for reviewing construction and commissioning of nuclear power plants. Missions have also been organized to assist in preparing emergency plans for nuclear power plants.

Our experience shows that all these activities and assistance are of great value for developing countries introducing nuclear power. But, even when a developing country has solved the manifold problems of man-power preparation and necessary infra-structure development, and a nuclear power plant or plants have started producing electricity, a number of long-term problems still require solution.

Among the most important of them are:

- assurance of supply of nuclear fuel, materials and services;
- solution of back-end fuel cycle problems (long-term spent fuel storage or reprocessing, waste disposal).

Here it is very important to remember that some nuclear technology, particularly in the nuclear fuel cycle, like the two-faced Janus, can be used both for producing the energy so required for further progress of mankind, and for creating the most destructive weapons in the history of mankind. This is why transfer of certain nuclear technology and material is inherently linked with the question of proliferation of nuclear weapons and of nuclear explosives.

As we know the vast majority of nations has concluded that it is in their own security interest to remain without nuclear weapons and they demonstrated this conviction by adhering to the Non-Proliferation Treaty.

Today, 98% of the world's nuclear facilities outside the Nuclear Weapons States (NWS) are under safeguards and, as far as we know, significant unsafeguarded nuclear operations are only taking place in four countries outside the five NWSs.

In return for the obligation assumed by the NNWS parties to the NPT not to acquire nuclear weapons or nuclear explosives, and to put all their nuclear activities under Agency safeguards, the NWS undertook in Article IV of the NPT that they would facilitate for these NNWS the fullest possible exchange of equipment, materials and information for the peaceful uses of nuclear energy. Similar expectations for access to nuclear supplies and information are expressed by countries party to other non-proliferation mechanisms than NPT. The feeling that the NWS and certain other nuclear supplier countries have been unduly restrictive in the provision of nuclear technology and material has led to pressure for a new co-operative framework for supply assurance.

This pressure became particularly strong after certain additional measures to strengthen the non-proliferation regime were undertaken by some supplier countries. Another pertinent factor was the INFCE study which confirmed that no particular fuel cycle is more proliferation prone than any other, and examined several ideas for new institutional mechanisms, including an international nuclear fuel bank and an international "safety network" of suppliers. So far, most institutional arrangements for transferring nuclear material and technology between industrialized and developing countries have been in the form of bilateral inter-governmental agreements. These provide a framework for specific co-operation arrangements, commercial contracts and, which is particularly important, connected safeguards and mutually agreed non-proliferation requirements. Sometimes, the supply as well as the safeguards arrangements have been made through the Agency under project agreements.

These bilateral agreements are usually fairly long-term, and any subsequent change in their terms or their application may have severe consequences for the developing, recipient, countries because of their dependence on industrialized countries for a large range of their supplies.

International institutional mechanisms for supplies to developing countries have mainly been limited to assistance projects of the IAEA itself, and those of the UNDP for which the IAEA has served as executive agency. Although only limited resources have been available for these programmes, they have, as I have already noted, had certain success in manpower development, in planning, in safety and some other fields important for introducing nuclear power.

The Agency may also supply nuclear fuel under its Statute, and has done so on several occasions for research reactors in developing countries and on two occasions for power reactors. The Agency is, however, not in a position, so far, to give additional assurances of supply comparable to those contained in bilateral agreements.

In 1980, the IAEA set up the Committee on Assurances of Supply (CAS) to consider ways and means in which supplies of nuclear material, equipment and technology and fuel cycle services could be assured on a more predictable and long-term basis, in accordance with mutually acceptable considerations of non-proliferation, and to examine the IAEA's role and responsibilities in relation thereto. The ideal outcome of CAS, as can be deduced from its terms of reference, is to reach agreement on a set of rules for international nuclear trade, including generally agreed non-proliferation conditions. CAS is already engaged in formulating a set of principles upon which international arrangements should be based and on devising back-up mechanisms in case of supply interruptions.

The Director General of the IAEA, Dr. Blix, has underlined in one of his speeches that " ... the fact that these matters are now being freely discussed in a world-wide forum instead of being discussed upon unilaterally or behind closed doors, really constitutes a very considerable advantage. The very existence of CAS will, we hope, discourage future radical and abrupt unilateral changes in supply policies."

Concluding, I would like to reiterate that the gradually changing situation in nuclear co-operation, particularly with the developing countries, with ever increasing emphasis on nuclear power production leads to the necessity of relevant changes in the framework for such co-operative arrangements.

However, the rate of these changes is rather slow, the number of new countries entering the "nuclear power group" is smaller than that of those entering from the bottom the middle group of countries using nuclear techniques and applications.

Therefore, one should not destroy or damage the existing framework which, for many years, has served quite well in a large number of developing countries of the middle echelon through a wide range of bilateral, multilateral and international arrangements for co-operation.

What seems to be necessry to do now - using positive experience of the existing framework - is to establish a new framework for co-operation to meet the emerging requirements for developing countries, members (or candidates for) of the nuclear power group.

To do this, it is necessary to consider the structure of bilateral, multilateral and international arrangements against the background of the need for long-term assurances of supply and in accordance with mutually acceptable considerations of non-proliferation.

The UN Conference for the Promotion of International Co-operation in the Peaceful Uses of Nuclear Energy now under preparation may serve as a useful forum in discussing and solving these problems and the IAEA is going to fulfil its appropriate role within the scope of its responsibilities at all stages of the preparation and work of the Conference.

Looking into the crystal ball and trying to see what developments will occur in the countries, I believe that one can expect that the exporting countries on their side will try to improve international harmonization of non-proliferation conditions for export, including safeguards and that with the continuing progress in nuclear technology, more supplier countries will agree and more items of export may be covered by these conditions.

One can also envisage that both negative consequences which should follow the non-acceptance of safeguards, and, which is equally important, positive consequences to follow acceptance of non-proliferation obligations would be agreed upon and pursued.

The actual situation with the assurances of supply in different stages of nuclear fuel cycle is different and the efforts to improve the situation should be proportional to the changes required.

For example, according to the INFCE study, "with respect to the foreseeable demand for enrichment services, one can state that a fairly competitive market, offering independent sources of supply in various countries will, by its very existence, guarantee enrichment services assurance at least until near the end of the century". On can only add that with the time passed after INFCE, the above statement has become even more valid.

The situation with the assurance of services in the back-end of the fuel cycle is not very certain so far, even for the industrialized countries, where only two reprocessors are at present available to provide commercial reprocessing services on an international basis. Some form of international co-operation in the provision of spent fuel storage and reprocessing services might have benefits from the economic point of view and also better meet non-proliferation interests. A contribution to the consideration of this is a study recently undertaken by the Agency to examine the potential for international co-operation in the management of spent fuel.

Also a good practical example of solving back-end fuel cycle problems is the conditions of the Soviet Union contracts under which the fuel of all Soviet reactors sold abroad is taken back to the SU for further reprocessing and disposal of wastes.

The general conclusion which must be drawn is that international co-operation has been and today remains essential in such (practically untouched in this discussion) areas as, for instance, exchange of information, setting-up of international standards, verification of international treaties obligations, that it has played and plays a valuable role in the transfer of technology and know-how through technical assistance, co-ordinated research programmes etc., and that international co-operation is the only way to serve newly emerging problems of assurances of supply of nuclear materials equipment and technology in accordance with non-proliferation requirements for countries starting nuclear power development. The task is not easy, even troublesome, but it has to be gradually solved.

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SESSION 3 H.N.セトナ博士

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Panel Discussion on "New Frame Work for International Nuclear Cooperation".

H.N. Sethna*

Most if not all of the developing countries have attained independence during the last three or four decades. They have missed the industrial revolution and the subsequent growth. The economy of most of these countries has been agricultural. In many cases the methods of production have been primitive. Their base for production and consumption of energy has been abysmally small. Their natural resources have not yet been fully identified. Emerging as independent nations into the postwar world of a handful of industrialised nations influencing the economics of the world, these developing countries have not been able to isolate themselves from the impact of the oil crisis and the big power compulsions on nuclear development, technological, economic and political. The oil crisis exposed their helplessness with respect to the conventional sources of energy and their attempts to resort to nuclear power as an alternate source are circumscribed by their own constraints of lack of infrastructure. Cooperation from the industrialised nations often involves submission to unacceptable conditions.

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is likely to hinder this fraternity. The principle of "Peace" in Islam is not only relevant to the mysterious spiritual world but rests on a clearly determined basis in all aspects of life.

RETROSPECT

Before proceeding to the actual topic, a retrospective consideration would be pertinent to the subject to be discussed. The IAEA began with the "Atoms for Peace" proposed by President Eisenhower of the United States in October 1953 and brought to the U.N. This speech was greeted with mixed reaction. It was a brave move by the President who was undoubtedly a better judge of the human race. This in essence is the fundamental principal of Islam since Islam considers man as a Vicegerent created by God on Earth. Man was created as His representative on Earth and was bestowed with the faculty to know the nature of things. Through science generally and nuclear science specifically he can eventually understand all the wonderful things created by the Almighty, which at first sight seems inexplicable. He must make use of all technical means and all technical acquisitions. He is under strict obligation to improve this world and enjoy the fruits of his work. This he shall do in such a way as to preserve faith in God and guarantee dignity, justice, equality, liberty and peace among men without any distinction. He will act in conformity with the devine law.

It is a matter of common knowledge that nuclear science has been growing rapidly. Before the war there was a gross inadequacy of resources to science in general but this is a different situation now - it is the large scale of expenditure on nuclear science specifically and science in general rather than the small scale that must be considered. The new magnitude makes inescapable the problem of whether and how to plan science (nuclear science). The whole problem - economic, scientific and political - must be regarded as one of a planned operation.

Unfortunately the politics of nuclear science, as evident, is in essence no different from the other politics. It has its elites, down-trodden, alliances, bosses, loves, hates and vested interests. It has already played important parts in public affairs and there can be no return from that position, though there is room for disagreement concerning the appropriate style of its' politics. It seems that mankind cannot progress without nuclear science. We see a world in which the use of nuclear science, for better or for worse, becoming a dominating factor. However, far from giving us a sense of power, it emphasises our awareness of our present weakness and futility. The powers of ignorance and greed distort nuclear science and lead it astray.

Following the speech on the "Atoms for Peace" in the U.N., a Conference of Statute was held. Two groups emerged at the Conference of Statute. One group advocated widespread use of atomic energy for peace while the other group feared that such widespread use might lead to the manufacture of nuclear weapons. Taking into account the various views, the Conference of Statute decided that the Agency should accelerate and enlarge the use of atomic energy for peaceful purposes throughout the world and at the same time to ensure that such activity does not lead to the manufacture of nuclear weapons.

The group opposed to the widespread use of atomic energy apparently had the upper hand all the way. Their arguments could no longer be ignored. Discussions on ways and means to control led to the signing of the Treaty on the Non-Proliferation of Nuclear Weapon (NPT) and the Tlatelolco Treaty which prohibit proliferation of nuclear weapons. This could be understood either as an auspicous moment or not so auspicous one.

The signing of the Non-Proliferation Treaty (NPT) and Tlatelolco Treaty by the majority of the States provides a strong basis for the Agency's Safeguard System. Under these frameworks the IAEA signed bilateral and trilateral agreements with States and International Organisations to facilitate the application of its Safeguards. But things are as simple as they look.

The NPT and the Tlatelolco Treaty are essentially a promise by Non-Nuclear Weapon States (NNWS) that they would never manufacture nuclear weapons <u>in return</u> for the access to nuclear technology for peaceful purpose. They are more or less reduced to beggers and beggers cannot be choosers as the saying goes. Nuclear.Weapon States (NWS), on the other hand, promise that they will facilitate the transfer of nuclear technology to countries subscribing to the Treaty. The NPT also provides that the Nuclear Weapon States start negotiations towards arms reduction and finally the disposal of their stock of nuclear weapons.

THE PROUD AND THE PROFANE

Now let us examine the motives and intentions of the IAEA Safeguards. It seems shrouded in intrigues and suspicions as to its intention. A large portion of the IAEA's finance is devoted to Safeguards when this could have been put to better use elsewhere. The IAEA Safeguards is in fact a system of verification, but for whom? It only verifies if the NNWS, who are party to the Treaty, have kept their promise not to manufacture nuclear weapons. The IAEA Safeguards has concluded that so far no NNWS has diverted the aid for military purposes. It appears that even without this Safeguards these states would never have done so. They have more common sense and goodwill than is credited to them by the NW States. The intention of Nuclear Weapon States, on the other hand, is questionable. They have been known to ignore their obligations under the Treaty. A system of double standards has been imposed upon the IAEA, all in the name of peace, but yet the threat of war forever looms over us.

With the signing of the NPT and other treaties it was thought that the use of nuclear energy for peaceful purposes would not be hindered. However, things turn out not that simple. India, a non-NPT country, exploded a nuclear device in 1974 for reasons of her won. The fear generated by the Indian explosion and the possible explosions by other non-NPT countries such as Pakistan, Israel and South Arfica gave new ideas to the group known to oppose the widespread use of nuclear energy. They once again gained the upper hand in the politics of nuclear power. But then, what right have they do dictate terms when the frontiers of knowledge is limit-less and common sense, and sanity prevail. The overbearingness of these states is being carried to the extreme. India might have her reasons for doing so under the term peaceful nuclear explosion (PNE).

A stream of events took place after the Indian explosion of 1974. Developed countries, being agitated by the group opposing the transfer of nuclear technology, tended to believe that the existing international treaties were insufficient and they could no longer able to control proliferation. This belief led to the formation of nuclear "cartel" by nuclear exporting countries.

Even among the developed countries there is discrimination. A case in point is in regard to the decision of the Carter Administration opposing the "plutonium economy" which met strong opposition in Europe, Japan, the U.S.S.R. and most of the developing world. This action tantamounts to an excessive unilateral political action that proved abnoxious to the rest of the world and an expression of arrogance on the part of the U.S.

Arising out of the various unilaterial political actions of the United States, there appears to be now technological denial, differential or discriminatory treatment of countries, stringent nuclear·export regulations, and above all, inconsistent nuclear policies, which may prove to be detrimental to the development of nuclear power in other countries as well as in the United States. The potential danger of such mutual mistrust and resentment and the consequent erosion of confidence is apparent, so that such emotional undertones would only contribute to allienating the United States from other countries, and as a result, to weakening the international nuclear regime as a whole. If this is felt by the developed countries, what about the developing countries who are on the threshold of nuclear age? Together with the policies of the London Suppliers Club and the restrictive measures adopted by certain advanced countries regarding technology transfer, the future of world will be in jeopardy due to the lack of understanding and trust; forearmed is forewarned. This is a form of protectionism i.e. the protectionism of knowledge which is a crime and an insult to the dignity of man.

Arising from these events many nuclear exporting states have drawn up their own conditions in addition to the conditions set by the "cartel" before they would allow the export of nuclear materials, equipments, and experts which affects the free flow of nuclear technology which, otherwise, should be the right of every citizen. The best example is the 1978 Non-Proliferation Act of the United States itself where stiff requirements are needed before a country could engage in nuclear trade with the United States.

The act to control rather than to accelerate the use of atomic energy is dominating the world now. Because of this obsession developed countries are inclined to use IAEA for purpose of control rather then the concern for the needs to spread the use of atomic energy for the betterment of mankind. This is reflected in the large portion of the IAEA budget being allocated to Safeguards, at the expense of scientific and technological aids as indicated previously. The Agency appears to base its judgement and role on suspicion and fear as if the whole world stands condemned. Nuclear power, wisely developed, helps to satisfy legitimate needs, hence to counteract economic and social despair that lead to internal and external unrest, and war itself. Therefore development in an atmosphere of international suspicion will enhance the chances of war. The boycotting of the U.S. from the IAEA as a result of what was termed as "politicization" of the Agency demonstrated this obsession. In a way the United States is again trying to deny technological transfer, aid, and the spread of knowledge; but above all she is giving us another exhibition of arrogance all under the banner of politicization. The failure of a good deed is the result of the failure of intention and this is the dilemma faced by some of the developed countries.

Nuclear energy has become a social concept and as such it is impossible to state which is apolitical and which is political. A nation stands condemned if a wrong has been committed by it, and no amount of doings can wash away the guilt and responsibility. It is all a question of morality and unfortunately this loss of morality will put over future generations in jeopardy in particular that of the alienation and illness of the spirit, the loss of conscience and, the dimming of outrage towards evil. However, the business of the IAEA goes on. The member countries are still receiving aids and experts, may be in moderation. Among these nations goodwill and trust still prevail. Trust, goodwill and openness are qualities which must be introduced into the

Agency. These nations must demonstrate the superiority of their moral weapons and dispel the forces of ignorance.

WISHFUL THINKING

With all these constraints, suspicion and fear, little wonder the international climate in the area of nuclear technology transfer is very uncertain. An international consensus on trade in nuclear technology is still being sought after in the Committee on Assurances of Supply (CAS). The international community would be better served if a way could be found to break the present impasse. Countries having only small nuclear programme really needed guaranteed access to the whole gamut of fuel cycle services, including waste disposal. So it is again a question of morality. Unfortunately there is now the emergence of the so-called "new morality" and "new ethic". There is also the erosion of credibility and faith in the democratic process. There is the breakdown of moral values never faced by man before. Arising from these everybody should then participate in the forum positively and see that no spoke is introduced to forestall this noble cause. One should adopt the philosophy that there is goodness in man and man has the capacity to get rid of evil and associate with good. Unfortunately certain quarters tend to react violently and abruptly like startled tortoises. It is high time the west looks to the needs of the NPT countries and have faith in the human race. Maybe we, for once, should pay less attention to those who are led astray but to the crying needs of the needy and who play the rules.

Another forum will be the second UN Meeting on the peaceful uses of nuclear energy and similar code of conduct should be followed by participating countries. There maybe nations grounded, perhaps wrecked on the rocks of unavailable fossil fuels at bearable costs, but with technical possibility of alleviating energy starvation and the accompanying possibility of reducing both international tension and inequity thereby. So, the West should act accordingly. Is this too much to ask for? Somehow one tend to underestimate the mentality of the developing countries who may not be quite as barbaric as the west might like to think. It is also known that most states with capabilities to producing nuclear weapons are not doing so, so as not to jeopardize the international cooperation needed for the development of peaceful uses. Earlier predictions about rapid spread have not materialised although nations with nuclear power reactors are potentially capable of doing so. In the Asia-Pacific areas, regional or sub-regional arrangements on the use of nuclear energy have yet to be conducted. The first and only one that has something to do with it would be the 5-year agreement concluded in 1964 between India, the Philippines and IAEA (IPA), whereby, under IAEA auspices, the parties should cooperate for the development of nuclear science and technology. It was succeeded by RCA. How this will fare remains to be seen but the indications are very positive. This is where all the help and understandings are necessary. The member states are at the various stages of nuclear sophistication as well financial. The question of sea dumping of radioactive wastes will be the acid test. A recent international agreement of great significant cannot be overlooked because of its universality as well as its decisively great impact on marine pollution control in general in the future. This is the 1982 U.N. convention on the law of the Sea which was adopted by a vote of 130 to 4, with 17 abstentions in April 1982 and was signed by 119 delegations in December 1982, making it's universality assured.

THE GREAT EXPECTATION

At present there are already a number of existing International Nuclear Cooperations ranging from that which encompasses almost all nations of the world namely IAEA, regional namely RCA and bilateral. One should try to make full use of them first until such time there appear some impasse. The impasse may be as a result of suspicions among member nations, political differences; maybe they just could not get along together; familiarity breeds contempt. In the past there are certain short-comings such as the overbearing attitude of the so-called donor countries, "I know what is good for you, period". There should be a two-way dialogue and the re-establishing of the sacred word "trust". No country likes to be taken advantage of or for a ride. If there is an agreement it is to be on equal footing without hidden motives. The concept of donor and receiver impinges on the dignity of man particularly on the question of energy. The need for energy is a universal right of everyone particularly so with the energy obtained from nuclear fission and eventually nuclear fusion since all things originated from fusion as a devine order as stated in the holy Quran. If there is a real need for alternative international cooperation it should be in this spirit. The best approach is to cooperate with one or more of the countries in the NPT regime as well as of similar belief and to maintain international safeguards on their nuclear exports for the time being, although this idea may not be in good taste if one is to promote real goodwill. A nation can save in man-years of duplicative scientific and technical effort and on development costs and benefit from the experience of its partner.

There are, of course, a number of sensitive issues to be overcome. A full understanding and awareness of one another's norms, sensitivities and values must be recognised before proceeding to any form of agreement because nuclear energy is a social concept; it is a politics and also a paradox of promise and peril. Since it is a social concept we must accept it as a topic of controversy, because in all societies, social concepts are controversal. The understanding of the realm of nuclear science presents us with another chapter in the development of man's personality because nuclear science provides us with glimpses into the process of creation.

This is particularly so in this region viz the Asia-Pacific region, which is made up of states in their various stages of nuclear sophistication. They range from the non-nuclear states to the very developed nuclear states. Japan can be described as an example of a very developed nuclear state while the Pacific Islands represent the non-nuclear states and are unique in themselves because they have been subjected to the full impact of nuclear testings conducted by the NW states and as a result do not want to be associated with nuclear energy, particularly with the nuclear waste. Anything to do with nuclear will arouse suspicion.

These countries' energy needs and options differ; the needs for nuclear energy in Australia, one of the "donor" countries in the RCA, does not depend on nuclear power although she has the potential to do so. Then on one hand we have some countries who are clamouring for energy but without the means of producing it and on the other those who have the means to acquire almost every available forms of energy by being industrialised and technically capable. All these constitute social problems and controversies and the game must be played differently when compared to the west. Most of these countries who are at present without nuclear energy will turn towards it eventually so as to ensure long term supplies of reasonable cost energy for their development particularly for industrialization; it is only a question of time.

Lastly it must be emphasised again that nuclear science is not only a politics but a social as well as an intellectual process. In the whole context of the development man it fits into what is termed "the call to life"; this is the fundemental concept of Islam. It is the truth and truth is eternal. It does not change though our understanding of it might change with the passage of time.

In the past we look at this science and its technology as different entities but modern man is already concerned about the relations between nuclear science and the rest of society. We are more aware of our social responsibility.

A society must not only reflect on the persuit of happiness and harmony and try to expel pain, tension and sorrow and the ubiquitous curse of ignorance but must ensure its own survival. Unfortunately the "modern" way of achieving this is through arms proliferation. But even if this were not so, there would remain millions of hungry and discontented people in the world. Without the promise of relief from that hunger and privation, disorder would still be inevitable.

Unfortunately it seems that the nature of our system is that we have production only because we first create the wants that require it. If this is the case, then we will have few resources to spare.

Finally, I would like to appeal to all to lean on the following lofty principles:-

(a) The dignity bestowed on man by God.

(b) The necessity for all peoples of universal peace on earth, to the exclusion of any kind of aggression and oppression whatsoever.

(c) The call to follow the road dealing to man's welfare, whether in the scientific, the social, or the economic domain.

(d) The exhortation to do good, and thus to improve man's living conditions, and to ensure his salvation.

(e) The prohibition of evil, which corrupts man's existence and endangers his security.

(f) The implementation of what the Prophet of Islam recommended: "I was asked to join a pact in the time of ignorance - pre-Islamic period (which was for the protection of the weak against oppression and aggression). If I were to be invited to such a pact now, I would join."

(g) In all these things one is bound to the concepts of good, the norms of reason, the facts of science, the notions of mind, and the logic of man.

CONCLUSION

The whole issue of nuclear field has been viewed on the fear of proliferation of nuclear weapons whether it is vertical or lateral. The main exponents prefer vertical proliferation which is presumably to be "safer" than lateral proliferation. This is based on fear; the fear that nuclear power will give rise to arms proliferation. Fortunately this has been proven wrong.

The whole issue of IAEA rests on safeguards which work against those who played the rules. This, in a way has worked but what a way, when suspicion and fear being the basis for the preservation of world peace. There is the evolution of the so-called "new morality" and "new code of ethics".

In future any form of cooperation should involve the whole gamut of nuclear science not based on a piece-meal manner. The Asia-Pacific region should never become like what had happened to the Pacific Island nations. Their position was exploitation of the worst sort next to a nuclear holocast not to the people, we hope, but to nature itself. There should never be a form of "nuclear colonization" with these nations becoming nothing but backyards for the more industrialized nations to exploit. The sovereign right of self-determination must be respected. This is very important in the North-South political context.

Future cooperation must be based on trust, goodwill and openness.

16th Japan Atomic Industrial Forum

Session 3: New Framework for International Nuclear Cooperation

Dr. Günter Lehr
Director General
Federal Ministry for Research and Technology, Bonn
Federal Republic of Germany

Ladies and gentlemen,

for enabling developing countries to benefit from the great economic potential of nuclear energy, one can build upon an elaborate network of international cooperation which has been developed over the part decades up to the remarkable present standard worldwide.

After the first phase of nuclear development, in which nuclear technologies were restricted to a very small number of countries, there has been a period of intensive and successful efforts aimed at the exchange of information and the transfer and integration of this new source of energy into the energy supply systems of a steadily increasing number of countries. A great number of international cooperation arrangements have been introduced which reflected the economic, financial and political impacts of nuclear energy. They were the result of the need to integrate scientific, commercial and political elements, which involved many different partners from science, industry and government.

The results of this development should not be undervalued or even jeopardized in facing new challenges of international nuclear relations. The present standard of international cooperation in research and peaceful uses of nuclear energy is remarkable, particularly in comparison with other technological fields.

...

Besides the numerous bilateral arrangements, - my country alone has made more than 40 of such arrangements with 20 other countries - the IAEA plays a central role in the promotion of peaceful nuclear technology, especially in the field of safeguards.

In the second half of the seventies, we have been confronted with an escalating public interest in nuclear energy in some countries and, on both the national and international level, with growing awareness of poliferation questions.

In spite of this developments it is extremely unlikely that any country will voluntarily abstain from the use of nuclear energy as a means of securing its own energy supply. Nor is it likely that the elaborate network of international cooperative ties will be weakened because of disagreements and differences of interpretation in the field of energy supply by nuclear power and non-proliferation of nuclear weapons.

It is obvious that many developing countries do not only want to import nuclear power stations while they remain excluded from technologies of the other parts of the fuel cycle. They, too, regard nuclear power stations as part of an overall fuel cycle system. Consistently they wish to get all essential components of this system. On the other hand, reasonable guarantees and safeguards are needed to discourage abuse in particular of these sensitive installations. Without underrating the problem described by these two lines, I am not certain wether, in this session, we ought to talk about "a <u>new</u> framework for international nuclear cooperation". In my opinion it is more a matter of furhter developing this framework. We can go forward from a well-founded basis of international nuclear relations.

After a comparatively late start in 1956 my country succeeded rather quickly in catching up with the progress in nuclear technology which had been made abroad.

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From this we have gained experience which may be of certain value when we are now asked by other countries, particularly by those in the Third World, in assisting them to move in the same direction Although normally industrial "know how" is owned and therefore has to be transferred by private firms through traditional commercial channels, the transfer of nuclear technology, unlike any conventional commercial transaction, depends for many reasons upon the support and active assistance of governments on both sides.

Firstly, the role which nuclear energy shall play in the future energy supply system of the receiving country has to be defined through long-term energy planning, after an examination of all options available. Undoubtedly nuclear energy can play a significant role for developing countries, however the specific economic possibilities and energy requirements have to be thoroughly investigated. In this planning and decision-making process, the government of the receiving country will benefit in many respects from the assistance and the advice offered by the supplying country. In particular, the integration of nuclear power into the national energy supply system and the right way of dealing with the different aspects of the nuclear fuel cycle are matters of genuine governmental interests and governmental responsibilities, where close cooperation and the exchange of experience may help to avoid or to overcome many a problem.

Secondly, the long-term commitment of considerable human, economic and financial resources not only on the suppliers' side, but also in the receiving countries has to be taken into account. This commitment can only be entered into on the basis fo a sound, long-term understanding between the governments. They have to secure stable and reliable relations, as a "prerequisite of the necessary far reaching decisions of the partners involved.

Thirdly, nuclear technology should be set up in an environment of qualified industrial research, development and training of skills. On the industrial level, joint ventures have proved to be particularly successful means of transferring technological knowledge, skills and capabilities.

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Although government support for the establishment of adequate industrial structures may be confined to ensuring favourable conditions for commercial investment and joint ventures, R and D and training institutions are mainly dependent on public money and active government support. Advice and assistance in this field, therefore, have to be among the main items of cooperation between governments.

Moreover, experience has shown that cooperation in R and D can be a very effective method of preparing the ground for better mutual understanding. Governments, therefore, should foster this cooperation not only because of its inherent merits in mutually stimulating scientific and technological efforts but also as a flexible and effective confidence-building measure. Thus, the Federal Republic of Germany, while having established strong links with other industrialized countries, has entered into fruitful nuclear R and D agreements with about a dozen developing countries which offered favourable conditions for the successful development of national programs in this field.

In the framework of this cooperation several hundred nuclear scientists and technicians are being exchanged year by year. Moreover, we have been able to help some of our partners by supplying highly sophisticated R and D instruments and facilities.

Fourthly and last but not least, governments have to ensure an effective system of safety and physical protection. The creation and management of a coherent legal and institutional structure for regulatory and controlling measures, as well as for training highly qualified personnel in these fields, ask for a close cooperation between governments.

It is obvious that, due to the differences in the constitutional and administrative structures of the countries concerned, there cannot be only one kind of universally applicable model for initiating and implementing the cooperative efforts to be made. The involvement of many different private, public or semi-public parthers on both sides will, in many cases, give rise to a complex network of interconnected arrangements and agreements. Nevertheless, in order to cover e whole range of issues just mentioned, this network will have to include three main kinds of contractual ties:

1. Commercial arrangements on the industrial level, providing for the transfer of hardware and know-how and taking care of all questions concerning industrial property rights, industrial investment and the financial obligations involved.
2. Intergovernmental agreements stipulating all rights and obligations with regard to ensuring peaceful use and non-proliferation together with a commitment by the government of the supplier country to grant export licences for items to be transferred under these agreements.
3. We need governmental undertakings which go beyond the limits of traditional agreements. For practical reasons there will normally be a general umbrella agreement at government level, covering and initiating a number of special cooperative arrangements and agreements to be concluded between universities, research centres and administrative bodies.

Without any doubt the bilateral cooperation is the main tool for promoting and implementing the transfer of large-scale nuclear technology. But this transfer is assisted by and dependent on principles, measures and practices elaborated on a multilateral basis. Without reiterating the significance of the IAEA in this connection, the NPT, INFCE and the guidelines of the supplier club of London must be mentioned. Furthermore, multilateral cooperation is understood increasingly as an efficient instrument for sharing the burdens entailed in setting up and operating costly facilities for research and development or for demonstration purposes.

In the second half of the seventies, we faced a period of non-proliferation policy which emphasized on restraints in nuclear exports and particularly in the dissemination of sensitive technologies.

...

In the meantime, I think, it is appreciated worldwide that nuclear commerce and cooperation cannot be supported without the confidence of receiving countries that suppliers recognize their necessity for stable and predictable arrangements. There is a need to minimize uncertainties about supplies in consumer countries that are caused by the interventions of producer governments. I have to add: there should be no doubt about an effective non-proliferation policy, in the view of my Government. This is vital for the preservation of both regional and global stability and security.

Since INFCE there is general agreement that the real challenge for strengthening international nuclear cooperation lies in discovering ways in which non-proliferation can be linked to the assurance of supply. It is clear that assurance of supply and safeguards against proliferation are complementary, that they are, indeed, two sides of the same coin.

This discussion is now being continued by the Committee on Assurances of Supply (CAS) of IAEA. My Government is aware of the important confidence-building character of CAS and shall therefore continue its active contribution to the work of this Committee. We are convinced that, by patient negotiations, acceptable and effective results can be reached.

I think it is self-evident that at the present time various models are being discussed under the following headings:

- international plutonium storage,
- international management for spent fuel elements,
- mechanisms for emergency supplies of uranium.

In each case diverse variants are possible. Of course, if the models have to be designed concretely, it will not be easy to reach a compromise on a number of key issues. Later on, in implementing such models, it is recommended that step-by-step procedures be adopted in order to keep requirements feasible.

My optimism that acceptable solutions can be elaborated which will improve the assurance of supply as well as reduce the proliferation problems is based upon the advantages that such institutionalized mechanisms in the form of international cooperation have, especially for countries with smaller nuclear programmes. The amount of investment to set up and operate facilities of the nuclear fuel cycle reaches very substantial dimensions - as do, moreover, the advanced reactors - so that in industrialized countries, too, the tendency to promote and join international facilities may increase.

Let me finally state that technical and administrative measures alone cannot prevent the misuse of nuclear energy. Additionally, we need a policy of consensus on a broad international basis which reduces fields of international conflict and minimizes strained relations. A secured energy supply as an important factor of economic and social development moved more and more into the centre of national interests. Nuclear energy can make a large contribution to the national energy supply. From this it is quite clear what risks can arise from restrictions in the export of nuclear technologies. On the other hand supplying countries cannot be expected - in the face of the great potential harmfulness of nuclear energy - to give blank checks for the provision of sensitive technologies; this should not be interpreted as an infringement on the sovereignty of receiving countries.

So, finally, international nuclear commerce and cooperation will make further progress only if, all legal subtleties aside, all partners contribute to an atmosphere of mutual confidence and understanding.

Presentation orale de Mr RAPIN

16TH. J A I F ANNUAL CONFERENCE

3

FRENCH APPROACH TO INTERNATIONAL COOPERATION

TECHNICAL AND SCIENTIFIC FEATURES

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M. RAPIN

I. CONDITIONS FOR A WELL BALANCED INTERNATIONAL NUCLEAR COOPERATION

It is clear that the world energy consumption can only increase in particular because of rapidly increasing needs of the developing countries, while the world available fossile ressources (oil and gas) can only decrease. In this respect, nuclear energy represents an efficient complement or substitute to fossile ressources at a large scale, in middle and long term perspectives. To play fully its role, and thereby to contribute to the world economic stability, nuclear energy has to be expanded all over the world and this can be achieved only with an international cooperation in which industrialized and developing countries are quite interdependant.

This interdependance of various countries requires a reciprocal confidence between the partners at both political and technical levels :

- Politically, they must agree to respect unequivocally all the international rules established in order to avoid nuclear weapon proliferation. Provided that they have commited themselves to fulfil these non proliferation requirements, the experienced countries should not change their export policies with respect to their developing partners for internal reasons.
- Technically, taking into account that nuclear energy development requires a long period of time, the customer country must be sure it can rely on the experienced one as long as it is necessary. This implies that the experienced country does not change its national nuclear policy according to domestic political events.
- Morally, the experienced country is bound to assist its developing partner as long as this last one needs help

From the technical standpoint, insofar energy independance is aimed at through nuclear energy development, each country has to reach a certain level of nuclear maturity. Such a maturity implies :

- to have a sufficient scientific and technical knowledge in all the fields involved in nuclear energy ;
- to organize a national administration competent for all what concerns the safety aspects and the regulatory problems.
- To set up progressively a national nuclear industry, able to contribute significantly to nuclear plant design, construction, operation and maintenance.

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Practically, for developing countries nuclear maturity can be obtained in a limited period of time and with acceptable expenses by an international cooperation which can be set up through bilateral or multilateral agreements or international agencies (typically OECD, IAEA), with various possible approaches

- exports of products and/or services, including at the maximum turn-key contracts for nuclear power units or fuel cycle plants ;
- technology transfer (typically from a licensor to a licensee) involving a participation of the receiver country to nuclear plant construction
- experts formation and eventually R and D programs performed jointly by experienced and developing countries.

II. TECHNICAL AND INDUSTRIAL FEATURES OF THE INTERNATIONAL COOPERATION SET UP BY FRANCE

France nuclear situation presents some specific characteristics which can comfort her position as a partner within an international cooperation :

. France - like Japan - has been led to develop activities covering the whole nuclear field in order to reach her energetic independence, and this orientation has been kept by all her successive governments

. Middle-size country, France has only limited financial capacities and must look for minimizing the cost of her nuclear program mainly by limitating the number of reactor types to be developed industrially and by standardizing the units constructed.

. Largely involved in international cooperation with developing countries in other fields, France is willing to put her nuclear experience at the disposal of these countries, so that they can progressively reach their own energetic independence.

International cooperation set up by France for PWRs

The French PWR program which started in the early seventies has been in a first step (1972-1981) founded upon Westinghouse licenses.

During this period, several R and D programs have been set up by CEA, the utility EDF and Framatome in order :

. to assimilate the license and to get a better knowledge of the licensor's technological choices,

. to develop new solutions corresponding to the French technological independence.

Among these R and D activities, one has to mention the pluriannual program realized jointly by Westinghouse, Framatome, EDF and CEA according to an agreement signed in 1976 for a six year period.

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The satisfactory conditions in which Framatome nuclear boilers have been constructed and operated have put into evidence the competence gained by the licensee during the realization of the French nuclear program. This has led to renegotiate the Framatome-Westinghouse agreements in order to replace the licensee to licensor relationships by a cooperation agreement between equal partners : the corresponding new agreements, signed in 1981, recognize that there is now an independent French technology for PWRs.

Standardization of the nuclear units constructed is one specific characteristic of the French PWR program. Standardization :

- helps the nuclear island maker to assimilate the license received from foreign licensor and allows to concentrate the national R and D efforts on precise technological problems ;
- helps to develop a national nuclear industry and allows to optimize organization and fabrication means,
- reduces costs and construction times,
- increases reliability at all construction steps,
- contributes to improve safety characteristics
- enables to integrate the experience gained with construction and operation of the first units in the design of the following ones.

However the experience of the French nuclear program shows that to benefit from all the advantages related to nuclear unit standardization, several conditions must be fulfilled :

. the nuclear program must the planned on a period which is unavoidably rather long ($\simeq$ 20 years) and must not be put into question during its realization,

. the industrial organization set up must be simple and consistent : as far as possible a single customer, a single responsible company for nuclear boiler construction, one organism in charge of the main part of R and D a single body in charge of the various steps of the fuel cycle.

. progressive assimilation by the national constructor and/or component fabricators of the knowledge transfered from another experienced constructor.

An efficient technology transfer requires in particular :

- a preliminary analysis of the existing national industry characteristics (means, competence),
- a study for defining the materials or services which can be provided on a national basis, and the costs and time schedules associated to the corresponding fabrications,
- the definition of the costs and times necessary to achieve the successive steps of the nuclear program,
- the determination of the technical assistance which is necessary as well for training staffs as for realizing the various steps of the nuclear program, notably for what concerns nuclear plant commissioning.

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International cooperation set up by France for fast breeders

Will not be examined here since it has been presented in session 2

International cooperation set up by France for fuel cycle activities

In certain cases, these technics and their associated engineering know-how can be placed at the disposal of fereign partners, provided that international rules for non-proliferation are taken into account by each partner :

For what concerns the back-end of the fuel cycle CEA has signed a cooperation agreement covering R and D activities with BNFL. After the parliamentary debate which took place at the end of 1981 and confirmed the reprocessing option a specific commission ("CASTAING Commission") was set up by French government notably in order to examine present reprocessing conditions in La Hague and to suggest desirable improvements for future plants. Important conclusions of this commission can be summarized as follows :

. CEA Group masters completely the oxide fuel reprocessing at industrial level under satisfactory availability and safety conditions : the present La Hague capacity, around 250t/year, should be increased up to 2 x 800t/year without major problem when the new plants UP2 800 and UP3 will be in operation (by the end of the eighties)

. Important R and D work has still to be done in order to improve α contaminated waste management (characterization, impact of deep burial to the environment) before any non-reversible storage be undertaken.

. In order to get all the information necessary to support the choices for irradiated fuel management, CEA should also devote some R and D efforts to other techniques including reprocessing after a long cooling ($\simeq$ 40 years), fuel storage and new waste technologies.

III. SCIENTIFIC AND TECHNICAL TRAINING

When looking at which specialists will be needed several specific aspects of the nuclear field must be kept in mind :

- the range of specialities which are involved in carrying out a nuclear program is quite wide and includes, besides obvious activities directly related to nuclear plants design, construction and operation, several others which must not be neglected (e.g. energetic planning, nuclear fuel transportation. protection against radiation...)

- nuclear industry is characterized by requirements which are in most cases more stringent that those used in the classical industry : e.g. factory tolerances. quality insurance.

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- as any other industry, nuclear industry requires not only theoretical knoledge of engineers and scientists, but also a practical one of technicians and workers executing the tasks

Efficient training of nuclear specialists at every level includes three steps which one has to differentiate clearly :

- general technical training suited to each level of responsability,
- basic nuclear training which is given by specialized organisms,
- specialized training corresponding more particularly to a specific work and given by the industry in charge of that work.

Finally, one must note that training nuclear specialists requires :

- to define precisely the needs starting from the general technical level down to the most specific nuclear problems to be handled,
- to plan these needs with earing in mind that complete training, involving the three steps, needs time and that there is unavoidably losses of candidates when going from one step to the following,
- to control the training at every step in order to be sure of its efficiency,
- to know which will be the final post of the trained nuclear specialist before assigning to a specialized nuclear training.

IV. CONCLUSION

Nuclear energy should become a major energy ressource all over the world in the next century in order to answer to world increasing energy needs.

To achieve this goal, it is indispensable that a tight international cooperation between most experienced countries and developing countries provide these last ones with all the know-how necessary to develop nuclear energy.

Such an international interdependence, which implies a full reciprocal confidence, has to taki place at every level : specialist training, R and D activities, industrial cooperation.

§3 フリードマン氏本論文

JAIF PANEL ON "NEW FRAMEWORK FOR International NUCLEAR COOPERATION"

Opening Statement of ABRAHAM S. FRIEDMAN, U.S. Department of State.

~~At the beginning, I would like to say that~~ Ambassador Kennedy regrets very much that he is unable to be with us here today in Tokyo. He has asked me to tell you that if his schedule had permitted, he would have been extremely pleased to attend your very important conference and meet with you and your members personally.

I myself am, of course, very pleased to be able to address this forum of representatives of the major nuclear suppliers and of important users or potential users of nuclear power. It gives all of us a useful opportunity to exchange views and ideas on how best to further the development and use of nuclear power. At the same time it provides an occasion to reflect on a vital concomitant to such development: the need to put in place a framework of institutions, practices, and rules to prevent the spread of nuclear explosives.

As you know, the United States commitment to contribute to the peaceful applications of nuclear energy throughout the world is longstanding. Under the Atoms for Peace program of President Eisenhower, the United States began to supply a large number of countries with nuclear assistance, nuclear fuel, and equipment for civil applications of nuclear energy. We opened international training institutes at Oak Ridge, Brookhaven and

発表は 3 月 24日 ~~午前 時~~ ~~午後 時~~ 正午 以降に願います。

EMBARGO UNTIL

Noon ~~a.m.~~ ~~p.m.~~ March 24

the Argonne National Laboratory. We initiated a grant program under which we gave research reactors to many countries interested in starting up their own nuclear programs. All of these initiatives, and many others, left no doubt about our readiness to share our resources and our expertise so that other nations, as well as our own, might reap the benefits of a peaceful atom.

We also recognized, however, the dangers of possible misuse of nuclear material. From the beginning we required that the supply of nuclear material be contingent on the entry into force of an agreement between the United States and the recipient country under which the nuclear material would be subject to physical inspection and accountability. The responsibility for these safeguards was subsequently assumed by the International Atomic Energy Agency and was recognized throughout the world as a reasonable and necessary condition of international nuclear trade. When the Non-Proliferation Treaty came into effect, the non-nuclear weapons countries party to the Treaty renounced the option to develop nuclear weapons and accepted IAEA safeguards on all their peaceful nuclear programs. In return they gained access to nuclear technology and assistance in their peaceful nuclear programs.

The United States today continues to believe as strongly as ever in the dual goals I have described. From time to time there are differences in my country about what means we should use to best achieve these goals. But on the basic policy, there is no dispute. ~~Ambassador Kennedy has asked me to emphasize that point.~~ It is fundamental to an understanding of America's position.

President Reagan, in describing nuclear policy, has made clear that his Administration intends to support the increased use of nuclear power at home and abroad. But he has stressed that this must be done without increasing the risk of nuclear weapons proliferation. The President believes very strongly that non-proliferation is a fundamental foreign policy and national security objective of the United States.

One key element of United States policy is directed to reducing the motivation that states have to acquire nuclear weapons by striving to improve regional and global stability. As part of this effort we need to preserve and strengthen U.S. security ties and alliances which contribute to that goal.

Continued support for the Nuclear Non-Proliferation Treaty of 1968 is also critical. We want that Treaty to be universal and are urging countries to adhere to it. We also seek to bring into force the Tlatelolco Treaty in Latin America. Adherence to these treaties is one way that countries can evince their peaceful intentions. The President has told the world that our country would view a material breach of these treaties or of an international safeguards agreement as having profound consequences for international order, and the U.S. would view any nuclear explosion by a non-nuclear weapons state with grave concern.

The United States will not seek to inhibit civil reprocessing and use of plutonium as a fuel in nations with advanced nuclear power programs where it does not constitute a proliferation risk. At the same time, my country's policy is to continue to inhibit the transfer of sensitive nuclear material, equipment and technology, particularly where the danger of proliferation demands. This approach can buy time for efforts to reduce proliferation incentives.

We also need to strengthen the rules of nuclear trade and to seek an international consensus in support of a broad framework of non-proliferation practices and procedures. In that regard, the United States is committed to requiring IAEA safeguares on all nuclear activities in a non-nuclear weapons state as a condition for any significant new nuclear supply commitment, and we believe that other suppliers should adhere to the guideline as well.

Finally, U.S. policy strongly supports and continues to work with other nations to strengthen the International Atomic Energy Agency to provide for an improved International safeguards regime. These safeguards are a vital part of our mutual efforts to realize the atom's promise while controlling its danger. They are in all countries' interest and all countries should strive to enhance their effectiveness by dealing with the IAEA in a cooperative spirit.

As Ambassador Kennedy Kennedy stated at Vienna last month, however, the U.S. commitment to the IAEA "must depend on the degree to which other members are determined to return this Agency to its status as an effective international technical organization." He went on to say, "It is our deep desire that member states will join with us in this sincere effort. Together we can strengthen this unique international organization and see that the Agency lives up to the principles contained in its chrter."

I would like ~~Ambassador Kennedy has asked me~~ to stress another theme ~~in these remarks~~ and that is the need for internationally agreed rules and procedures to ensure the risk of proliferation is minimal when civilian nuclear commerce occurs, now and in the future.

Obviously, nuclear equipment importers must have a clear civil requirement for the material and equipment they wish to import. Nuclear exporters must recognize the need for restraint in the export of sensitive items. In the supply of nuclear material to countries for their legitimate civil nuclear requirements, we can make no compromises in the effective implementation of safeguards.

When countries <u>do</u> have a need for peaceful nuclear power and recognize the importance of demonstrating to the world their peaceful intentions, they willingly accept international safeguards and related non-proliferation controls. Many examples testify to the fact that a supplier and a recipient country are very much able to cooperate effectively and to their mutual benefit within such a framework. Our host country

-- Japan -- offers an excellent example of how it is possible to cooperative effectively with other nations through mutual understanding, discussion, and negotiation, and through its strong commitments to non-proliferation.

In addition, a sound basis for safe international nuclear commerce also requires predictability. In each of our countries, the rules of the game must be known to companies seeking nuclear exports and those companies should be able to find out quickly and accurately whether a proposed action would run counter to those rules.

Internationally, there is an even greater need for predictability if countries are to plan and be able to make sensitive energy decisions for their future. Here, too, stable and agreed nuclear rules of the game are of vital importance. Countries must not fear that those rules will change suddenly, secretly or without consultation. The standards for nuclear exports cannot be set unilaterally by any one nation. All nuclear exporters as well as the purchasers of nuclear facilities must work together. We, for our part, will not sacrifice our non-proliferation goals to commercial gains, and expect others to share that commitment.

We in the United States recognize this need for a stable basis for nuclear planning. It is important that the United States be seen as a reliable nuclear supplier. We are seeking a reinvigorated and more predictable basis for our cooperation with Japan, for example, which would minimize uncertainty about future U.S. actions under our Agreement for Nuclear Cooperation. We believe that laying such a foundation for our nuclear relations will serve both of our countries' long-term interests.

In view of the serious energy situation in many countries throughout the world, nuclear power can and should play an important role in assuring a country's energy security. For many countries there is no economically viable alternative to nuclear power. Regrettably, a number of factors have come together to produce a slowdown in new orders for nuclear power plants, even as more and more suppliers of nuclear facilities and technology have entered the market. In this buyers' market, it is essential that the nuclear supplier countries do not use relaxed non-proliferation and safeguards criteria as selling points in their export efforts. It is most important that all nuclear suppliers use the same realistic and prudent criteria in implementing their nuclear export policies. Speaking for the United States, our commitment to satisfy the legitimate civil nuclear needs of nations while assuring that the necessary safeguards and non-proliferatiuon controls are in effect requires that we continue to cooperate with both suppliers and user nations, and that we arrive at a universally accepted set of rules to which all can adhere. This is the only sound basis for nuclear commerce, and for ensuring the long-term security and well being of all people.

58.4.25

発表は 3 月 25 日 午前 10 時 ~~午後 時~~
以降に願います。
EMBARGO UNTIL
10:00 a.m. ~~p.m.~~ March 25

§4

H.デントン氏

SAFETY GOAL DEVELOPMENT PROGRAM

OF THE UNITED STATES NUCLEAR REGULATORY COMMISSION

SLIDES USED BY

HAROLD R. DENTON
DIRECTOR
OFFICE OF NUCLEAR REACTOR REGULATION
U.S. NUCLEAR REGULATORY COMMISSION

AT

JAPAN ATOMIC INDUSTRIAL FORUM
16TH ANNUAL CONFERENCE

TOKYO, JAPAN

MARCH 25, 1983

LIST OF SLIDES

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COMMISSION ACTION
MARCH 1983

- ISSUED POLICY STATEMENT ON SAFETY GOALS FOR NUCLEAR POWER PLANTS
- FOR 2-YEAR EVALUATION PERIOD
- EXPRESSES PRELIMINARY VIEWS:
  - On acceptable level of risks
  - On role of safety-cost tradeoffs

BACKGROUND

- November 1979: RESPONSE TO PRESIDENT'S COMMISSION ON TMI: NRC "PREPARED TO MOVE FORWARD WITH AN EXPLICIT POLICY STATEMENT ON SAFETY PHILOSOPHY."
- October 1980: PLAN FOR DEVELOPING A SAFETY GOAL
- October 1980: ACRS: AN APPROACH TO QUANTITATIVE SAFETY GOALS: "TO SERVE AS ONE FOCUS FOR DISCUSSION ...A FIRST STEP..."
- April and July 1981: SAFETY GOAL WORKSHOPS
- February 1982: PROPOSED POLICY STATEMENT AND DISCUSSION PAPER:FOR PUBLIC COMMENT

OBJECTIVES

- TO PROVIDE A BETTER MEANS FOR TESTING THE ADEQUACY AND NEED FOR CURRENT AND PROPOSED REGULATORY REQUIREMENTS
- MORE COHERENT AND CONSISTENT REGULATION
- MORE PREDICTABLE REGULATORY PROCESS
- BETTER PUBLIC UNDERSTANDING OF NRC REGULATORY CRITERIA
- PUBLIC CONFIDENCE IN THE SAFETY OF OPERATING PLANTS

SCOPE

- NUCLEAR POWER PLANTS
  (fuel cycle not included)
- NORMAL OPERATIONS, ACCIDENTS
- NOT SABOTAGE OR DIVERSION OF NUCLEAR MATERIAL

REGULATORY STATUS

- 2-YEAR EVALUATION PERIOD:
  To judge effectiveness
- NOT TO BE USED IN LICENSING PROCESS
- CONFORMANCE TO REGULATORY REQUIREMENTS AS THE EXCLUSIVE LICENSING BASIS

GOAL STRUCTURE

- QUALITATIVE SAFETY GOALS
- Supported by:
  QUANTITATIVE DESIGN OBJECTIVES

FIRST SAFETY GOAL

INDIVIDUAL MEMBERS OF THE PUBLIC SHOULD BE PROVIDED A LEVEL OF PROTECTION FROM THE CONSEQUENCES OF NUCLEAR POWER PLANT OPERATION SUCH THAT INDIVIDUALS BEAR NO SIGNIFICANT ADDITIONAL RISK TO LIFE AND HEALTH.

SECOND SAFETY GOAL

SOCIETAL RISKS TO LIFE AND HEALTH FROM NUCLEAR POWER PLANT OPERATION SHOULD BE COMPARABLE TO OR LESS THAN THE RISKS OF GENERATING ELECTRICITY BY VIABLE COMPETING TECHNOLOGIES AND SHOULD NOT BE A SIGNIFICANT ADDITION TO OTHER SOCIETAL RISKS.

QUANTITATIVE DESIGN OBJECTIVES TO BE EVALUATED

- AIMING POINT FOR RISK REDUCTION WHICH DESIGNERS AND OPERATORS SHOULD MEET WHERE FEASIBLE
- BASED ON USE OF PROBABILISTIC RISK ASSESSMENT
- PROGRESS IN DEVELOPING PRA AND IN ACCUMULATING RELEVANT DATA:
  - Feasible to use quantitative reactor safety design objectives for limited purposes
  - Remaining sizable uncertainties in methods and data to gauge whether objectives have been achieved
- DESIGN OBJECTIVES ARE NOT SUBSTITUTES FOR EXISTING REGULATIONS

PERSPECTIVE ON DESIGN OBJECTIVES

NO DEATH ATTRIBUTABLE TO NUCLEAR POWER PLANT OPERATION WILL EVER BE "ACCEPTABLE" IN THE SENSE THAT THE COMMISSION WOULD REGARD IT AS A ROUTINE OR PERMISSIBLE EVENT.

WE INTEND THAT NO SUCH ACCIDENT(S) WILL OCCUR, BUT THE POSSIBILITY CANNOT BE ENTIRELY ELIMINATED.

PRINCIPAL DESIGN OBJECTIVES

- THE RISK TO AN AVERAGE INDIVIDUAL IN THE VICINITY OF A NUCLEAR POWER PLANT OF PROMPT FATALITIES THAT MIGHT RESULT FROM REACTOR ACCIDENTS SHOULD NOT EXCEED 0.1% OF THE SUM OF PROMPT FATALITY RISKS RESULTING FROM OTHER ACCIDENTS TO WHICH MEMBERS OF THE U.S. POPULATION ARE GENERALLY EXPOSED.

- THE RISK TO THE POPULATION IN THE AREA NEAR A NUCLEAR POWER PLANT OF CANCER FATALITIES THAT MIGHT RESULT FROM NUCLEAR POWER PLANT OPERATION SHOULD NOT EXCEED 0.1% OF THE SUM OF CANCER FATALITY RISKS RESULTING FROM ALL OTHER CAUSES.

PERSPECTIVE ON
BENEFIT-COST GUIDELINE

- ONE CONSIDERATION IN DECISIONS ON SAFETY IMPROVEMENTS
- INTENDED TO ENCOURAGE EFFICIENT ALLOCATION OF RESOURCES
- FOCUSED PRINCIPALLY ON SITUATIONS WHERE ONE OF THE QUANTITATIVE DESIGN OBJECTIVES IS NOT MET
- DOES NOT REPLACE BACKFITTING REGULATION

BENEFIT-COST GUIDELINE

THE BENEFIT OF AN INCREMENTAL REDUCTION OF SOCIETAL MORTALITY RISKS SHOULD BE COMPARED WITH THE ASSOCIATED COSTS ON THE BASIS OF $1,000 PER PERSON-REM AVERTED.

PLANT PERFORMANCE DESIGN OBJECTIVE

THE LIKELIHOOD OF A NUCLEAR REACTOR ACCIDENT THAT RESULTS IN A LARGE-SCALE CORE MELT SHOULD NORMALLY BE LESS THAN ONE IN 10,000 PER YEAR OF REACTOR OPERATION.

PERSPECTIVE ON PLANT PERFORMANCE OBJECTIVE

- TO ASSURE EMPHASIS ON ACCIDENT PREVENTION
- SUBORDINATE TO PRINCIPAL DESIGN OBJECTIVES LIMITING INDIVIDUAL AND SOCIETAL RISKS
- CONTINUED EMPHASIS ON FEATURES SUCH AS CONTAINMENT, SITING IN LESS POPULATED AREAS, AND EMERGENCY PLANNING AS INTEGRAL PARTS OF THE DEFENSE-IN-DEPTH CONCEPT

EVALUATION PERIOD

- THE QUALITATIVE SAFETY GOALS SUPPORTED BY THE QUANTITATIVE DESIGN OBJECTIVES ARE BEING ADOPTED FOR USE DURING A 2-YEAR EVALUATION PERIOD
- TO JUDGE EFFECTIVENESS OF THE GOALS AND DESIGN OBJECTIVES; GAIN FAMILIARIZATION WITH TECHNIQUES
- POTENTIAL EFFECT OF GOALS ON REGULATORY REQUIREMENTS NOT CLEAR NOW
- AT THE END OF EVALUATION PERIOD COMMISSION WILL CONSIDER WHAT REGULATORY CHANGES APPEAR NECESSARY
- PROPOSED CHANGES IN THE REGULATIONS WILL BE ADDRESSED IN RULEMAKING PROCEEDINGS

IMPEDIMENTS TO ADOPTION OF QUANTITATIVE RISK LIMITS

- ESTIMATES ARE COMPLEX; HAVE SUBSTANTIAL UNCERTAINTIES
- SERIOUS QUESTION WHETHER, FOR A SPECIFIC PLANT, ACHIEVEMENT OF OBJECTIVES CAN BE VERIFIED WITH SUFFICIENT CONFIDENCE

LIMITED APPLICATION

- IMPLEMENTATION LIMITED TO SUCH USES AS:
  - Examining proposed and existing regulatory requirements
  - Establishing research priorities
  - Resolving generic issues
  - Defining relative importance of issues as they arise
  - Developing information and understanding on how to further define and use cost-benefit guidelines
- WILL NOT BE USED IN LICENSING OR REQUIRE PRA

EVALUATION PLAN

- DETAILED STAFF EVALUATION PLAN ISSUED BY COMMISSION FOR PUBLIC COMMENT
- TO GAIN EXPERIENCE NECESSARY FOR LATER APPLICATION IN THE REGULATORY PROCESS
- OUTLINES PROCESS FOR OBTAINING EXPERIENCE IN DEVELOPING NEW REGULATORY REQUIREMENTS AND EXAMINING EXISTING REQUIREMENTS

CONCLUDING REMARKS

- DECADE SINCE WASH-1400
  - Many PRAs in US, elsewhere
  - Progress on PRA procedures (e.g., ANS/IEEE)
- NOW SAFETY GOAL EVALUATION PERIOD
  - Important technological attempt at aid to better systematizing safety regulation
- NOT SUBSTITUTE FOR REGULATIONS
- OPPORTUNITY FOR INTERNATIONAL COOPERATION

20/E

§4 A. ビルクホーファー博士

16th JAIF Annual Conference
Tokyo, March 23 - 25, 1983

TRENDS IN NUCLEAR SAFETY TECHNOLOGY WITHIN THE FEDERAL REPUBLIC OF GERMANY

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1. INTRODUCTION

This paper deals with Trends in Nuclear Safety Technology within the Federal Republic of Germany (FRG). Starting with the experience in nuclear safety technology, improvements in plant design will be discussed. Thereupon, some remarks of the present risk evaluation program and a short review of design basis accident (DBA) analyses will be given. Furthermore; the present status of scenarios beyond DBA will be presented. Finally, trends in the development of safety goals will be outlined.

2. EXPERIENCE WITH NUCLEAR SAFETY TECHNOLOGY

Compared with fossile power plants the operation of commercial nuclear power plants is - in the public opinion - frequently related with a low availability. In this context an average load factor of about 60 per cent is referred to.

In Fig. 1 load factors of German PWR commercial power plants are compared with the world wide average value.

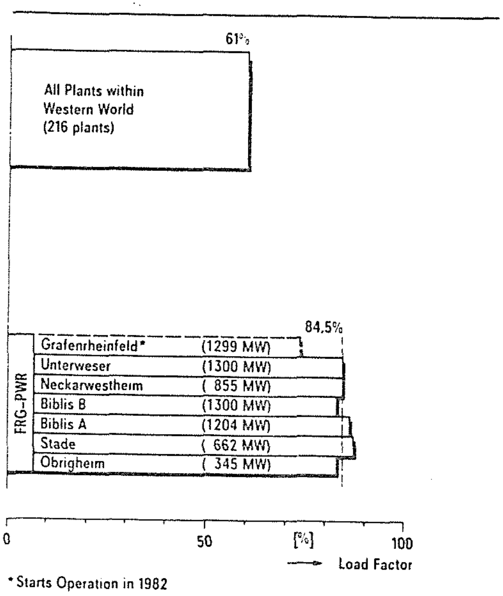


Figure 1: NPP Performance in 1982, % Load Factor (Nucleonics Weak from Jan. '83)

The average load factor for all commercial NPPs in the western world is about 61 %. This value differs considerably, depending on plant types, countries and vendors.

At present, in the spring of 1983, 15 NPPs are operating within the FRG. The last NPP, the 1300 MW PWR Grafenrheinfeld, went into operation in 1982. Therefore, this plant is not considered in the average. Altogether the installed net power is about 10.000 MW, which means that 18 % of the generated electric power in the FRG was produced by NPPs. The average load factor of German PWR commercial power plants is about 81 % in 1982.

The vendor - KWU - is very proud that Nuclear Engineering reported German PWRs having the worlds highest load factor of LWRs.

However, it should be mentioned that similar results about plant availabilities can be found for some other countries.

More than 70 % of the installed nuclear power in the FRG results from PWRs, the rest was mainly produced by BWRs. Because of this ratio, the aspects to be presented focus on PWRs. Other types of reactors, e.g. the sodium cooled fast breeder and the gas cooled high temperature reactor, are operating as research plants only, with output rates smaller than 50 MW.

It should be added that the 1982 load factors for BWRs in the FRG are quite lower than for PWRs due to shut down periods caused by preventive exchanges of improved piping system in the main steam and feedwater circuit.

At present, 12 NPPs with a net power of more than 13.000 MW are under construction. Seven of these are PWRs. The recently ordered three 1300 MW PWR plants are of an identical standardized design except for a few site-dependent factors. To avoid construction delays and to streamline the licensing procedure, the manufacturer and the utilities created the Convoy-project.

The design of these Convoy-plants reflects the actual state of the PWR concept in the FRG. It has been based on all the experience gained in the course of the last years from the licensing procedure, including the concept evaluation by the Reactor Safety Commission and a detailed examination of the engineered safety features by independent experts agencies. Experience has also been gained from findings during construction, commissioning and from operation. Furthermore, results from the diverse and extensive R&D activities and from detailed investigation of the PWR plant within the German Risk Study contribute to this actual design.

All the results gained confirmed the fundamental safety concept and design of the PWR in the FRG. For that reason there are no major differences in the design of the most recent Convoy plants compared to the precursors.

3. IMPROVEMENTS IN PLANT DESIGN

The progress in nuclear safety technology results in improvements to existing engineered safety features. These improvements are primarily aimed to assure the 'Defense-in-Depth' safety concept . Within this concept preventive measures to avoid and control accidents have always priority over design features to limit consequences of hypothetical unprotected accidents. In this sense, more stringent requirements have been formulated for components and systems of both the primary as well as the secondary side of the plant.

In the following, more recent conceptual aspects will be discussed.

3.1 Basic Safety Concept

In order to assume the component integrity of the pressure retaining boundary and other safety related systems the basic safety concept has been introduced. The principles of this concept are listed in Fig. 2.

- High-grade material characteristic
  Adequate material selection in connection with the limitation of the content of trace elements and optimized technologies for manufacturing result in high toughness, high homogeneity and lower failure frequency.

- High - grade material characteristics
- Minimization of the number of welding seams
- Optimization of the material strength design
- Limitation of operational loads and conditions
- Leakage control and recurrent inspections

Figure 2: KEY - PRINCIPLES OF THE CONCEPT OF BASIC SAFETY

- A Minimum number of weld seams and the location of weld seams outside areas of increased stress are required.

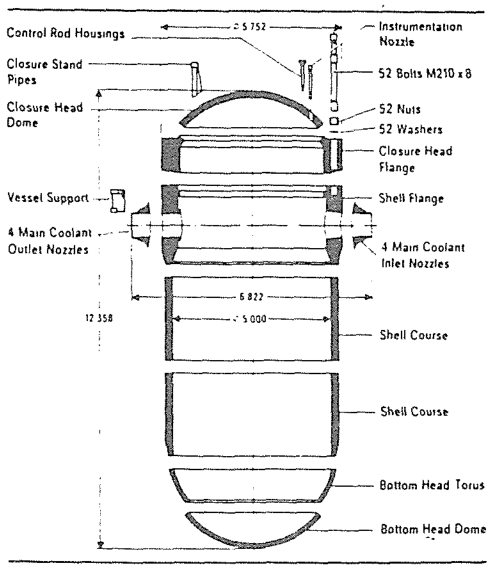
- Optimization of the material strength design has to be performed.

- Limitations of operational loads and control of operational conditions must be assured.

- Furthermore, operational control for abnormal leakages and recurrent inspections must be performed.

If these requirements are fulfilled, a catastrophic failure of the respective component can be precluded and has no longer be postulate. The basic safety concept covers not only the primary reactor coolant pipes with connected systems, but also the pressure-retaining walls of pipes, fittings, valves, presssurizers, and pumps of other systems, which are important to safety. Components of the main steam and feedwater system between steam generators and the included valve compartment are also subject to this concept.

The Reactor Pressure Vessel (RPV) of a 1300 MW PWR is shown in Fig. 3 as an example of a design, adequate for the basic safety. To ensure highest possible quality, the RPV is made of seamless forged cylindrical shell courses. The bottom is closed by a forged dome. At the top a thick forged ring which incorporates the nozzles, serves as a flange for the RPV's closure head. A head dome welded together with the closure head flange forms the closure head. The head dome accomodates the nozzle for the instrumentation lines and the control rods. This RPV is free of longitudal welds and without penetrations in the bottom.



Reactor Pressure Vessel 1300 MW_{el}

Figure 3:

Additionally, with respect to RPV-safety considerations it should be mentioned that more recent PWRs in the FRG have the provision to allow high pressure injection only into the hot legs. This, in any case, avoids thermal shocks to the reactor pressure vessel wall.

3.2 LOCA-philosophy

The improvements in the design of the pressure-retaining boundary has led to changes in the LOCA-philosophy.

10 % of the main coolant pipe cross section (0.1 A) has been defined as a maximum break size value, e.g. for the design analyses of reaction and jet forces on pipes, components, component internals and walls. On the one hand this break size represents approximately the cross section of the largest connected pipe to the main recirculation line. On the other hand it amply covers all conceivable subcritical flaws in the pressure retaining boundary.

To assure the integrity during the overall lifetime of the plant a comprehensive and multiple inspection program is necessary. This requires sufficient inservice inspection during shut down periods as well as adequate detection systems to monitor vibration of components and loose parts detection within the primary circuit. The performance of this surveillance system has been demonstrated in several plants.

However, resulting from fundamental safety considerations the double ended break is still postulated for the integrity of the containment barrier and its internals and the stability of large components as well as the effectiveness of the ECC-Systems.

The modified LOCA-concept has already resulted in deleting unnecessary pipe whip restraints limiting the reaction forces on pipes. It has turned out that inspection and maintenance was, therefore, quite easier causing also a considerable reduction of the radiation exposure to the maintenance crew.

The requirements of the basic safety concept are described in detail and published in the Guidelines of the German Reactor Safety Commission.

3.3 Steam Generator (SG) Tube Failure

Another improvement is related to the consequence of a steam generator tube failure. Despite the physical separation of the primary and secondary side of a PWR, contaminated steam could be released to the environment via relief valves in case of tube failures.

To limit this release procedures have been defined and several provisions have been installed in more recent German PWRs. For example, for the most serious accident sequence - steam generator tube failure in combination with loss of off-site power and start of the high pressure injection pump (HPI) - the SG will be isolated. This procedure includes an increase of the set point of the main steam safety valves to a level higher than the maximum pump head of the HPI-pumps.

Without this procedure the operator would have been forced to monitor very carefully the system behaviour in order to manage this type of accident.

The above mentioned provisions are considered as preventive measures. Because of the current experience with operating SGs, at the present safety considerations with respect to tube failures is not a major issue in the FRG.

3.4 Limitation Systems

In the classical approach the reactor protection system will always be activated if specified operating limits are exceeded. Increasing experience in commissioning and operation resulted in the installation of an additional instrumentation and control (I&C) system (Limitation System) with the objective to correct disturbances. This measure decreases the loads on the power plant as well as the total shut down time resulting in higher availability. This system is an appropriate measure to control small operating disturbances.

Fig. 4 shows the hierarchical structure of counter-measures, represented by three independent automatically acting partial systems

- the operational control systems,
- the limitation systems and
- the reactor protection system

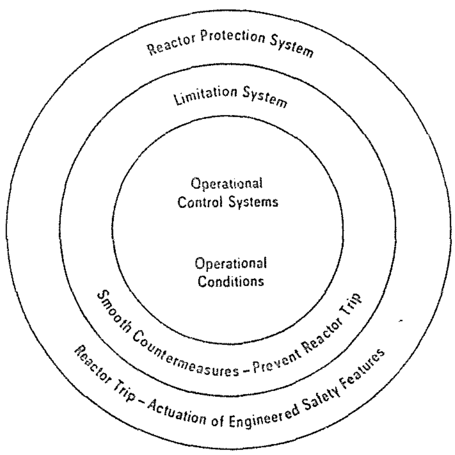


Figure 4: "Defense-in-Depth" Concept for Instrumentation and Control (I & C) Systems

The automatic operational control systems are designed to keep systems within their operational limits, to cope with minor disturbances and to optimize plant operation.

The next level of this concept of defense-in-depth is formed by the limitation systems. There are two different types of limitation systems. One is the condition limitation, which assures that process values in the related systems do not exceed limits specified in the safety analysis. The other is the protection limitation, which is designed for protective counter-measures for certain events.

For example, in case of a reactor coolant pump failure, the limitation system reduces reactor power by 'rod dropping' within a few seconds such that limit values for reactor protection system response are not exceeded and the plant remains in operation.

The highest level within the 'defense-in-depth' concept is formed by the reactor protection system, which initiates the reactor trip and actuates the engineered safety features to bring the plant into a safe shutdown state. The reactor protection system itself responds only in case of incidents or accidents which cannot be handled by the other counter-measures described.

With this defense-in-depth concept, an appropriate response to disturbances and incidents can be achieved.

3.5 Heat Removal via Secondary-Side Systems

Reliable decay heat removal in NPPs is one major objective in safety considerations. Several possibilities exist to meet this objective. In the FRG much emphasis has been put on a most reliable SG feeding for heat removal. The capacitiy of this systems allows, besides decay heat removal, primary system pressure decrease to a sufficiently low pressure level within a reasonable time. The decay heat removal is then taken over by the residual heat removal system (RHRS).

The improvements realized in more recent PWR plants underline the significance for heat removal via secondary-side systems, increasing both the redundancy and the capacity of SG feeding and main steam removal as shown in Fig. 5.

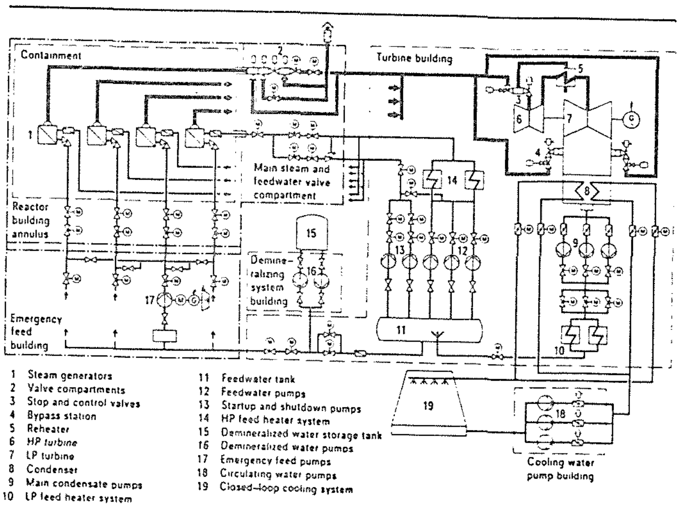


Figure 5: 1300 MW PWR
Systems for Secondary-side Heat Removal (Survey)

SG feedwater supply is performed by three automatically actuated systems. In addition to the main feedwater system an auxiliary feedwater system, which can operate on emergency power, has been installed. This auxiliary feedwater system is primarily designed to perform the start-up and shutdown operation. Furthermore, a completely independent emergency feedwater system does exist for special events and further redundancy.

In accordance with the guidelines of the German Reactor Safety Commission the emergency feedwater system consists of four trains, each with autonomous water and power supply. To cope with external impacts the system has been designed to operate 10 h at least without external heat removal and water supply. The individual trains are strictly separated, both physically and functionally, each being dedicated to a different steam generator.

Steam relief (after turbine trip) is achieved by the turbine bypass station. If the station is not available four main steam relief stations, each connected to one SG, and each dimensioned for a 100 % shutdown capacity are automatically actuated.

With the aid of these highly redundant systems plant shutdown is performed via the secondary side at a rate of 100 K/h in the event of accidents and is automatically initiated and controlled.

4. RISK ANALYSIS

This paper considers major developments in nuclear safety within the recent years. One of these is represented by the first extensive risk evaluation of German plants, known as German Risk Study. Phase A of the study was published in 1979. In its main assumptions the study refers to the Reactor Safety Study WASH 1400. As a consequence of the study qualifications have been performed in PWRs in order to improve the system reliability and accident management. In the German Risk Study, core melt down was assumed in all accident sequences as soon as calculations resulted in cladding temperatures above 1200 °C, taking into account conservative licensing assumptions. Based upon this conservative assumptions, the melt down frequency has been estimated to about 10^{-4} per reactor year.

Phase B of the German Risk Study has been started in 1982 in order to analyse the unavailability of systems and the melt down consequences on a best estimate level. In addition, special aspects will be treated in more detail, which in phase A have been considered only globally. On the basis of the current R&D work the results of phase B, which are expected to be available in about two years time, will demonstrate the conservatism of the results published in phase A.

5. BEST ESTIMATE CALCULATIONS ABOUT THE EFFECTIVENESS OF ECCs

For the thermohydraulic analysis of DBAs, the most important physical phenomena have been identified and are understood. The capability of systems controlling DBAs have been examined on the basis of best estimate calculations, in particular with respect to

- availability of systems,
- boundary conditions for calculations (e.g power peaking and hot spot factors),
- modelling of physical phenomena (e.g.coolability of the core at a high temperature level) and
- definition of ultimate limits (e.g. 1200 °C).

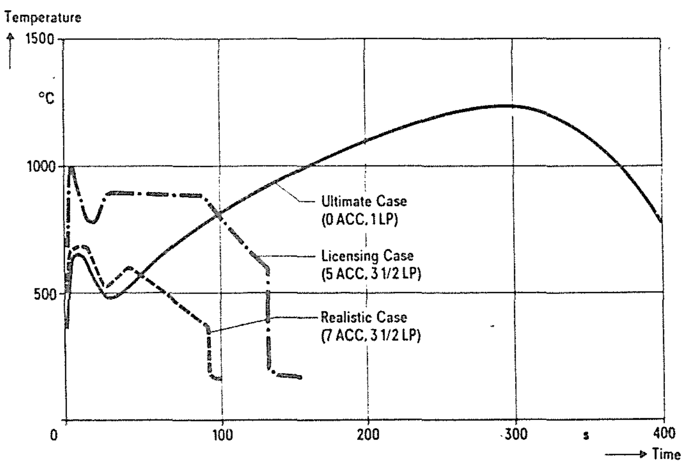


Figure 6: Maximal Cladding Temperature as a Function of Time for a large LOCA

The results of one selected analysis are summarized in Fig. 6, which shows the hot spot cladding temperature versus time after a double ended break of the cold leg in the primary coolant system. In the "licensing case", with five accumulators (ACC) and 3 1/2 injection trains of the low pressure (LP) core cooling systems, a maximum cladding temperature of about

1000 °C is calculated during the first peak. Seven ACCs and the same number of LPs are considered in the "realistic case". Compared with the licensing case, two additional ACCs results in a significant decrease of the temperature peaks by about 300 K. The "ultimate case", with no ACCs and only 1 LP, has been analysed to demonstrate the safety margins available when best estimate assumptions are taken into account. A considerable margin to core melt temperatures was found, demonstrating the conservative nature of the licensing procedure. This result can also be transferred to small leaks and transients as initiating events.

In conclusion, a best estimate type analysis illustrates - compared with licensing assumptions - the high safety margins.

6. CONSEQUENCE ANALYSES ON EVENTS BEYOND DBAs

Since the early 70s, R&D work has been performed to study physical phenomena for accident sequences beyond DBAs. The main purpose includes the development of physical models - experimentally verified as far as possible - and the combination of these models in computer codes. The codes are established to analyse, on a best estimate basis, the consequences of hypothetical accidents. Further R&D work is underway to improve the confidence level of the calculations.

The analysis is performed to study the capabilities of the present design of PWRs to limit the consequences of severe accidents.

The most effective approach to improve plant safety is to reduce the likelihood of accident initiation as well as its subsequent possible sequences.

Within melt down sequence consequence analyses thermodynamic containment calculations determine the time interval, until containment failure through overpressurization occur. Recent calculations with realistic assumptions show that this type of failure is expected to be more delayed than it was calculated in the German Risk Study, even without assuming any heat removal from the containment.

Emphasis has also been placed on the analysis of fission product behaviour. Analytical and experimental results indicate a much more rapid decrease of aerosol particles within the containment atmosphere than was calculated in the German Risk Study and in WASH-1400.

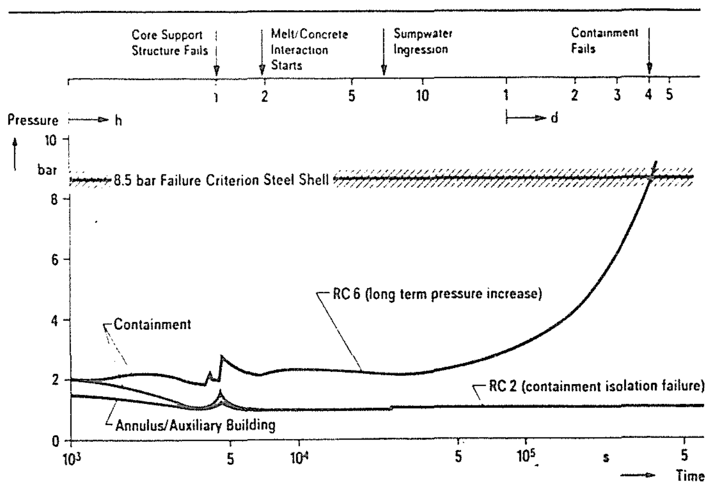


Figure 7: Pressure–Time History for Release Categories (RC) 2 and 6

For a large LOCA followed by complete failure of all low pressure recirculation systems, Fig. 7 shows the pressure/time history in the containment for two different cases with (RC 2) and without containment isolation failure (RC 6). If the containment is isolated, the long-term pressure increase is influenced by sump water ingression to the surface of the melt. Compared to other designs, the German design comprises a dry innermost reactor cavity. The innermost shielding within the reactor cavity, separating the melt and the sump, is penetrated in this case by melt/concrete interaction hours after blow down. Based upon the evaporation rates, over-pressure failure of the containment shell, which has been analysed to occur at about 8.5 bar, is not expected before 4 days. Within this time interval, the aerosol acitivity decreases within the containment atmosphere by several orders of magnitude.

Assuming isolation failure of the containment ventilation system Fig. 7 also shows the pressure-time history. In this case, depletion and condensation of fission products in the annulus and/or auxiliary building reduces the fission product release into the environment. For this melt down sequence, only small pressure differences occur between the containment and the environment during the time interval fission products are transported from the molten fuel to the containment atmosphere. Small driving forces produce only low leakage rates and additionally reduce the activity release to the environment.

During all hypothetical accidents analysed so far, a large amount of non-condensable gas, including the combustible components H_2 and CO, was found to be released into the containment atmosphere. For instance, if 50 % of the Zirconium core inventory is assumed to oxidize, the H_2-content in a large dry PWR-containment amounts to about 10 Vol %.

The significance of H_2-explosions with respect to their impact on the tightness of the containment shell has been discussed at several occasions. Fig. 8 shows the results of a parametric study performed with a simple energy- and mass balance to predict the pressure peaks within the containment during violent H_2-combustion. In all three cases, H_2 is released to the containment and ignited immediately after the enrichment of H_2 has

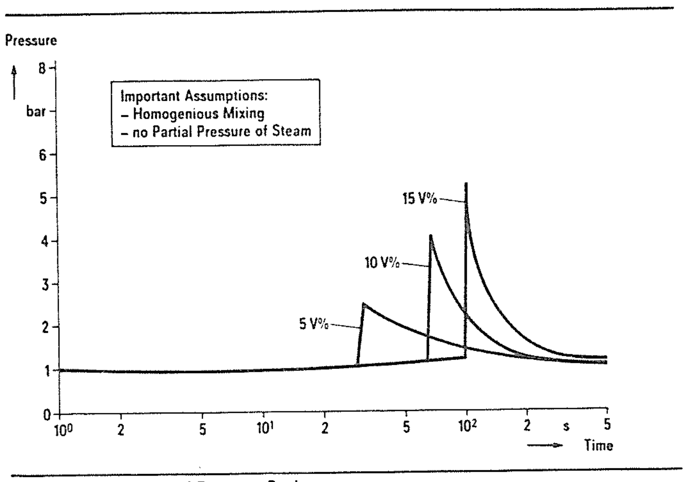


Figure 8: Parametric Evaluation of Pressure Peaks within the Containment During Violent H_2-Combustion

reached 5, 10, and 15 volume per cent. The maximum energy generated during the burning process results in a pressure peak equal to the design pressure level of the containment shell. This result is only valid for a dry, homogeneously mixed containment atmosphere. During melt down accidents, in almost all cases, the containment contains a significant amount of steam which, by its heat capacity and partial pressure, influences the pressure and temperature peaks during the burning process. R&D-work is being performed to analyse the influence of non homogenious distribution of H_2/O_2 and steam.

If the heat-up and melt-down process continues further, even more hydrogen is generated due to the reduction of steam by the metallic components of the molten corium and the concrete. In addition, CO_2 released during heat-up of the concrete aggregates is partially reduced to CO. Therefore, long-term generation of combustibles is expected during the course of a melt down accident. Assuming ignition of the combustible mixture, the consequences to the containment integrity have been analysed using a containment code based upon a one-compartment model. Taking into account the simplifying assumptions the peak pressures obtained were always found to be below the failure pressure of the containment.

Nevertheless, a more detailed modelling of the combustion processes has been initiated to analyse whether local burning effects can result in a dangerously high loading of the containment shell. For such detailed analysis of combustion processes, a knowledge of the state of the atmosphere and the mixing of the different constituents is needed. In order to get the most realistic failure mode of the containment during overpressurization a more detailed analysis of the actual steel shell and its penetrations has to be performed.

Improvements in safety design and best estimate calculations for different accident sequences indicate that core melt frequencies, as well as the consequences of such severe accidents, are lower than previously estimated. Despite the fact that preventive measures have the highest priority, studies and sequence analyses about the effectiveness of mitigation measures are underway. Results indicate up to now no necessity for special mitigation measures. However, before final conclusions can be drawn, ongoing research work on specific aspects related to severe accidents has to be completed. In particular, this includes:

- melt down scenarios with high system pressure
- hydrogen distribution and explosion phenomena
- best estimate modelling of fission product behaviour, taking into account all fission product retention mechanism
- demonstration and verification of long-term melt/concrete behaviour
- demonstration of aerosol plate-out

All of the R&D work mentioned above has been initiated and is expected to be completed by 1985. At that time, analytical tools experimentically verified should be available to confirm the expected tendency to lower melt down consequences than previously estimated.

7. SAFETY GOALS

From the present research programs a more accurate description of possible severe accidents and their consequences is emerging. During the past years, experience has been gained from probabilistic risk assessment (PRA), especially related to the methods and the analysis of main accident sequences. Based on this experience work on probabilistic risk criteria is well founded. Despite the well known limitations of probabilistic risk analyses they have proven to be a powerful tool in assessing nuclear safety.

Risks to the public from generating electricity in nuclear power plants have to be seen in relation to other risks the public is exposed to. It is therefore a rational move to define safety goals based on the risk concept. The USNRC was the first licensing authority in formulating safety goals. It is quite clear that these safety goals can not replace the present deterministic approach laid down in criteria and rules. Probabilistic safety criteria will supplement the present licensing approach.

The purpose and scope of the USNRC safety goals are defined in the policy statement of the Commission in January 1983.

What are the merits in applying probabilistic criteria within a deterministic frame?

Also in the future, deterministic rules should be applied for the plant layout. If a plant design fulfills all relevant requirements it can be operated safely. Then, probabilistic methods can be used supplementary to check if the plant design is well-balanced from the safety point of view. The advantage of deterministic criteria is that they give clear description to the constructor.

However, they are applied to all relevant components independent how frequent the specific component is called upon, how reliable it is and independent of the consequences of component failure In a PRA the safety significance of different components is considered very detailed.

Within the Federal Republic of Germany GRS is putting some effort also in formulating probabilistic risk criteria. Like in the USA it is not intended to replace present deterministic criteria and regulations by general probabilistic ones. The aim is to formulate criteria that can be used in further development of deterministic criteria and to enhance a well-balanced safety concept. The idea is to relate a criterion to the individual risk expressed by the annual whole body dose of 30 mrem laid down in the Radiation Protection Ordinance for normal operation. Cumulative frequency distribution showing frequency versus dose can be constructed in such a way that the integral of the curve, which corresponds to the total risk, is equal to 30 mrem/a (Fig. 9).

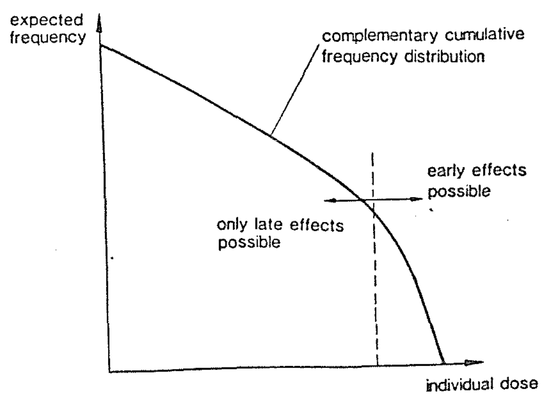


Figure 9: M1337 PRINCIPLE OF PROBABILISTIC SAFETY CRITERIA GRS

Such an apporach is especially suited if radiation exposure, resulting from an accident can cause only stochastic or late effects.

It is discussed if this principle should be extended to such radiation exposure where early effects can not be excluded. For this range, one could alternatively relate the criteria to the individual risk to life and health, like it is done by the NRC concept. Anyhow, in this range a risk aversion factor is going to be applied. In addition to the individual risk the formulation of a societal risk criterion is under discussion.

A direct application on a case by case basis, especially in the licensing procedure, causes extreme difficulties. The major one being completeness and evaluation of the error bounds. A detailed description of the calculation procedure would help to some extent.

Probabilistic risk criteria may assist in defining the necessity of backfitting measures and in solving generic issues resulting from operating experience and licensing demands.

SESSION 4

16th JAIF Annual Conference

Tokyo, March 23 - 25, 1983

TRENDS IN NUCLEAR SAFETY TECHNOLOGY WITHIN THE FEDERAL REPUBLIC OF GERMANY

Slides Used by

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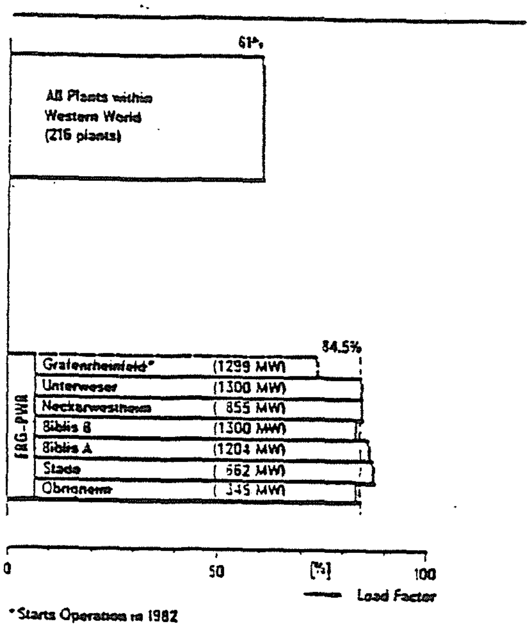


Figure 1: NPP Performance in 1982, % Load Factor (Nucleonics Weak from Jan. '83)

Figure 2: KEY - PRINCIPLES OF THE CONCEPT OF BASIC SAFETY

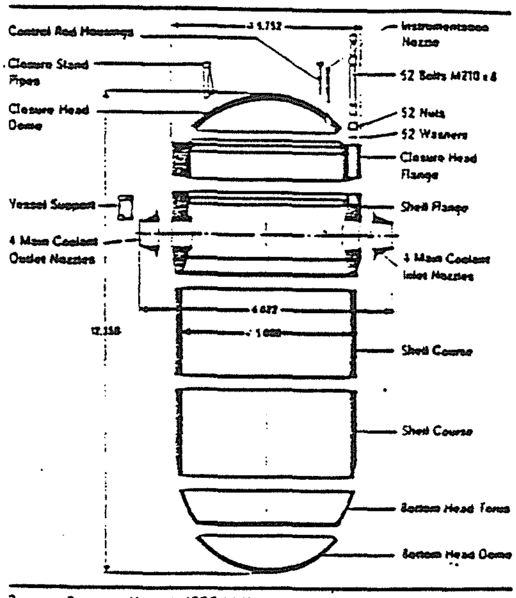
GRS

- A Minimum number of weld seams and the location of weld seams outside areas of increased stress are required.

- Optimization of the material strength design has to be performed.

- Limitations of operational loads and control of operational conditions must be assured.

- Furthermore, operational control for abnormal leakages and recurrent inspections must be performed.



Reactor Pressure Vessel 1300 MW_{el}

Figure 3:

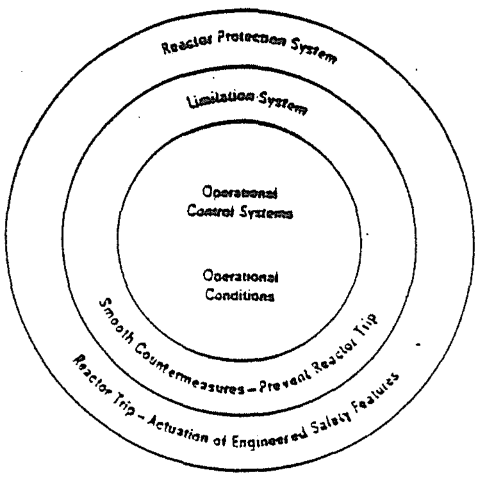


Figure 4:

"Defense–in–Depth" Concept
for Instrumentation and Control (I & C) Systems

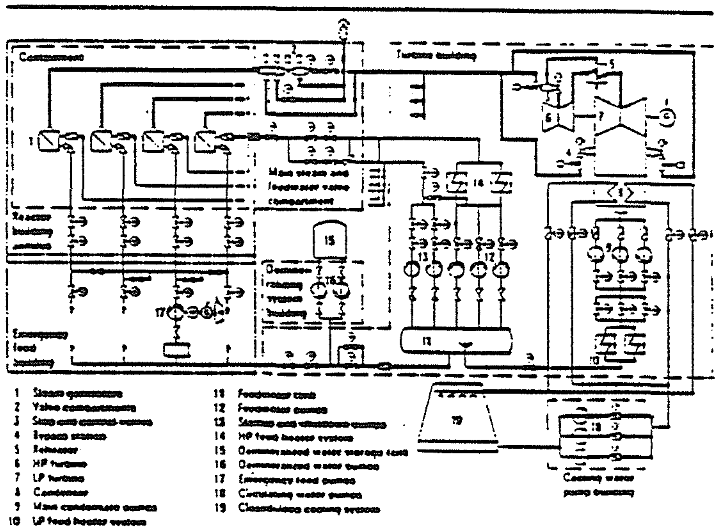


Figure 5: 1300 MW PWR
Systems for Secondary-side Heat Removal (Survey)

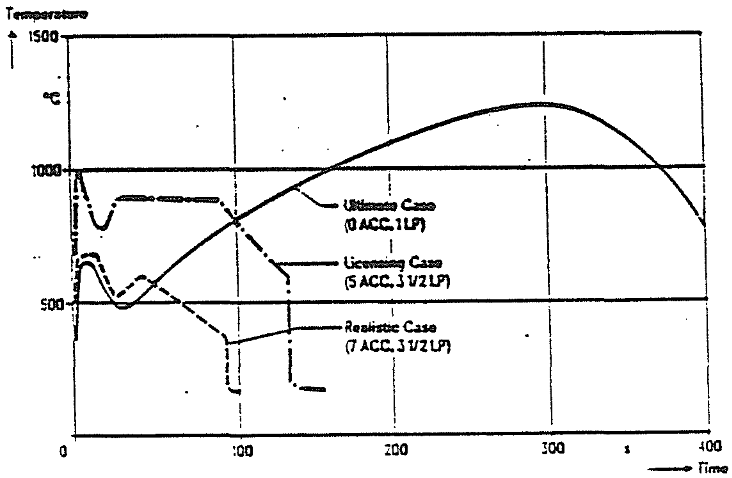


Figure 6: Maximal Cladding Temperature
as a Function of Time for a large LOCA

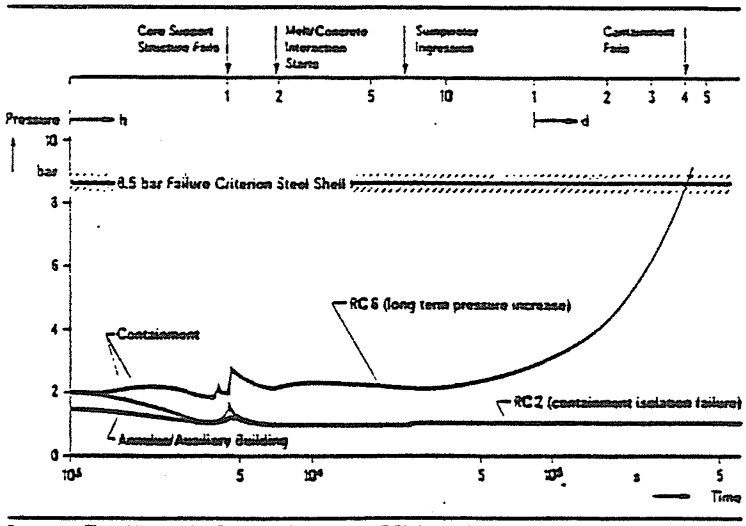


Figure 7: Pressure–Time History for Release Categories (RC) 2 and 6

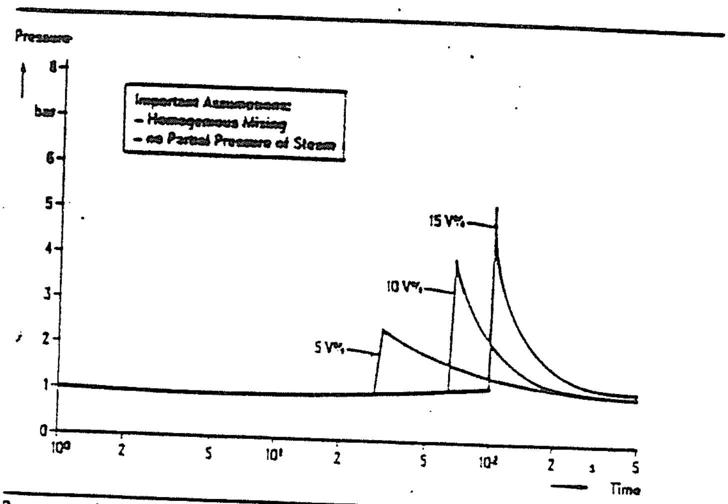


Figure 8: Parametric Evaluation of Pressure Peaks within the Containment During Violent H_2 – Combustion

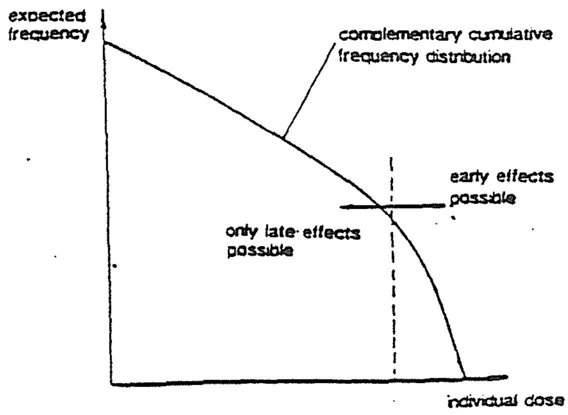


Figure 9: M1337 PRINCIPLE OF PROBABILISTIC SAFETY CRITERIA

16th JAIF ANNUAL CONFERENCE - Tokyo - March 23-25, 1983

ECONOMICS OF PLUTONIUM RECYCLE IN LIGHT WATER REACTORS

by Robert CAYRON
Chairman of the Board and Executive Director, BELGONUCLEAIRE

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ECONOMICS OF PLUTONIUM RECYCLE IN LIGHT WATER REACTORS

by Robert CAYRON
Chairman of the Board and Executive Director, BELGONUCLEAIRE

The problem of plutonium recycling in water reactors is linked basically to a choice, the aspects of which are technical, economic and ecological. This choice is that of reprocessing or non reprocessing of spent fuel. An economic analysis of plutonium recycling must therefore include that of spent fuel reprocessing.

Various arguments have been put forward to justify reprocessing, others to discard it. We shall recall them briefly.

Why reprocess ?

First, reprocessing is needed in order to recover the residual energy from spent fuel. By simply recycling uranium and plutonium, future uranium imports would be reduced by 30 to 40%. When breeders will become operational, a same amount of uranium will enable to recover 60 times more energy, which means a significant increase in nuclear fuel supply autonomy. This is an important argument in countries like Japan and those of Western Europe without significant national energy sources including uranium.

Secondly, reprocessing enables to separate high level radioactive material, i.e. plutonium and possibly other actinides, from short life fission products whose final storage will create less problems for the environment in the long term.

Why give up reprocessing ?

First, the reprocessing technique is a costly one. Within the last few years, the estimated figure of reprocessing cost has increased in such a proportion that the value of recovered fissile material is only a small part of the cost of the operation, although the present tendency is falsified by the existence of monopolies and a lasting regression in the prices of natural uranium.

Secondly, reprocessing is not without inconvenients as far as the environment is concerned. The exposure risks for the personnel exist, even if technological progress made in the protection against radiations have brought these risks down to a perfectly acceptable level. The risks of diverting plutonium, although generally not of military grade, are also greater in the case of reprocessing than in that of non reprocessing, which entails increased security measures compared with the storage of spent fuel.

Of all these elements for or against reprocessing, none is conclusive. Up to now a majority of countries having a significant nuclear program have shown a marked preference for reprocessing according to an industrial logic which may be summed up as follows.

The choice of the nuclear option was originally based on the possibility of obtaining, starting from a high potential energy source - uranium - a competitive energy capable of liberating users from the insecurity of energy supply for electricity. The full use of this potential depends on the setting up of a complete uranium cycle including breeders. Reprocessing is an essential step of that uranium cycle.

The non reprocessing option or "once through cycle" thus appears as a replacement option, in case of failure of the complete cycle, either for economic or for security reasons. In spite of its high cost, nothing allows us to state today that reprocessing is a more costly solution than the final disposal of spent fuel when taking due account of all environmental safety requirements.

Likewise, on the level of safety and non proliferation, we find that arguments which are in favor today of non reprocessing are reversed as time goes by, because of the presence of long life radio-elements in spent fuels and the easier "access" to plutonium due to the decreasing activity of fission products.

Finally, it is useful to recall that the non reprocessing option or the "once through cycle" originated in non proliferation political considerations, the validity of which was not confirmed by the extensive work carried out by INFCE on an international scale under President Carter.

Let us now come to the analysis of plutonium recycling in light water reactors, which can only be contemplated in the option of fuel reprocessing.

In order to simplify the analysis, we take it for granted that plutonium is best used in breeder reactors compared to its recycling in light water reactors. We also admit that the breeder and the accompanying plutonium cycle would reach their economic maturity in a future which would not exceed two decades.

This being accepted, there are three possible options :

- Adapt the rate of construction of new reprocessing installations according to the development of breeders, so as to have in due time enough but not too much plutonium for this new type of reactors.

- Assume the development in parallel, but separately, of reprocessing and breeder installations, so as to avoid accumulating spent fuel in new temporary storage installations. The plutonium ex reprocessing plants would be kept while waiting for it to be used in breeder reactors.

- In the same hypothesis of the development of reprocessing plants, burn the available plutonium (as it comes out progressively from reprocessing plants), instead of enriched uranium in light water reactors.

The first option is ideally the best but it ignores industrial realities. The development of new technologies takes a long time. This is true both for reprocessing and breeder reactors. Choosing the site, obtaining the consensus of the neighbouring populations, resolving the problems linked to the creation of new temporary storage capacity for spent fuel, are all constraining factors which are in favor of the progressive but continuous development of new reprocessing capacities in not too distant a future.

It must be added that in the existing reprocessing plants, the capacity reserved for foreign fuels is limited in time. This prompts countries having an important nuclear program to set up their own reprocessing capacity.

The second option relies on a temporary storage of the plutonium coming out of the reprocessing plants. This option has been and is still defended by those countries which recommend an intensive breeder construction program, but as we shall see later on, this storage must be limited in time.

The general setback of nuclear programs on the one hand and the impact of this setback on the prices and the availability of both uranium and enrichment services on the other hand, has delayed the progress of breeders whose economical interest has moved away in time. Plutonium storage should therefore be considered for long periods, up to decades. Such storage is expensive because of the precautions which have to be taken to minimise the risks of diversion and of the physical imperatives inherent to plutonium itself. Furthermore the plutonium produced in light water fuels, (fuels with a high burnup) contains a large proportion of a heavy isotope, plutonium 241, which transforms spontaneously into Am241, emitter of γ rays.

This transformation occurs quickly and renders the plutonium difficult to handle by human intervention after a time which varies according to the composition of the plutonium and the methods of work.

In the present mixed oxide fabrication plants, where human intervention remains important, a period of 3 years between the production of fresh plutonium and the end of fabrication constitutes a limit beyond which purification of plutonium prior to fabrication should take place.

The third option concerns plutonium recycling in light water reactors. Our analysis shall answer important questions raised by the utilities.

Question 1 : Is it possible to recycle plutonium on a large scale in a light water power plant without important modifications or adaptations ? Does it have an influence on the plant operation and especially on its availability ?

As regards the plant operation, if the proportion of plutonium assemblies in the core does not exceed 30%, the partial substitution of uranium fuel by plutonium fuel can be done without any special operational inconvenient provided certain precautions regarding the positioning of the fresh plutonium assemblies are taken.
As regards fuel handling and storage, there will be no need to modify considerably either the installations or the prevailing procedures because of plutonium recycling.

Question 2 : Does plutonium recycle present a greater risk for the operational staff or the public outside the power plant ?

Where a long experience is acquired, mainly in FRG, the utilities confirm that plutonium recycling has not modified significantly their security measures. It was not necessary to make any special arrangements for the supervision of work on site. Experience has shown that there was no increase in collective radiation doses. The quantities of gazeous and liquid effluents are more or less the same for uranium and plutonium fuel.

Question 3 : Does spent fuel reprocessing raise special problems ?

The reprocessing plants refuse at present to accept plutonium assemblies, as this operation reduces the availability of these plants which are already saturated by standard uranium fuel.

Plutonium assemblies can normally be reprocessed the same way as uranium assemblies. The difficulties inherent to reprocessing plutonium assemblies come on the one hand from the low solubility in nitric acid of pure or mechanically mixed PuO2, and on the other hand of the higher Pu/U ratio in the solution. As regards the first point, the reprocessing of plutonium manufactured by new processes of powder preparation should not raise particular problems any more. The second difficulty arises from the fact that the relative quantities of plutonium contained in plutonium assemblies after irradiatiohn in PWR's are about three times higher than those in uranium fuel; in the present plants this entails a reduced reprocessing capacity and therefore extra cost which could however be lessened by various means.

The plutonium produced after irradiation of mixed fuel (2nd generation plutonium) has an isotopic composition resulting in a lower performance in thermal reactors. On the other hand, it remains perfectly well adapted for use in breeder reactors. Plutonium originating from reprocessing of plutonium fuel is therefore to be reserved for breeder reactors : this entails a temporary storage of spent plutonium fuel.

Question 4 : What is the influence of plutonium reprocessing on the price of the kWh ? What is its general economic impact ?

To answer this question, it is assumed that in a more general context the fundamental option of spent fuel reprocessing has been chosen. In this context, the impact of reprocessing may be evaluated by comparing two scenarios.

1. - Enriched uranium fuel reprocessing
   - Mixed oxide fuel fabrication (natural uranium + plutonium)
   - Use of these mixed fuels as a substitute for new enriched uranium fuel
   - Reprocessing of mixed oxide fuel (possibly after long storage of irradiated assemblies) in time to introduce the recovered Pu in breeders.

2. - Enriched uranium fuel reprocessing
   - Storage of plutonium ex-reprocessing plants until it is introduced in breeders.

Evaluations have been made on the basis of the best available cost estimates. The cost supplement of plutonium fuel fabrication depends on the size and the use of existing plants, but it should be around US $ 500/kgHM for a 30 tHM/year plant. The cost supplement of reprocessing is rather a theoretical notion as there is no market : the capacity of the operational plants is saturated by uranium fuel and the conception of these plants is not meant for reprocessing plutonium fuel. On the basis of known information, the cost supplement of reprocessing plutonium can be estimated (in a plant conceived or adapted to reprocessing this type of fuel) to around US $ 300/kgHM (in their evaluations the Germans consider that there is no cost supplement). The cost of plutonium storage is composed of three main elements : storage itself, plutonium purification needed when it comes out of storage (because of the progressive production of Americium) and the plutonium degradation with time which decreases its value. Both the storage cost itself (minimum $ 1/gr Pu/year) and the purification cost which will be necessary after a few years ($ 6/gr Pu) are very high.

The relative economy between the two scenarios may be measured by two different ways :

- Either by giving to plutonium a zero value and by calculating the saving of expenses from one scenario to the other.

- Or by admitting that all additional expenses from one scenario compared to the other are to be borne by the plutonium surplus produced at the end of this scenario, if any.

If one assigns to natural uranium a range of price varying from \$ 22 to 35/lb U308 and to enriching services a range from \$ 120 to 150/kSWU, it can be shown that the economy resulting from plutonium recycling is of the order of \$ 2 to 6 M/year for a 1,000 MWe power plant, or 0.35 to 1.1 mill/kWh, provided a zero value is given to plutonium.

On the other hand, if all the additional expenses entailed by non recycling of plutonium are supported by the plutonium surplus produced in this scenario, the unit cost of this plutonium is, according to the various hypotheses, between \$ 30 and 160/gr, i.e. 6 to 30 times the present admitted market price of this plutonium. Longer is the storage of plutonium, higher is the cost penalty, and larger the degradation of plutonium 241. These results are illustrated in Table I.

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This quick survey shows that the choice of the reprocessing option should result, for economic reasons, in that of plutonium recycling in so far as the plutonium production in reprocessing plants exceeds for the time being the absorption capacity of fast breeders, as the storage of plutonium in view of its subsequent use is very expensive and not to be advised technologically.

On the basis of known investment programs both in the reprocessing and in the breeder fields, it can now be foreseen that important excess quantities of plutonium will be produced in 5 years from now, and this for a period of minimum 10 to 15 years. This 5 years delay is adequate to proceed with recycling tests on an industrial scale, so as to enable the industry to master all the technological aspects and the safety authorities to approve its systematic use.

TABLE I

ECONOMY RESULTING FROM A PU AUTO-RECYCLING (ONE RECYCLING)
FOR A 1,000 MWe REACTOR
(1982 $ actualized at 9%)

	High Hypothesis	Low Hypothesis
NAT U PRICE	$ 35/lb U308	$ 22/lb U308
SWU PRICE	$ 150/k SWU	$ 120/k SWU
COST SUPPL. U + Pu ASSEMBL. FABRIC.	$ 500/k METAL	$ 700/k METAL
COST SUPPL. U + Pu ASSEMBL. REPROC.	$ 300/k METAL	$ 300/k METAL
Pu STORAGE TIME	15 years	15 years
ECONOMY DUE TO Pu RECYCLING (Pu value = 0)	) $ 6.2 M/year) 1.1 mill/kWh	$ 3.1 M/year 0.55 mill/kWh
COST OF SURPLUS PLUTONIUM AVAILABLE AT END OF PERIOD IN CASE OF NON RECYCLING (actualized cost)	$ 160/gr	$ 81/gr
Pu STORAGE TIME	5 years	5 years
ECONOMY DUE TO Pu RECYCLING (Pu value = 0)	) $ 4.8 M/year) 0.85 mill/kWh	$ 1.9 M/year 0.34 mill/kWh
COST OF SURPLUS PLUTONIUM AVAILABLE BY NON RECYCLING	$ 75/gr	$ 30/gr

M A T U R I T Y O F T H E P W R

BY

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16th, JAIF ANNUAL CONFERENCE

Session 5

Nuclear Industry and LWR maturity

Tokyo, March 25th 1983

(Short note)

Nuclear power plants based on the Pressurized Water Reactor design had accumulated throughout the world 750 reactor-years of experience by the end of 1982 and represented by the most widely used technology :

- the end of 1982, 110 PWR units were in service, this number is expected to increase to around 230 in the mid 1990s.
- PWR units presently account for 47% of the 234 units in service worldwide and should represent 55% of the total units in operation in 1995.
- the PWR units already in service now have a capacity of 90 GW or roughly 50% of the total electrical output of all nuclear power plants combined and will have an approximate generating capacity of 210 GW in 1995.

Can it thus be concluded that the PWR system has reached industrial maturity ? The following cases, which are based on French operating experience, are designed to show how PWR characteristics compare with certain criteria which can be considered as indicative of a certain maturity.

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First of all, it should be noted that the world's PWR manufacturers converged simultaneously toward a rather large degree of uniformity in their choice concerning the main design options for the PWR system.

The following developments in the design of PWR are examples of this trend :

- the loop type reactor coolant system,
- the steam generators which are generally the recirculation type with a "U" shaped tube bundle in which dry and satured steam is generated,
- the controlled leakage seal type reactor coolant pumps,
- the use of cylindrical fuel rods arranged in a 17 x 17 square shaped assembly with reloadings at reactor shutdowns.

*

A trend toward greater uniformity in the efficiency and size of the main PWR components is also noticeable.

The parameters specific to the efficiency of PWR components are very similar from one country to another. The electrical capacity of each unit and the size of each PWR component have achieved an optimum technical and economic level of development which is close to the technological limits of the existing industrial capability.

*

Problems which were initially encountered in the design stage have progressively disappeared.

Two examples among others in France can be cited to demonstrate this trend:

The first example concerns the disappearance of the various types of attack (mechanical or chemical) on steam generator tubes, through appropriate operating procedures such as modification of water chemistry and cleaning of the tubesheet, and through modifications in design and improved manufacturing processes.

Out of a total of more than 200 000 tubes installed in 22 units in operation over a period ranging from one to eight years, 63 tubes have been plugged for a various number of reasons which gives a plugging coefficient of 2.5 $x10^{-4}$.

The second example is the highly satisfactory behavior of the fuel assemblies. Out of a total of 52 fuel cycles - either completed or near completion - the maxium level of activity detected in the reactor coolant is lower than 5 x 10^{-2} Ci/t which is only 2.5 % the maximum design value.

*

One of the consequences of this trend is a change in the orientation and contents of the R & D programs.

Prior to this change, R & D programs were aimed primarily at providing aid in solving the various problems encountered.

Today's R & D programs are more oriented toward refining component performance and reliability as well as improving plant operation and maintenance.

Examples of this new trend are :

- the qualification of a new advanced fuel assembly which provides improved performance,
- increased steam drying capacity,
- qualification of modifications which provide the reactor with increased load follow capacity.

*

The manufacture of the key components for PWR nuclear steam supply systems required considerable effort in the production plants in order to ensure the best possible design of production tools, establish design specifications for the various products, develop and improve manufacturing methods, standardize and classify design calculations and operating modes.

The expertise in manufacturing methods produced by these developments is reflected in such activities as welding, machining and non-destructive testing.

*

The fact that PWR technology has reached a certain degree of stability combined with France's considerable experience in this field enabled establishment of a set of French PWR design and construction rules (Règles de Conception et de Construction - RCC) which reflect the degree of expertise achieved as these rules are a direct result of the experience gained.

*

Production costs in France constitute still another criterion which show the maturity attained in PWR technology. Present economic conditions in France give a clear advantage as far as generating costs are concerned to nuclear power plants over fossil fueled plants for periods of plant operation of 2000 hours/year or more.

The estimated kWh generating costs on the basis of January 1982 economic conditions, and for plants put into commercial operation by 1992, were the following in France : 0.20 Francs for PWR units, 0.33 Francs for coal fired plants and 0.68 Francs for oil powered plants.

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The above described evolution of PWR design has had a number of consequences.

First of all, the stability acquired in the design and size of PWR components enabled manufacturers to standardize components and plants. What is involved in France,when we speak of standardization, is a whole series of plants of a large domestic program and not only a few units of one single site. This policy received the backing of EDF which had already applied the same method for France's fossil fueled plants. This policy was used in the manufacture of the PWR components, for example :

- two types of PWR 17 x 17 fuel assemblies which differ only by the active length and in the design of the nozzles,
- two types of steam generators and two recent models being developped,
- two reactor coolant pump models and a more recent one under development.

This standardization policy was also applied to nuclear steam supply systems and resulted in the following models :

- the 3-loop 900 MWe Model, 34 units of which are in service or under construction ; this standardized series was preceded by an initial series of seven units,
- two improved 3-loop 1000 MWe Models, which are currently offered,

- two 4-loop 1300 MWe Models (P4 and P'4) ; 18 units of this class are under construction or on option,
- the 4-loop 1500 MWe Model which is currently in the negotiating phase with EDF.

This policy of standardization plus the implementation of a large number of units made possible the development of extensive manufacturing, engineering and design capabilities and the tremendous industrial capacity required for such a program.

A scientific, technological and industrial potential of the highest quality was thus created. This potential enable corrective actions to be performed rapidly, even on a large scale, in the event of unexpected problems. The most noteworthy example combining rapid response to a problem with a high degree of efficiency is the problem involving underclad cracks in reactor vessels and steam generators. This problem was treated in 1979 and 1980 and has been completely solved. Another more recent example concerns the cracks detected in the RCC guide tube centering pins. Rapid on-site corrective action kept outage of the different units to a minimum.

*

Another result of the expertise acquired by France in PWR technology is the reduction in the completion times required for commissioning the units of France's 900 MWe units : whereas about 80 months were required for commissioning the first of these units (Fessenheim) this figure has dropped to around 60 months for the last units of this series.

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In the light of the analysis presented above, everyone is free to draw his own conclusion concerning the degree of maturity achieved by the PWR.

It should be noted, however, that if the decision initially taken by the French government, EDF and French industry to develop the PWR system has since proven to be the best choice this is because France's nuclear program was based in 1969 on a reactor type which had, at that time the greatest potential for ensuring full success of this program. This potential was subsequently developed to a much larger extent by the policy applied in France and which can be summarized by three key worlds : concentration, standardization and continuity :

- concentration of the industrial and engineering capabilities
- standardization of components and models
- continuity in the program.

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Final Draft
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MEASURES FOR A NUCLEAR POWER REVIVAL IN THE U.S.

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Nuclear Industry with Light-Water Reactors at Maturity

The use of nuclear energy in the United States is, at the same time, full of promise and faced with problems. Before I talk about what can be done to solve the problems, I would like to briefly review the promise of nuclear power in the U.S.

There are 78 nuclear stations with a total capacity of over 62,000 MW licensed to operate in America. This represents over 40% of the operating nuclear capacity of the world.

Nuclear power is the fastest growing segment of central power production in America. Another 64 units with a total capacity of about 70,000 MWe are under construction or on order. By 1990, nuclear is expected to account for one-quarter of the electricity generated in America, and the U.S. will continue to have over one-third of the world's nuclear capacity.

Despite its promise, the use of nuclear power in the U.S. is threatened by some serious problems. The nuclear regulatory process has become complex, time-consuming and uncertain. The American public is divided on the acceptability of nuclear power. These factors, coupled with some short-sighted utility regulation by state commissions, have driven up the cost of new plants.

There are four major things that need to be done to make nuclear power a viable choice in the U.S. for additional generating capacity in the 1990s.

- The nuclear regulatory process needs to be reformed so that construction schedules can be shortened and accurate cost predictions made
- Public acceptance of nuclear must be increased
- The economy needs to improve and the connection between an adequate supply of electricity and a healthy economy needs to be made clear, and
- The performance (that is, capacity factor) of operating nuclear units must continue to improve

Reform Nuclear Regulation

A stable regulatory process is critically important to a nuclear recovery in the U.S. Changes in licensing requirements in the last decade have greatly increased the cost of nuclear power, while over protective safety procedures are increasing rather than reducing public concern. Regulatory reform is necessary to turn both of these trends around.

An important first step is improved control of "backfitting" or the imposition of additional requirements on previously approved designs. A realistic quantitative safety goal for nuclear plants needs to be established. In addition, safety improvements must be limited to those with a safety value greater than cost.

The U.S. Nuclear Regulatory Commission (NRC) has adopted a trial policy that sets safety goals for nuclear plants. The policy sets limits on risks from radiation postulation to be released in reactor accidents and establishes a benefit-cost guideline for radiation exposure averted by safety modifications.. Although this policy is extremely conservative, it is a step in the right direction and should be a useful guideline for evaluating future backfitting requirements.

One-step licensing is another needed regulatory change. The NRC is expected to give final design approval to the first standardized NSSS later this year. Following rule-making, this could effectively provide one-step licensing, and minimize delays and uncertainties in construction and startup of new plants.

Both the U.S. Dept. of Energy (DOE) and the NRC recognize the need for licensing reform. Several changes in the licensing process are under consideration by the NRC. Separate reform legislation has been proposed by both the DOE and the NRC. The AIF believes that there is a fair chance that legislation will be passed within the next several years.

Meanwhile, there are some bright spots among the nuclear plants scheduled to begin operation in the U.S. this year. Construction of St. Lucie 2 in Florida is expected to be completed in under six years and Palo Verde 1 in Arizona is scheduled to start up a little over seven years after construction began. Although these construction times may not sound all that impressive to you, they are very impressive for the U.S. where average construction time now runs about 10 years. The challenge for the U.S. nuclear industry in the future is to make these impressive construction times the norm.

Increase Public Acceptance of Nuclear Power

A second challenge the industry faces is to increase public acceptance of nuclear power. A strong government policy favoring nuclear is critical to success in this area.

The passage of The Nuclear Waste Policy Act last year is an indication of what can be accomplished with government support. The Act charts a course toward permanent waste disposal. Sites for a test and evaluation facility are to be identified by the end of this year. Recommendations on the needs for monitored retrievable storage are to be made by mid-1985, and the first permanent geological repository site is to be selected by the President in March 1987.

The Act also provides for emergency, short-term storage of spent fuel at federal facilities if a utility exhausts its onsite storage space. The costs of carrying out the act are to be recovered through a one mill per kWh fee on electricity produced by nuclear power.

The nuclear industry in America has also greatly expanded its own publicity program to bring to the American public's attention nuclear energy's record of safety, reliabilit and economy.

Promote a Healthy Economy

A healthier economy is another important element in a nuclear revival. The combination of reduced inflation, lower long-term interest rates, and an upturn in demand for goods and services would have two significant beneficial effects on the future of nuclear power in the U.S.: it would strengthen the utilities financially and increase demand for electricity.

There are a number of encouraging signs. Inflation in the U.S. was down dramatically in 1982 and is expected to remain low in 1983. Long-term interest rates, though still higher than expected based on current rates of inflation, have been coming down. And a small but measurable increase in demand for electricity has been seen in recent months. Continuation of these trends through the rest of the decade is critical to a nuclear comeback in America.

Continue to Improve Nuclear Performance

Over the long-term, the nuclear industry holds part of its future in its own hands. It can help insure its own revival by establishing a record of excellence in all phases of its operation. The key industry group created for this purpose, the Institute of Nuclear Power Operations, is making progress on this front. While the industry's record of safety continues to be enviable, there is renewed emphasis in the U.S. on increasing availability and thus the economy of nuclear generation.

Small and medium size reactors have been suggested as an attractive alternative in this regard. Smaller units have been considered by the American nuclear industry.

and the consensus seems to be that the economical choice <u>in the U.S.</u> would be a unit with capacity of 900 MW or above. In developing countries where fossil fuels are less readily available than they are in the U.S., small reactors can be economical, and U.S. manufacturers can meet the need for smaller units by scaling back their established designs.

Orders for new generating capacity in the U.S. are expected to be low until the late eighties. By that time, the U.S. should have made substantial progress toward reforming nuclear regulation, increasing public acceptance of nuclear power and continuing to improve the performance of operating nuclear reactors. Progress in these areas as well as a healthy economy should bring back nuclear orders in the U.S.

SPEAKING TEXT FOR T. PRICE'S PANEL CONTRIBUTION TO JAIF DISCUSSION

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As I think everyone here already knows, uranium supplies present no immediate problem. World stocks - about half being in government hands - are equivalent to 7 years' consumption at present levels, or 5 years consumption allowing for growth. This is more than is needed either for fuel fabrication, or for covering supply interruptions. Japan's own needs are well covered until the mid or late 1990s. Nevertheless, I find that some people here are worried whether the situation might then suddenly deteriorate. What they fear is the possibility of a massive price increase, together with shortages which might weaken the basis for economic power from thermal - as opposed to breeder - reactors. What I shall be saying amounts to a statement of faith in the continuing availability of uranium, at prices which will probably not add substantially to the cost of producing power from thermal reactors, ~~for at least the~~ next 50 years.

In saying this I am of course making some assumptions. I am assuming that nuclear progress will be slower than we tended to assume some years ago, and that it will roughly follow the Low Growth case of the most recent IAEA 'Red Book' on uranium. But even that would take us from the present world level of around 180 Gigawatts to about 600 by the end of the century, and on to about 1400 Gigawatts by the year 2030. That is still a very massive growth - by more than seven times compared with now; so 'Low Growth' certainly does not mean 'No Growth'. However, as you will see from Figure 5 — which should be in your papers — by the year 2030 cumulative uranium consumption would still amount to only 5 million metric tonnes of uranium. We can be quite sure that the world's mineable resources are considerably greater than this. After all, one single ore-body (Olympic Dam in Australia) itself contains no less than one million tonnes of uranium. Nuclear power would have to develop very much faster for a resource crisis to occur as soon as the year 2030.

But there are other worries - about supply security; about managing the expansion of the mining industry so that it keeps in step with nuclear developments; and of course about the uranium price.

Supply security is concerned with events outside one's own control - political decisions in supplier countries, trades union actions, or even a disaster at a major mine. It can be dealt with by diversifying supply sources, and keeping adequate stocks. If you have four suppliers, even a two-year buffer stock provides protection for eight years against the failure of one of them.

Trade in nuclear materials was seriously affected a few years ago by the special problems of nuclear non-proliferation.

Fortunately this is ~~no longer a serious~~ problem - at least for countries with peaceable intentions - thanks to the willingness of producer governments to listen to representations by the industry.

Then there is the question of the mining and nuclear industries keeping their expansion in step. Again, I see no real problem. Lead times for both industries are about the same. So all we need to do is to ensure that exploration is maintained, so that there is always a pool of ore-bodies waiting to be exploited. This pool is already sufficient to last probably until the end of the century. Exploration activity is very cyclic. It depends on the market prices, as you can see by comparing Figures 1 and 2. But when there is a need for more exploration there are always exploration geologists available - they simply transfer their interests from other minerals.

This leaves the uranium price as the only remaining worry. This is difficult to talk about, except in very general terms, because it can be so much affected by temporary market forces. But it is possible to give some general indications.

First, there is the point that market stability - which both producers and consumers need - will be helped by long-term contracts which build up long-term relationships between consumers and producers. Secondly, need realistic forecasting. Overoptimistic targets which are never reached only lead to over-production and build-up of stocks, and so to large market instabilities when those stocks are sold off. In other words, both consumers and producers need to understand each other's positions, so that sensible future plans can be made by both sides. My own organisation, the Uranium Institute, tries to assist this process - with considerable help from our Japanese members.

The long-term trend of uranium prices of course depends on the cost of exploiting the available ore-bodies. That in turn depends on their grade, and on whether they are near the surface or need deep mining. Prices rise when the easier ore-bodies are used up. But on present expectations such price-rises seem unlikely to lead quickly to any dramatic increase in the cost of electricity from thermal reactors. As you will see from Figure 3, price increases of about 50 per cent in constant money terms are thought possible in the next 10 years. The Figure assumes that the selling price is 1.8 times the direct production cost, to cover overheads like maintenance, exploration and capital charges.

Figure 4 is another analysis, taken from the British Central Electricity Generating Board's submission to the current Sizewell enquiry. It predicts a fairly low price increase in the next ten years, and only a three-fold increase by 2030. This estimate is based on the IAEA Red Book data - which are of course themselves based on present knowledge. Further exploration could improve the position.

~~To conclude~~, I should like to draw two inferences from these diagrams. First, any price rise will progressively allow the more costly ore-bodies to be exploited. There will therefore be no sudden steep price increase, as some here seem to fear - simply because every ore-body is unique, each with its own individual cost structure, and therefore its own timing for exploitation.

Secondly, the foreseeable price increases are sufficiently modest for this ~~fact~~ to have some bearing on energy policy. In Europe natural uranium at present contributes only about 6 to 10 per cent to the cost of electricity. As the rest of the fuel costs – conversion, enrichment and fabrication – are not affected by the natural uranium price, this means that a 50 per cent price rise will have no more than a 3 to 5 per cent effect on the electricity price. Even a three-fold increase by the year 2030 would cause only a 12 to 20 per cent increase in the electricity price.

The interesting thing for energy policy is to set this alongside the probable cost difference between electricity from breeders and thermal reactors. There are still real uncertainties as to whether the ~~I don't yet know of anyone who is sufficiently optimistic to predict that the~~ breeder can get within 20 per cent of thermal reactor electricity costs. ~~Indeed, a difference of 20 per cent is often quoted~~.

Unless the fast reactor can do better, ~~than this~~, what these figures are telling us is that <u>either</u> there will be a prolonged period of economic competition between thermal and fast reactors, lasting for at least the next 50 years; <u>or</u> some extra cost ~~price~~ will have to be accepted, as the price of energy security ~~paid for energy security~~.

Despite this, what I have said should not be taken as seriously challenging the ~~I do not think that what I have said challenges the~~ case for developing the FBR, with its promise of independence for at least part of the energy scene. Such development work (for instance) could ~~could~~ lead to technological breakthroughs which might invalidate my analysis - though we must not forget that thermal reactors will also develop, so that the target is not necessarily standing still. But perhaps the main point is that whatever happens it will be physically impossible to deploy the breeder to take over the major part of the 1400 hundred gigawatts of nuclear electricity, which we shall have 50 years from now, in any short space of time. So perhaps it's just as well that we probably don't need to rush into the changeover.

~~As you will see,~~ Despite the far better fuel utilisation of the breeder, my conclusion is that the mature thermal reactor is likely to remain king for a very long time.