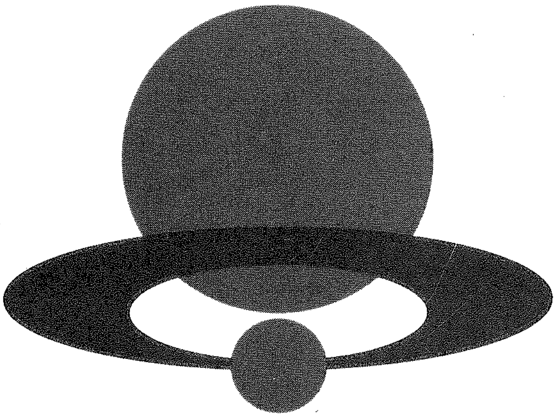
The 19th JAIF
Annual Conference
第19回原産年次大会
報文集



April 8 and 9, 1986

Japan Atomic Industrial Forum
日本原子力産業会議

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［特別講演］

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<セッション２>原子力産業の活力ある発展をめざして

<午餐会>

<セッション３>原子力開発と国際協力 ― ２１世紀への展望

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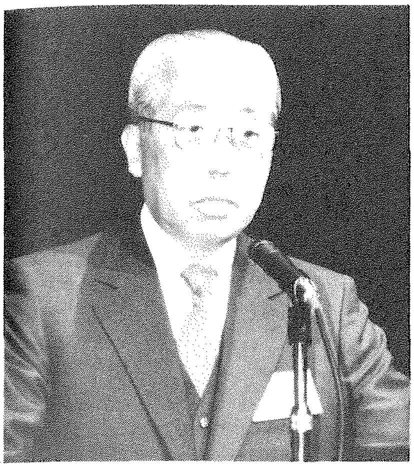
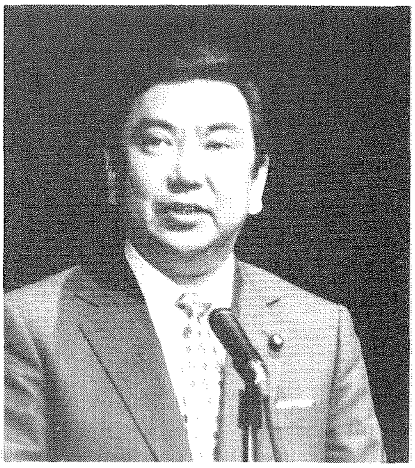


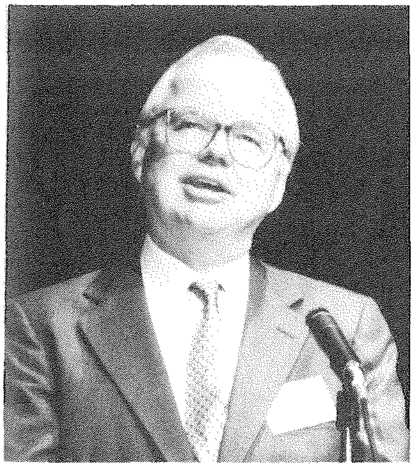
圓城寺大会準備委員長挨拶

有澤原産会長所信表明

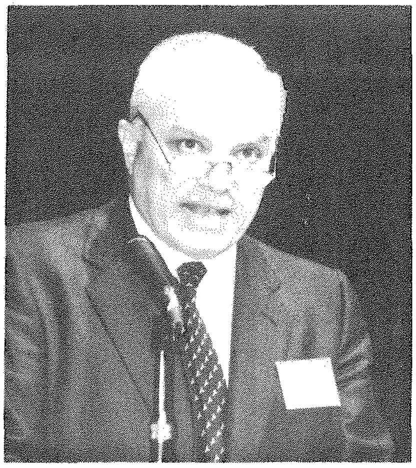


河野原子力委員長所感

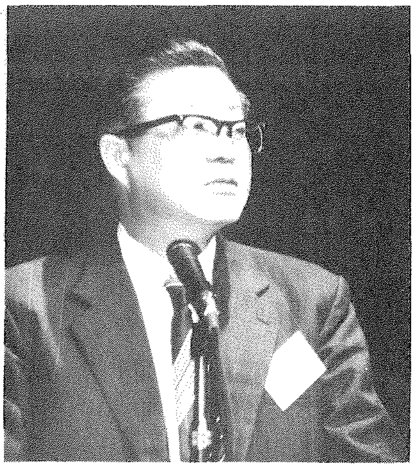
~~~~~開会セッションにおける特別講演~~~~~



ジョンソンMIT名誉理事長



コロンボ伊ENEA委員長



蒋中国原子力工業大臣
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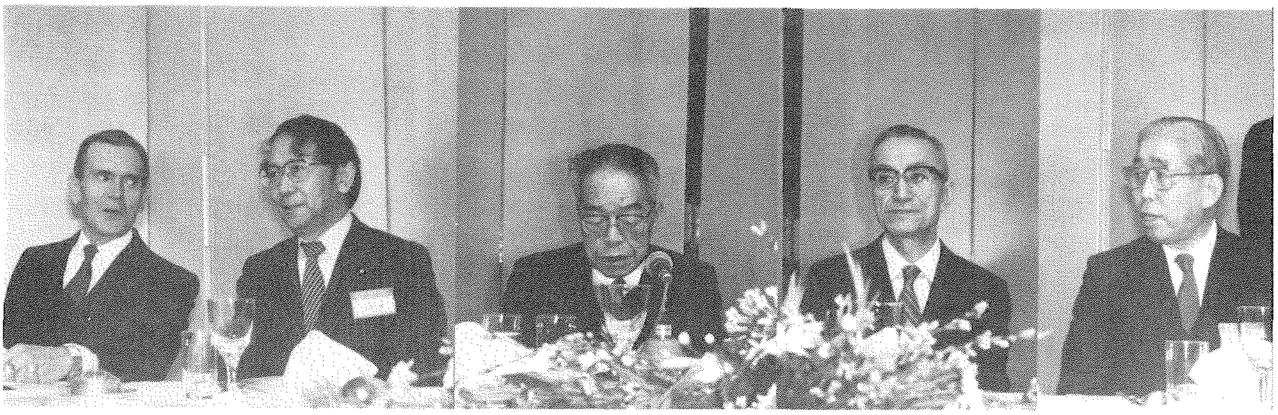
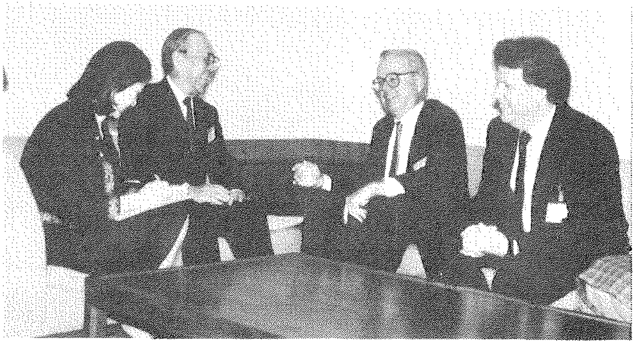


午餐会：左からペロル駐日仏大使，田原通商産業政務次官，有澤原産会長，石井松下政経塾専門講師，圓城寺原産副会長

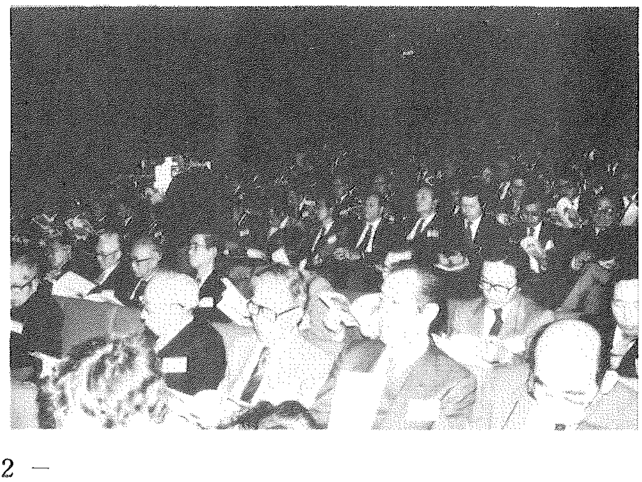
午餐会で原産創立30周年記念の祝辞を述べるシスラーAIF名誉理事(AIF初代会長)

なごやかな歓談風景のレセプション

セッション開始前に談笑する平岩東京電力会長とジョンソンMIT名誉理事長



海外参加者受付風景(下)，年次大会会場風景(右下)



第１９回原産年次大会

プログラム

昭和６１年４月８日（火）〜９日（水）
東京・ニッショーホール

基調テーマ ： ２１世紀に向かっての原子力産業の展開

	第 1 日 4月8日（火）	第 2 日 4月9日（水）
午前	開会セッション （9:30〜12:20） 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 ［特別講演］	セッション２ （9:30〜12:00） 「原子力産業の活力ある発展をめざして」 講 演
午後	セッション１ （13:30〜18:10） 「原子力：回顧と展望」 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 原子力映画上映 （13:00〜14:10） セッション３ （14:30〜18:00） 「原子力開発と国際協力 — ２１世紀への展望」 パネル討論
	レセプション （18:30〜20:00） 於 ホテル・オークラ	

4月8日（火）

開会セッション（9:30～12:20）

議長：	平岩外四	東京電力㈱会長
大会準備委員長挨拶	圓城寺次郎	(社)日本原子力産業会議副会長
原産会長所信表明	有澤廣巳	(社)日本原子力産業会議会長
原子力委員長所感	河野洋平	原子力委員会委員長、科学技術庁長官

議長：　池浦喜三郎　　㈱日本興業銀行会長

特別講演

「２１世紀の世界のエネルギー戦略」
H．ジョンソン　　マサチューセッツ工科大学（ＭＩＴ）名誉理事長

「エネルギーの選択と地球環境」
U．コロンボ　　国際連合「開発のための科学技術諮問委員会」委員長
イタリア原子力・代替ｴﾈﾙｷﾞｰ研究開発委員会(ENEA)委員長

「中国の原子力開発の基本方針」
蔣　心雄　　中国原子力工業大臣

セッション１　：　原子力 － 回顧と展望（13:30～18:10）

議長：　門田　正三　　電源開発㈱総裁

「原子力平和利用の回顧と展望」
S．エクルンド　　国際原子力機関（ＩＡＥＡ）名誉事務総長

「多角的展開を図るフランスの原子力産業」
G．ルノン　　フランス原子力庁（ＣＥＡ）長官

「日本の原子力開発の原点と展望」
向坊　隆　　原子力委員会委員長代理

議長：　藤崎　章　　住友原子力工業㈱社長

「原子力の現状と将来　－　燃料供給の観点から」
J．グレイ　　ｲﾝﾀｰﾅｼｮﾅﾙ･ｴﾅｼﾞｰ･ｱｿｼｴｰﾂ社（IEAL）会長

「燃料サイクルのバックエンド　－　技術、供給能力、経済性」
H．シェーパー　　ＯＥＣＤ原子力機関（ＮＥＡ）事務局長

＜休憩１０分＞

議長：　石川　六郎　　鹿島建設㈱会長

「世界の高速増殖炉開発：技術の実証から経済性の確立へ」
R．カール　　フランス電力庁（ＥＤＦ）副総裁

「原子力の多角的利用をめざして」
H.-H.ハウンシルド　　西ドイツ研究技術省（ＢＭＦＴ）次官

「原子力技術のポテンシャル」
M．レヴンソン　　ベクテルパワー社筆頭技師
元アメリカ原子力学会（ＡＮＳ）会長

レセプション　（18:30～20:00）

於ホテル・オークラ 本館１階「平安の間」

4月9日（水）

セッション２　：　原子力産業の活力ある発展をめざして（9:30～12:00）

議長：　飯田庸太郎　　　　三菱重工業㈱社長

「アメリカにおける原子力発電の将来」

　　C．ウォルスキー　　　米国原子力産業会議（ＡＩＦ）理事長

「原子力産業基盤強化への課題」

　　飯田　孝三　　　　　関西電力㈱副社長

　　　　　　　　　　　　(社)日本原子力産業会議産業基盤強化小委員会委員長

「総合電機産業と原子力」

　　三田　勝茂　　　　　㈱日立製作所社長

午　餐　会（12:20～14:15）

於ホテル・オークラ　本館１階「平安の間」

所感　　渡辺美智雄　　　　通商産業大臣

特別講演「日本の心・言葉・文字」

　　石井　　勲　　　　　松下政経塾専門講師

原子力映画上映（13:00～14:10）

於ニッショーホール

- よみがえる砂丘－柏崎刈羽原子力発電所建設記録総集編（東京電力）
- ２１世紀に向けて－原子燃料サイクルの確立（電気事業連合会）
- スーパーフェニックス－熱伝達（仏ノバトム社）

セッション３　：　原子力開発と国際協力－２１世紀への展望（14:30～18:00）

議長：　村田　　浩　　　　(社)日本原子力産業会議副会長

　　　　　　　　　　　　　(財)原子力安全研究協会理事長

＜基調講演＞

「原子力国際協力の意義 ― 回顧と展望」

　　大島　恵一　　　　　東京大学名誉教授

［パネル討論］

　　M．ジフェレロ　　　　国際原子力機関（ＩＡＥＡ）事務次長

　　J．ネグロポンテ　　　米国国務省海洋・国際環境・科学問題担当次官補

　　H．ウィリョスマルト　インドネシア技術評価応用庁次官

　　H．フレーヴァー　　　ヨーロッパ原子力学会理事

　　呂　得　賢　　　　　中国原子力工業省北京原子炉工学研究設計院院長

　　大島　恵一　　　　　東京大学名誉教授

19TH JAIF ANNUAL CONFERENCE

PROGRAM

TUESDAY, APRIL 8

9:30 am – 12:20 pm
OPENING SESSION

Chairman: Gaishi Hiraiwa — Chairman
The Tokyo Electric Power Co., Inc.

Remarks by Chairman of Program Committee
Jiro Enjoji — Vice Chairman
Japan Atomic Industrial Forum, Inc.

JAIF Chairman's Address
Hiromi Arisawa — Chairman
Japan Atomic Industrial Forum, Inc.

Remarks by Chairman of Atomic Energy Commission
Yohei Kono — Chairman, Atomic Energy Commission
Minister of State for Science and Technology

SPECIAL LECTURES

Chairman: Kisaburo Ikeura — Chairman
The Industrial Bank of Japan, Ltd.

"World Energy Strategies into the 21st Century"
Howard W. Johnson — Honorary Chairman of the Corporation
Massachusetts Institute of Technology

"Energy Options and the Global Environment"
Umberto Colombo — Chairman, Advisory Committee on Science
and Technology for Development, United Nations
Chairman, Italian Commission for
Nuclear and Alternative Energy Sources

"China's Basic Policy on Nuclear Power Development"
Jiang Xin-Xiong — Minister for Nuclear Industry, China

1:30 pm – 6:10 pm
SESSION 1: NUCLEAR ENERGY: REVIEW AND FUTURE PROSPECTS

Chairman: Masami Kadota — President
Electric Power Development Co., Ltd.

"Review and Future Prospects of Peaceful Uses of Atomic Energy"

Sigvard Eklund — Director General Emeritus
International Atomic Energy Agency

"The French Nuclear Industry Effort for Dynamic Evolution"
Gérard Renon — Administrateur Général
Commissariat à l'Energie Atomique
France

"Nuclear Energy Development in Japan – Original Spirits and Prospects"
Takashi Mukaibo — Deputy Chairman
Atomic Energy Commission

Chairman: Akira Fujisaki — President
Sumitomo Atomic Energy Industries, Ltd.

"Nuclear Energy: Present Situation and Future Prospects – From Nuclear Fuel Supply Perspective"
John E. Gray — Chairman
International Energy Associates, Ltd.
U.S.A.

"Back-end of the Nuclear Fuel Cycle – Technology, Supply Capacity and Economics"
Howard K. Shaper — Director General
OECD Nuclear Energy Agency

Chairman: Rokuro Ishikawa — Chairman
Kajima Corporation

"Development of Fast Breeder Reactor in the World"
Remy L. Carle — Director Général
Engineering and Construction Division
Electricité de France

"How to Use the Full Potential of Nuclear Energy"
Hans-Hilger Haunschild — State Secretary
Federal Ministry of Research and Technology
F.R. Germany

"Nuclear Energy Potential"
Milton Leverson — Executive Engineer, Bechtel Power Corporation
Ex-President, American Nuclear Soceity
U.S.A.

6:30 pm – 8:00 pm
JAIF CHAIRMAN'S RECEPTION

ROOM "HEIAN"
HOTEL OKURA
(Main Building, 1st Floor)

WEDNESDAY, APRIL 9

9:30 am – 12:00 noon

SESSION: TOWARDS DEVELOPMENT OF A VIABLE NUCLEAR INDUSTRY

Chairman: Yotaro Iida
President
Mitsubishi Heavy Industries, Ltd.

"Future of the Nuclear Power Option in the United States"
Carl Walske
President
Atomic Industrial Forum, Inc.
U.S.A.

"Ways to Strengthen the Nuclear Industry Foundation"
Kozo Iida
Executive Vice President
The Kansai Electric Power Co., Inc.

"Nuclear Power and the Electric Machinery Industry"
Katsushige Mita
President
Hitachi, Ltd.

12:20 pm – 2:15 pm

LUNCHEN

Room "HEIAN"
HOTEL OKURA
(Main Building, 1st Floor)

Remarks: Michio Watanabe
Minister for International Trade and Industry

Special Lecture: "Soul, Words and Letters of Japan"
Isao Ishii
Lecturer
The Matsushita School of Government and Management

1:00 pm – 2:10 pm

FILMS

CONFERENCE HALL

Most recent films dealing with nuclear energy development will be shown.

2:30 pm – 6:00 pm

SESSION 3: NUCLEAR ENERGY DEVELOPMENT AND INTERNATIONAL COOPERATION – PROSPECTS FOR THE 21ST CENTURY

Chairman: Hiroshi Murata
Chairman
International Nuclear Cooperation Center
Japan Atomic Industrial Forum, Inc.

Keynote Address:

"Significance of International Cooperation in Atomic Energy – Retrospect and Prospect"
Keichi Oshima
Professor Emeritus
University of Tokyo

Panelists:
Maurizio Ziffereo
Deputy Director General
International Atomic Energy Agency

Lu De-Xian	President Beijing Institute of Nuclear Engineering Ministry of Nuclear Industry China
Hans Frewer	Representative European Nuclear Society
Harsono Wirysounmarto	Deputy Chairman for Technology Development Agency for the Assessment and Application of Technology Indonesia
Keichi Oshima	Professor Emeritus University of Tokyo
John D. Negroponte	Assistant Secretary for Oceans and International Environmental and Scientific Affairs U.S. Department of State

第１９回原産年次大会準備委員会委員名簿

（敬称略・五十音順）

委員長	圓城寺 次郎	日本原子力産業会議副会長
委　員	青井 舒一	㈱東芝副社長
	秋元 勇巳	三菱金属㈱常務取締役
	阿部 栄夫	富士電機㈱社長
	安部 浩平	電気事業連合会専務理事
	飯田 孝三	関西電力㈱副社長
	石川 寛	日本原子力研究所副理事長
	石坂 誠一	野村総合研究所㈱顧問（昭和６１年3月１５日まで）
	石渡 鷹雄	動力炉・核燃料開発事業団副理事長
	大島 恵一	東京大学名誉教授
	川上 幸一	神奈川大学教授
	木村 繁	朝日新聞調査研究室主任研究員
	近藤 駿介	東京大学教授
	末次 克彦	日本経済新聞論説委員
	鈴木 武夫	前国立公衆衛生院長
	武田 修三郎	東海大学教授
	田中 好雄	日本原子力発電㈱副社長
	豊田 正敏	東京電力㈱副社長
	中根 秀彦	三菱重工業㈱常務取締役
	西 政隆	㈱日立製作所副社長
	東野 俊一	住友電気工業㈱顧問
	松田 泰	日本エネルギー経済研究所研究顧問
	三島 良績	東京大学名誉教授
	望月 嘉幸	㈱日本興業銀行常務取締役
	湯川 譲	日本原燃産業㈱副社長
オブザーバー		
	逢坂 国一	通商産業省資源エネルギー庁長官官房審議官
	鈴木 勝也	外務省国際連合局外務参事官
	松井 隆	科学技術庁長官官房審議官

開会セッション

大会準備委員長挨拶

（社）日本原子力産業会議副会長
圓城寺次郎

原産会長所信表明

（社）日本原子力産業会議会長
有澤　廣巳

原子力委員長所感

原子力委員会委員長、科学技術庁長官
河野　洋平

＜特別講演＞
２１世紀の世界のエネルギー戦略

マサチューセッツ工科大学（ＭＩＴ）名誉理事長
H．ジョンソン

エネルギーの選択と地球環境

国際連合「開発のための科学技術諮問委員会」委員長
イタリア原子力・代替エネルギー研究開発委員会（ＥＮＥＡ）委員長
U．コロンボ

中国の原子力開発の基本方針

中国原子力工業大臣
蔣　　心雄

OPENING SESSION

Remarks by Chairman of Program Committee
Jiro Enjoji
Vice Chairman
Japan Atomic Industrial Forum, Inc.

JAIF Chairman's Address
Hiromi Arisawa
Chairman
Japan Atomic Industrial Forum, Inc.

Remarks by Chairman of Atomic Energy Commission
Yohei Kono
Chairman, Atomic Energy Commission
Minister of State for Science and Technology

[SPECIAL LECTURES]

"World Energy Strategies into the 21st Century"
Howard W. Johnson
Honorary Chairman of the Corporation
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"Energy Options and the Global Environment"
Umberto Colombo
Chairman, Advisory Committee on Science and Technology for Development, United Nations
Chairman, Italian Commission for Nuclear and Alternative Energy Sources (ENEA)

"China's Basic Policy on Nuclear Power Development"
Xin-Xiong Jiang
Minister for Nuclear Industry
China

大会準備委員長挨拶

(社)日本原子力産業会議
副会長　圓城寺 次 郎

ご臨席の皆様、第１９回原産年次大会の開会に当たり、準備委員会を代表してご挨拶申し上げる機会を得ましたことは、私の大きな喜びであります。

本日は、国内からは河野洋平国務大臣・科学技術庁長官、向坊隆原子力委員会委員長代理、海外からはハワード・ジョンソン・マサチューセッツ工科大学名誉理事長、ウンベルト・コロンボ国際連合「開発のための科学技術諮問委員会」委員長、イタリア原子力・代替エネルギー研究開発委員会委員長、蒋心雄・中国原子力工業大臣、シグバルド・エクルンド国際原子力機関名誉事務総長、ジェラルド・ルノン・フランス原子力庁長官をはじめとして、国内外の高名な原子力関係者多数のご参加を得まして、本年次大会を盛大に開催する運びとなりましたことは大変光栄に存じます。

ここに改めて、本年次大会における議長、スピーカーをご快諾いただきました大会関係者各位に厚くお礼申し上げますとともに、本年次大会に参加された国内ならびにはるばる海外から参加された方々に深甚なる感謝の意を表する次第であります。

ご高承のとおり、本年はわが国が原子力開発に着手してから３０年になりますが、わが国の原子力発電は電力供給の四分の一を占め、かなりすぐれた運転実績を示すまでに成長しました。本年はさらに当日本原子力産業会議の創立３０周年という記念すべき年でもありますことから、それにふさわしく従来の年次大会を拡大する形で、本日と明日の２日間に第１９回原産年次大会を、その後引きつづき２日間を「軽水炉技術高度化に関する国際会議」を開催することとなりました。

私ども準備委員会は、本年次大会のプログラムの編成にあたり基調テーマを「２１世紀に向かっての原子力産業の展開」と定めました。

２１世紀を見通した場合、原子力発電は電力供給の主役になると考えられますが、そのためには在来電源に対する優位性の確保が不可欠であり、経済性、信頼性の一層の向上が必要であります。しかるに、現在原子力供給産業は、低成長経済により原子力発電所の発注をはじめとする原子力市場がスローウダウンしており、非常に厳しい状況にあります。しかし２１世紀において原子力時代というにふさわしい栄光をものにするためには、今後の情勢の中で原子力産業が先進性と柔軟性を発揮し、産業の活性化を図っていかねばなりません。

また、放射性廃棄物の処理処分を含めた燃料サイクル事業の確立・発展、軽水炉および高速増殖炉におけるプルトニウム利用体系の確立、さらには熱エネルギーとしての原子力利用の追求など、トータルシステムとしての原子力の真価を十分に発揮させていかねばなりません。

準備委員会は、以上のような現状認識の下に、現在のこの節目の時期に２１世紀における原子力の大きな役割に向けて原子力産業の展開を図っていくための当面の諸課題および長期展望について議論し、今後の原子力開発の促進に資することは非常に有意義であるとの考えから、本年次大会の基調テーマを「２１世紀に向かっての原子力産業の展開」と定めた次第であります。

本大会では、この開会セッションの後半に特別講演を行ったあと、３つのセッションを予定しております。ここではそれぞれの内容について簡単に紹介致します。

まず、特別講演では、「２１世紀の世界のエネルギー戦略」、「エネルギーの選択と地球環境」、「中国の原子力開発の基本方針」の３つの講演を予定しております。

現在、石油需給の大幅緩和により石油価格が急落し、原子力発電は化石燃料価格の低下の挑戦を受けて立つ形となっています。しかし、長期的には石油需給のタイト化が予想され、今後とも引きつづき原子力を中心に石炭、天然ガス、新エネルギー等の開発利用を進めていかねばなりません。

エネルギーの中核として期待されている原子力は人類の叡智によって生み出した技術エネルギーであり、長期的、地球的規模での資源問題や環境問題を考えましたと

き、技術エネルギーとしての原子力の役割と意義は一層重味を増してくると考えられます。

原子力平和利用は、先進工業国だけでなく、より多くの開発途上国もその恩恵を享受できるように、原子力平和利用が世界全体の発展に貢献し得る体系を構築していかねばなりません。とくにこれから原子力発電開発に本格的に取組んでいく国は、堅実で確固たる開発方針と国際協力のもとに着実に進めていくことが大切であると考えます。

特別講演では、以上のような趣旨に則って、３人の方々からそれぞれ講演していただくことに致しております。

セッション１の「原子力 － 回顧と展望」では、国際原子力機関、フランス、アメリカ、ＯＥＣＤ原子力機関、西ドイツそして日本の６か国の８人の代表から、原子力平和利用、原子力産業、国際協力、燃料サイクルのフロントエンドおよびバックエンド、高速増殖炉、原子炉熱利用開発、原子力技術開発等について過去および現在をレビューし、２１世紀の将来を展望していただくことに致しております。

セッション２は「原子力産業の活力ある発展をめざして」であります。このセッションは本大会の基調テーマとも一番密接に関連しているところであり、まず世界最大の原子力発電国であるアメリカから将来展望を伺います。その後、日本原子力産業会議の産業基盤強化小委員会で約１年半にわたって行われました検討結果の概要の発表と、日本の総合電機産業による原子力への取組み、原子力戦略といった講演をお願い致しております。

セッション３は「原子力開発と国際協力 － ２１世紀への展望」と題して６名の方々により討論が行われます。２１世紀を見通した場合、高速増殖炉、核融合、その他先進技術等の巨大プロジェクトの開発、さらに開発途上国における原子力発電の健全な発展にとって国際協力の役割はきわめて重要であります。本セッションでは、原子力開発当初のアトムズ・フォー・ピースの精神を思い起こしつつ、原子力平和利用は人類の幸福と繁栄にとって不可欠であるとの考えから、２１世紀に向けての原子力

国際協力のあるべき姿について、さまざまな見解の発表や提言があると思います。

以上をもちまして大会準備のご報告とご挨拶といたします。

第１９回年次大会

原産会長所信表明

日本原子力産業会議

会長　有澤　廣巳

日本原子力産業会議第１９回年次大会を開催するにあたり一言ご挨拶申し上げます。

昨年後半から石油価格の低落がつづき，それにともなって，原子力発電のコスト上の優位性が次第に失われてきています。石油価格は将来どうなるか，人々の注視の的となっています。かつて世界の原油生産の７０％を占めていたＯＰＥＣのシェアは，非ＯＰＥＣによる石油の増産と代替エネルギー開発によって，３０％にまで低下しています。一方，代替エネルギーの中核として大きな役割を担っています原子力発電は，世界でみますと２億５，０００万ｋＷに達し，石油換算で１日当たり６００万バレルに相当する石油代替エネルギーとしての役割を果たし得るまでに成長しました。この量は，昨年のＯＰＥＣ産油量の４０％に迫るものともいえます。

今後は，ＯＰＥＣのかつてのような石油市場の支配は再現しないと思いますが，石油価格が，第二次石油ショック以前の価格まで低落することは，目前はともかくも，長期にわたってつづくとは思えません。私は，石油価格は将来おそらく２０ドル前後で安定するものと思います。従って，わが国の昭和３０年代高度成長期に新増設された火力発電のリプレースの時期が迫っていますが，石油価格の低落を大きく見込んで，石油火力の割合を現在より大幅に増やすことは危険です。原油価格の動揺は，なおつづくとしても，われわれはそれに揺さぶられることなく，今後とも原子力発電の開発を進めていかなければならないと考えます。

さて，わが国の原子力発電は，昭和３１年に原子力委員会が設置され，本格的に原子力開発が始まって以来，今年でちょうど３０年目を迎えました。原子力発電はこの間，発電規模で２，５００万ｋＷに達し，すでに電力需要の４分の１を安定に供給するまでになりました。昨年度の設備利用率は，７６％とこれまでの最高値であり，昨年運転入りしました５基のうち１基は，４年１か月で完成し，５基の平均でも４年８か月程度の短い建設期間で完成しています。

こうしてみていきますと，わが国の軽水炉技術は，すでに成熟したと申せますが，一方において原子力は大きな節目を迎えており，解決しなければいけない課題も多いといえま

す。

その一つは，現在の軽水炉の稼働率に満足することなく，さらに高いレベルにもいけるよう高度化を進めることです。昨年も申しましたが，平均して３か月程度かかっている定期検査を２か月程度に，また運転継続期間を１５か月程度にすることによって，稼働率の当面の達成目標である８５％に近づけていくべきです。

また，軽水炉が成熟したということは，次の大きな飛躍の機会でもあります。あらゆる新技術がそうであるように，その初期段階は，未解決の問題を最悪のケースで考え，一歩一歩全体系をつくりあげるわけですが，その結果出来上がったものは，全体からみれば非経済的で，安全上もバランスのないものになっているケースもあります。つまり，そのバランスを検討しないで最初につくられたものを安易に継承し，積み重ねて，全体系をつくり上げることになりがちですが，この点を改めなければいけません。

これは安全性の確保を軽視するというのではなく，安全確保に役立っていない過重な附属設備を除去しようというものです。軽水炉についていえば，例えば緊急炉心冷却装置のデザインがオーバー・デザインではないのか，あるいは配管の瞬時における破断は実際にありえない，などの点が指摘されています。ある面だけ丈夫にしても，それは安全上意味がなく，むだな投資といえます。そのため，軽水炉で高い実績を積み上げてきた電力やメーカーが，これまでの経験や実証をもとに，その改善策を提案する時期に来ていると考えます。安全規制当局も厳正な安全審査などを行うだけにとどまらず，これまでの豊富な経験をもとに，どこまでなら安全なのか，その指針を示すことも必要だと思います。

今年は原産も３０周年を迎えたこともあり，年次大会にあわせて「軽水炉技術高度化に関する国際会議」を開催しますが，この国際会議を通して，世界中の原子炉が，より一層の高度化を達成できますよう，また高度化によって原子力の新たな発展へとつながっていきますよう念願いたします。

軽水炉の成熟によって，それで原子力の開発問題のすべてが終わるわけではありません。２０００年をめどに，世紀の大事業である核燃料サイクルを完成させていくことも当面の課題です。現在，下北で準備が進められています低レベル廃棄物貯蔵，ウラン濃縮および再処理の三施設を完成させてこそ，はじめて原子力の全行程を見渡すことができ，これにより原子力発電コストの最終的な評価も下すことができるわけです。

この燃料サイクル開発のための関連会社は，すべて設立されましたが，これからは，動力炉・核燃料開発事業団などで得られた技術あるいはノウハウのすべてを，これらの会社

に注入し，関係者と一体となって実用化規模での開発に立ち向っていくべきであります。実用化規模での技術の確立については，簡単に考えるわけにはまいりません。世界に通用する燃料サイクルを完成させることによって，永年の夢である「準国産エネルギー」を手に入れていかなければいけません。平和利用に徹したわが国が，民間の手により，燃料サイクルを完結させていくことの意味とその責任を，産業界は自覚すべきです。

新会社の設立とともに問題となっていました放射性廃棄物の廃棄事業についてですが，廃棄物の保管あるいは埋設による最終処分をするための事業者に対する規制法の整備を急ぐべきです。これにともない，社会通念上あるレベル以下なら特別の扱いを必要としない，放射性物質の「規制免除レベル」の設定も必要です。これにより，廃棄物を安全に保管・埋設する事業者の責任体制が一層明確にされるといえます。

高度化，燃料サイクルとともに，常に技術革新が進んでいる原子力の先端分野の研究開発も効率的に進めなければいけない課題の一つです。

これまでわが国は，国の研究開発機関を中心に，わが国の原子力技術ポテンシャルを世界的なレベルにまで高めてきましたが，これからは民間が事業化に向けて研究開発を自発的に進めていかなければ，世界に通用する技術は生まれてこないと考えます。すでに成熟した軽水炉，これから実用化をめざす燃料サイクル，さらに，「もんじゅ」につづくＦＢＲあるいはレーザー濃縮など将来の技術開発のそれぞれの段階に適した対応が必要です。どこまでを国でやるのか，どこからを民間がやっていくのか，３０年来の研究開発のあり方を見直す時期に来ているといえます。

低成長時代を迎え，限られた研究開発資金を，官民協力して効率的に生かしていくためには，動燃などの研究開発機関が，開放的に民間の力を導入していくことも必要です。一方，民間においても，ただひたすら国の発意をまつばかりでなく，自主構想のもとに自ら開発にとりくむ心構えをもってもらいたいと思います。特に軽水炉の改良などの成果を享受するのは，一義的には電力会社であることから，電力会社は，開発の方向づけと経費の面で一層大きな役割を果たすべきだと考えます。

原子力機器メーカーの市場規模についてですが，今後その伸び悩みが予想され，メーカーの活力の維持，向上に不安が投げかけられ深刻な問題となっています。このため，原産では昨年から「原子力産業基盤強化」の検討を進めてきました。その検討結果では，今後２０００年ごろまでの年間平均運開基数は２基程度で，それ以降徐々に上向くと予測しています。２０００年ごろまでは，原子力メーカーにとりましては，成長がなく厳しい状況

にあるといえますが，自らが新たな研究開発に取り組み，自発的に新たなシェアの拡大と，これまでの高い品質の維持を図っていかなければいけません。そうすることによって２１世紀に向かって原子力産業の活力ある展開を図っていくことができると考えます。２０世紀の遺産といえる原子力を，これまで申し上げました通り，さらに進めることによって，これを来世紀の人々につなげていくことが，わたし達関係者の使命と考えます。

わが国原子力産業界は，原子力を国内だけでなく，途上国の人々にも，この恩恵に浴せるよう努めていく考えです。また，そうしていくことがリーダー国の一つとしての役割と考えます。

国際協力を行っていくためには，原子力協定をはじめとする当事国の官・民あげてのコンセンスが必要なうえ，導入国との計画当初からの緊密な関係なしには，原子力という巨大技術を育てあげていくことはできません。さらに核不拡散などの国際的配慮も必要です。わたし達は，これらの障害を取り除いたうえで，導入国と緊密な話合いを通じて原子力が根づいていくよう協力を進めていく考えです。

最後になりましたが，「原産年次大会」および「軽水炉技術高度化に関する国際会議」のため，わざわざ国内外からご参加下さいました議長ならびに発表者の方々に厚くお礼申し上げます。各国を代表する皆様方，原子力関係のエキスパートの方々に参加いただき，この大会が年々国際色豊かに盛況になっていきますことは，主催者の一人として喜びに耐えません。また，原産設立当初からご指導をいただいています米国のウォーカー・シスラーさんはじめ，本日お集まりの方々皆様に対しまして，これまでの３０年間のお礼を申し上げるとともに，さらに，今後のご支援をお願いいたしまして，私の所信を終らせていただきます。

JAIF CHAIRMAN'S ADDRESS

Hiromi ARISAWA
Chairman
Japan Atomic Industrial Forum, Inc.
April 8, 1986

LADIES AND GENTLEMEN:
It is an honor to speak on the occasion of the 19th Annual Conference of the Japan Atomic Industrial Forum (JAIF).

Atomic Power generation's cost superiority is being gradually lost, due to the fall in oil prices since late last year. We are paying close attention to future oil prices. The OPEC share of the world's oil production, which once accounted for 70 percent, has been cut to 30 percent due to the rising oil production of non-OPEC countries and the development of alternative energy sources.

Atomic power generation, which now plays a major role as alternative energy, has amounted to 250 million kilowatts. This atomic power is equivalent to 6 million barrels of oil a day. This amount corresponds to almost 40 percent of last year's oil production by OPEC countries.

I believe that OPEC's domination of the oil market will not revive. Even if in the immediate future oil prices will drop below the level seen before the second oil crisis, I think such fall in oil prices will not continue. Oil prices will probably stabilize at around 20 dollars per barrel in the long run.

Facility replacement is imminent for steam generation plants that were built or enlarged during the high economic growth decade from 1955 - 1965. The replacement of oil steam generation facilities should be carried out on a smaller scale than is now done. It is dangerous for us to increase the ratio of steam operation greatly in anticipation of a sharp drop in oil prices.

Atomic power generation is expected to increase at almost the same rate as it does today. We think that the development of atomic power should be continued firmly, even if oil prices continue to fluctuate.

It is 30 years since Japan's atomic power development started with the establishment of the Atomic Energy Commission in 1956. The output generated by atomic power now amounts to 25-million kilowatts, enough to supply a quarter of Japan's total electric power demand. The capacity factor of atomic power reactors reached a record high of 76 percent last year.

One of the five nuclear power plants which went into operation last year was built in four years and one month. The period for constructing these five units averaged four years and eight months. In my opinion, the light-water reactor technique has already been matured in Japan. However, Japan's atomic power is now facing a turning point and many tasks have been left unresolved.

One of these tasks is to promote the advancement of technology to increase the operating rate of light-water reactors. As I mentioned last year, by reducing the average time of periodical inspections from three to two months, and by extending the operating period between periodic inspections to about 15 months, we can continue to strive for the immediate goal of an 85 percent availability factor. The fact that the technology of light-water reactors has been matured also offers a chance for a major leap forward.

As is often seen in the introduction of new techniques, in the early stages, efforts are made to construct the whole system around the safety-first principle. This has sometimes resulted in the completion of facilities which are non-economical in relation to the whole system. Moreover, some are clearly safer than others. In short, we are inclined to continue to use old facilities as long as they are safe, to accumulate old ones, and thus to form our whole system. I think we should change this approach.

I am not arguing that we be permitted to ignore safety entirely in the introduction of new techniques and facilities. What I want to do is to emphasize the need to remove excessive subordinate facilities, which really have no use in securing safety.

With light-water reactors, for instance, the possibility of over-designing the emergency core cooling system has been pointed out. It has also been noted that the instant rupture of piping cannot possibly occur. Too much effort to achieve absolute certainty in one area is meaningless from the viewpoint of overall safety, and is a fruitless investment as well.

We believe that the time has come for electric power companies and manufacturers to propose improvement measures, based on their actual past experience and on the results of various safety research and proof tests. It seems necessary that safety control authorities should not only conduct strict examinations, but should also develop safety principles that reflect their experiences, i.e. how safe is safe enough.

1986 marks the 30th anniversary of JAIF. An International Meeting on Further Improvement of LWR Technologies will be held to discuss ways to advance the technical aspects of light-water reactors. It is my hope that the conference will increase efforts to advance the state of atomic reactors in the world, which in turn will bring new atomic power development.

The completion of light-water reactors does not solve all of the problems about atomic power development. The immediate task is to continue our efforts to close the nuclear fuel cycle by the year 2000--the biggest project of this century. After the completion of the three Shimokita facilities (low-level radioactive waste storage, uranium enrichment, and reprocessing), we will be able to survey the whole cycle of atomic power and make a final judgement about the cost of atomic power generation.

All of the companies related to the development of the nuclear fuel cycle have already been established. The technology and knowhow obtained by the Power Reactor and Nuclear Fuel Development Corporation (PNC) and other organizations should be used by these companies to develop practical uses for nuclear energy. The estabilshment of practical techniques is not an easy task for Japan.

We may acquire the quasi-domestic energy we have long dreamed of, by closing the nuclear fuel cycle. Industry circles should wake up to the meaning and responsibility of closing the nuclear fuel cycle through the private sector--a task which does conform to Japan's policy of peaceful use of nuclear energy.

As for the disposal of radioactive waste, hasty arrangements should be made regarding the laws for regulating enterprises that undertake waste storage or disposal in geological formations. These laws are now under debate in the Diet. A level should be set, below which all radioactive materials shall be exempted from control. This will further clarify the extent of responsibility of the enterprises that store radioactive waste in geological formations.

Research and development in the high-tech aspects of nuclear power should be strongly promoted. Technical innovation is always appreciated in this field.

Japan has raised its atomic power technology to the international level because national research and development agencies have served as the driving force. Now, the private sector should voluntarily promote research and development for the production and commercialization of the technology that the whole world is calling for.

To this end, we should pace our actions according to individual stage of technical development; the light-water reactors that have already been matured; the nuclear fuel cycle whose commercialization is now pursued; fast breeder reactors which follow the prototype reactor Monju; and uranium enrichment by laser.

The time is now ripe for us to reconsider our 30-year-old ways of conducting research and development. Specifically, we must change the roles played by national agencies and by the private sector.

In this age of low economic growth, we must use our limited research and development funds as efficiently as possible. The Power Reactor and Nuclear Fuel Development Corporation, as well as other national research and development organizations, should openly make use of the role of private organizations. Meawhile, the private sector should not wait for the initiative of the Government, but be prepared for wrestling willingly with the development based on its own plan. Electric power companies should lead the way and bear most of the cost for R&D. After all, they are the ones who primarily enjoy the benefits of such R&D as the improvement of LWRs.

The extension of the market scale for atomic power device manufacturers is expected to be limited in the future. This poses a serious problem bacause makers feel now uneasy to maintain and increase their vitality. Th JAIF has been investigating ways to strengthen the atomic industry foundation since the year before last. The study forecasts that the number of new atomic power units to start operation each year will be two for the remainder of this century and will increase gradually after the year 2000.

In other words, the atomic power plant equipment makers find themselves surrounded by a very gloomy environment, which will last until around the end of this century. These makers should tackle new research and development projects to increase their market share and maintain the present high quality of their technology and goods. This will lead to the increased development of the nuclear power industry into the 21st century.

I think it is our mission to develop atomic power further. It should be a positive inheritance of the 20th century that we can proudly hand over to the people of the 21st century.

Japan's atomic energy industry intends to bring the benefits of atomic power not only to the Japanese people, but also to the people of developing countries. This, I think, is the role to be played by Japan as a leader in this field.

To achieve complete international cooperation, a consensus of opinion must be reached by all official and private organizations. Clear atomic power agreements should then be concluded among all concerned countries. Without close relations with the countries in which they intend to introduce atomic energy, we cannot develop the huge nuclear-related technology. Specifically, international consideration must be given to nuclear non-proliferation and other critical issues. We intend to remove these obstacls and promote cooperation with emerging countries so that nuclear energy may take root there, through close consultation.

Finally, I wish to extend my thanks to the Chairman and to all those who are to make presentations at the 19th JAIF Annual Conference and the International Meeting on Further Improvement of LWR Technologies.

As one of the promoters of this conference, I want to express my heart-felt pleasure at seeing its success. The conference is being attended by nuclear experts representing many countries.

I want to conclude my speech by expressing deep gratitude to Mr. Walker Cisler, who has played a leading role since the inauguration of the forum, and to all the other participants. I thank all of you for the help you have given over the last 30 years, and I appeal to you for further assistance.

河野原子力委員長所感

第１９回日本原子力産業会議年次大会
昭和６１年4月８日

本日、ここに内外から多数の原子力関係者をお迎えして、第１９回日本原子力産業会議年次大会がかくも盛大に開催される運びとなりましたことは、誠に慶賀にたえません。有澤会長、圓城寺大会準備委員長をはじめ、今大会の開催にご尽力された皆様方に心からお祝を申し上げますとともに、原子力分野で指導的な役割を果たされている参加者の皆様方に対し、心から歓迎の意を表する次第であります。

今大会においては、「２１世紀に向かっての原子力産業の展開」という基調テーマのもとで様々な討論が行われると伺っております。わが国が原子力開発利用に本格的に着手して以来３０年という一つの節目を迎え、今後の発展を目指す新しい時代を迎えている今日、今大会における討論は誠に時宜を得たものであり、実り多い成果があげられるであろうことを確信するところであります。

皆様御高承のとおり、昭和３１年の1月１日に原子力委員会が発足し、間をおかずに3月１日には日本原子力産業会議が発足いたしました。爾来、同会議は、原子力委員会の方針に沿って民間における原子力平和利用の推進に努め、これまで多くの業績を挙げてきたところであります。

今や原子力発電が、総発電電力量の２６パーセントを占め、稼働率も過去最高の７６パーセントという実績を示す等、原子力は国民生活及び経済活動に不可欠な存在となっております。

この３０年の間の道のりには多くの迂余曲折があり、様々な課題を克服して今日に至ったものであります。原子力発電がスタートした昭和３０年代当時は、低廉な石油の導入により、石炭から石油への転換が鋭意進められていた時代でありましたが、先見性をもって原子力発電の開発に積極的に取り組み、関係者一丸となって努力を傾注したのであります。このことが結果として後年における二度にわたる石油危機の克服にも寄与するところとなったのであります。

また、昭和４０年代後半から５０年代初期にかけては、様々な原子力発電機器の故障等が発生し、稼働率も

４０パーセントから５０パーセントに低迷する時代を経験いたしましたが、官民一体となってこれらの困難を一つずつ克服した結果、今日のわが国の原子力発電はエネルギー供給面及び技術水準の面ともに国際的にみても高く評価される水準に到達いたしました。

わが国の原子力開発の歩みをふり返る時、初代原子力委員として１６年間の長きにわたり原子力政策の舵とりに尽力され、また昭和４８年以来、日本原子力産業会議会長として原子力産業の発展に大きく貢献してこられた有澤会長の御功績に対し改めて心より敬意を表する次第であります。

わが国のエネルギー供給に主要な役割を果たしている石油需給の動向をみますと過去において石油価格の急騰による二度にわたる石油ショックにみまわれ、かつここ数ヵ月に石油価格が急激に下落していることからもわかるように石油市場は極めて不安定であり、その動向を長期にわたり的確に予測することは困難であります。今後の石油需給については種々の見方が存在しておりますが、エネルギー供給が国民生活に与える影響の大きさを考えるならば、短期的な石油情勢に左右されることなく、エネルギー供給の安定化を図るためには石油依存度

の引き下げが必要であり、代替エネルギーの中核たる原子力について開発利用を着実に進めていくことが肝要であります。

今後の原子力政策を進めるうえで特に重要と考えられる諸点につき基本的な考え方を申し述べたいと思います。

第一は、原子力発電技術の高度化であります。原子力発電は、今日、わが国の経済社会を支える不可欠なエネルギーとなっており、今後１０年の間には、石油、石炭等各種電源のなかで最大となり、主力電源としての地位を占めることが期待されております。　このような原子力発電に対する期待に応えてエネルギーの安定供給の役割を担っていくためには今日の優れた稼働実績に甘んずることなく、安全の確保を大前提として、より一層の経済性の向上を図っていく必要があります。昨今、化石エネルギー価格の低下により原子力発電と火力発電との間で経済性を競う状況が具体化しはじめており、原子力発電の経済性向上が大きな課題となっております。しかしながら、経済性追求がかりにも安全性、信頼性を損うようなものであってはならないことは言うまでもありません。経済性向上のための努力は、安全性、信頼性を含め

て、原子力発電の一層の技術進歩の上に立って進められるものでなければなりません。こうした技術の高度化を図っていくことが、原子力発電の長期的な展望を拓いていくうえで極めて重要であります。

第二は、核燃料サイクルの確立であります。

原子力発電を支える核燃料サイクルの確立は、わが国原子力政策の基本であります。現在、国内における核燃料サイクルの確立に向けて、青森県六ヶ所村において、商業用のウラン濃縮施設及び再処理施設、並びに低レベル放射性廃棄物の最終貯蔵施設の建設計画が進められていることは誠にに喜ばしいことであります。これら施設の立地に当たり、種々ご協力いただいている地元の方々に対し深く感謝申し上げるとともに、今後とも関係者の一層の努力を期待しているところであり、政府としては、これらの計画が円滑に進められるよう積極的に支援して参りたいと考えております。

特に、原子力発電体系を完成する上で、現下の最大の課題は、現在事業所内に安全に保管されている放射性廃棄物の処理処分対策の確立であります。このため、放射性廃棄物の廃棄の事業に関する規制を新たに設けることを内容とする原子炉等規制法の一部を改正する法律案を

今国会に提出したところであり、今国会での成立に全力を上げて取り組み、これにより、放射性廃棄物の処理処分に対する安全規制に万全を期す所存であります。

高レベル放射性廃棄物については、今回の法改正案では地層処分に至る前段階としての貯蔵が適切に実施できるように致しておりますが、その最終処分については、実際に行う時期は相当先になるにしても、その見通しを得ることが現在の原子力政策上の重要課題と認識しており、この観点から、深地層試験を行うなどにより、処分技術を確立するとともに、処分地選定のための調査の推進に最大の努力を傾注し、できる限り早い時期に処分地の見通しを得ていきたいと考えております。

第三は核分裂による究極の炉と言われる高速増殖炉の開発であります。

高速増殖炉の開発については、経済性、ウラン資源の状況等の観点から種々議論されておりますが、国内にウラン資源を持たないわが国においては、ウラン資源を軽水炉に比し、およそ６０倍にも活用しうる高速増殖炉において使用済燃料から回収される国内エネルギー資源とも言えるプルトニウムを積極的に利用していくことが極めて重要であり、軽水炉から高速増殖炉へ移行すること

を原子力開発の基本路線として推進しております。

今後、高速増殖炉を本格的に導入していくためには、経済性が重要なポイントであることは論を待ちません。従って、軽水炉に拮抗しうる経済性を達成していくという高い目標を掲げ、関係者一丸となって努力を傾注していくことが肝要であります。さらに、言いかえれば、開発に取組む基本的姿勢として、例えばウラン価格の上昇により経済的に優位な状況が出てくるのを待つといった受動的な考え方ではなくて、安全性、経済性を含め軽水炉利用に勝る技術体系として高速増殖炉を軸としたプルトニウム利用体系を確立していくことを目指すという考え方で臨むべきであるとの意見があり、傾聴に値すると考えております。

いずれにしても、高速増殖炉の開発については、既に、実証炉であるスーパーフェニックスを運転開始させているフランスに対して立ち遅れており、また、実用化には、長期間の研究開発努力と技術蓄積を必要としていることから、実証炉計画についても、積極的に取り組んでいく必要があります。

第四は先端的な研究開発であります。

従来より、わが国は自主開発を基本として原子力研究

開発を進めてきたところでありますが、本格的な原子力研究開発の着手が先進諸国より遅れたこともあり、先進諸国の技術体系をモデルとして、先進諸国に追いつくことを目指したいわば「キャッチアップ型」の研究開発の色彩が濃かったところであります。これまでの研究開発努力による技術の蓄積の結果、今やわが国の技術レベルは軽水炉技術などかなりの分野で世界の原子力先進国のレベルに遜色のないところまで到達していると認識しております。こうした技術蓄積を踏まえてわが国独自の独創的なアイデアを生み出すような体制を整備するとともに先駆的な研究開発に、より積極的に取り組んでいく時期が到来していると考えております。

先端的な研究開発として核融合研究開発を例にあげれば、大型超電導磁石を世界に先がけて完成した他、ＪＴ－６０開発の過程においてプラズマ中の不純物を除去するダイバーターを実用化するなどの世界のトップレベルの研究成果を上げております。今後、これらの分野のみならず、多くの分野において積極的に先端的な研究開発に取り組むことにより、わが国の原子力利用の幅を広げていくことが必要であります。また、これらの成果について他分野への波及効果についてもこれを向上させ

ていくことが重要と考えております。

第五に、国際的な視点に立った原子力開発利用についてであります。

わが国は、厳に平和利用に限り原子力開発利用を進めており、今後ともこの方針を堅持していくこととし、かかる観点から、全世界的な原子力平和利用の推進に大きく貢献していくことは、わが国の責務と考えております。

また、わが国が２１世紀に向けて、わが国経済の国際的地位にふさわしい役割を果たしていくためには、科学技術の面から国際社会の発展に貢献していくことが重要であります。

原子力技術は、世界の共通課題であるエネルギー問題の解決に役立ち得るという性格を有しております。わが国としては、今後とも原子力利用に係る新しい技術の開発を積極的に進め、国際的な原子力平和利用のためにそれを提供していく役割を果たしていくことが重要と考えております。特に高速増殖炉、核融合の如き２１世紀に向けて長期的かつ大型のプロジェクトについては、先進国との連携に努め、今後の研究開発推進の牽引車としての役割を分担していくべきものと認識しております。今

後、わが国が世界の原子力平和利用の有力な担い手としての責務を果たしていくためには、わが国が国際的に評価される先進的・独創的な計画を推進していくことが重要であり、このような努力により国際的な原子力研究のメッカの一つとなることを目指していくべきと考えております。

原子力委員会におきましては、以上申し述べた課題に対応し、今後の原子力開発利用の目指すべき方向と推進のための具体的指針を明らかにするため、昭和５７年に策定した現行の「原子力開発利用長期計画」の改定作業に今月から着手することを予定しており、現在その準備を進めているところであります。

最後に、本大会におきましては、多数ご参加の内外の有識者、専門家の方々の間で活発な意見の交換、忌憚のない提言がなされ、本大会が盛況のうちに成功を収められんことを祈念いたしまして私の所感を締め括らせていただきます。

World Energy Strategies into the 21st Century

Howard W. Johnson
Massachusetts Institute of Technology
19th JAIF Annual Conference
April 8, 1986

It is a pleasure and a privilege to speak before this distinguished Forum on the occasion of its 19th Annual Conference (1). I feel much at home here again as I visit old friends. Yet I am not far from this same atmosphere of joint concern and joint solution of technological, economic, and societal problems even on my home base at M.I.T.

My plan today is to review the world energy outlook from the perspective of the 21st century. It is a great temptation for any speaker with such a franchise to go directly to the 21st century not stopping at "go" and then staying there in his remarks. The 21st century is distant in time and place and those present then will tend to forget what we say now about their times. But we human beings must get from here to there and it would be inappropriate for me to omit some analysis regarding the present situation before I consider with you the issues for the future. I will argue that the past and present few months have created a situation that is, perhaps, a singular one in technology history that can be used to great advantage by the energy users of the world in dealing with the future and can be lost as a time of advantage if we delay.

I will propose that there is now a window of opportunity that creates a healthy time for action during an unexpected breathing space in the economic scene if we will but use the opportunities.

My plan today is to review the energy outlook and I will begin by summarizing the findings of an energy study by a company with which I have been associated as a director for many years. Then I will offer some observations about the likely effects of the recent declines in oil prices and take a brief look at the far future and its requirements. The company to which I refer is Conoco, the energy subsidiary of the Du Pont Company. The study is their 1985 World Supply and Demand Forecast.

I should point out that the study was completed before the recent decline in oil prices which began in late January, but we take the position that price variations over a period of two or three months do not change the outlook over the next ten or twenty years. Another way of putting this is to say that one cannot draw up long term plans on the basis of current headlines, but must look out over the smoke, dust, and confusion of current events to where one expects to be at some designated point in the future.

Looking beyond current events to the mid-1990s, we project tighter oil supplies and firmer and higher prices due to declining production in non-OPEC countries. I should point out that it has been <u>increased</u> production from non-OPEC sources that has undercut OPEC in recent years and the impact of this competition has been dramatic.

The OPEC members have an oil production capacity of 30 million barrels a day, approximately 1/3 of which is Saudi Arabia. Last year OPEC produced 17 million barrels a day, approximately 1-1/2 million barrels a day less than the year before. There were several reasons for this.

First, world oil demand was down about 600,000 barrels a day due primarily to continued substitution of natural gas, coal and nuclear power for residual fuel oil in boilers. The conclusion of the UK coal strike also contributed to the drop in demand for residual fuel oil. Economic growth was too sluggish to offset the substitution effects.

Secondly, non-OPEC production continued to grow -- rising by 500,000 barrels a day to 28 million barrels a day in 1985. This was largely the result of projects initiated years ago in the North Sea and many provinces around the world. Finally, stocks were drawn down by 100,000 barrels a day, compared with a build up of about 400,000 barrels a day in 1984.

For perspective, crude oil production from non-OPEC sources has more than doubled since the first wave of price increases that began in 1973. Just since 1979 the beginning of the second wave of sharply higher prices non-OPEC production has risen by 5 million barrels a day or 50 percent. Lower prices will reverse the trend of non-OPEC production, however, by discouraging investment in the exploration and development needed to replace dwindling reserves outside of the Middle East. A lower level of competition from non-OPEC producers presumably would restore some of the organization's power. However, assuming no major disruption in Middle East oil production, energy supplies will be ample to meet projected demand through the next decade.

Our study forecasts that non-communist world primary energy demand will grow from current levels of about 200 quadrillion BTU's to 240 quads by 1995 and 265 quads by the year 2000 -- an annual growth rate of less than 2 percent. This assumes economic growth of 3 percent a year worldwide.

Investments in energy efficiency driven by energy price increases in the past decade will restrain energy demand growth through the 1990s to 1 percent a year in the United States and Western Europe, 1-1/2 percent in Japan and 2 percent in other OECD nations. Demand growth in the less developed countries is forecast at 3-1/2 percent a year, due to more population growth and their energy intensive stages of economic development, particularly as heavy industries move from developed countries to those low cost regions. I project those same increase rates into the 21st century.

Another factor in demand trends is the near saturation of the market for energy consuming goods in the richer nations. There is a limit to the number of refrigerators, air conditioners, and television sets that can be fitted into the average home.

World oil demand growth is projected at 1 percent a year led by growth in the LDC's and constrained in the industrialized nations by sunk investments in energy efficient plant and equipment.

Natural gas use is expected to increase at a somewhat faster rate, 1-1/2 percent a year driven by large world reserves and excess near term capacity in the United States, Western Europe and Canada. However, most of this "gas bubble" is likely to be worked off over the next five years.

Coal consumption is forecast to grow at a rate of 2-1/2 percent a year through the 1980s and the 1990s. Environmental concerns, particularly regarding acid rain, may be a constraint on coal use in some regions, but this is a problem amenable to technological solutions. There are three avenues of technology leading to cleaner coal use. These are precombustion technology, which includes widely used systems for washing coal, and current research into chemical extraction of sulfur. Other processes focus on the removal of "pollutants" during combustion and these include limestone injection and fluidized bed systems. Post combustion technology include systems that remove pollutants between the boiler and the electrostatic precipitator by injecting lime and sulfur absorbing chemicals into the gas stream. Other post combustion systems, of course, include stack gas scrubbers.

There are no barriers to the clean burning of coal within existing environmental laws that cannot be overcome by current technology, and that applies to nations with very high environmental standards such as Japan. The next generation of technology is aimed at meeting higher standards at lower costs.

Most of the growth in coal use will come from the electric utility market, where steam coal remains an economically attractive option for new base load capacity, particularly in the United States.

The Pacific rim, led by Japan, will be a source of steady growth in steam coal demand, importing about 70 million tons by the mid 1990s, compared with only 20 million tons in 1981. Europe will import 110 million tons by the 1990s versus 64 million tons in 1981. Metallurgical coal use, primarily for steel production, will grow slowly due to more energy efficient plants.

U. S. coal exports to the Pacific rim have been adversely affected by competition from the growing Australian coal industry, but recent declines in the relative value of the American dollar should enhance the cost competitiveness of U.S. coal. Let me add, parenthetically, that increased purchases of U.S. coal might be one way to reduce Japan's trade surplus with the United States and ease Japanese American trade tensions. The United States, for its part, should lift the ban on the sale of Alaskan North Slope oil to Japan. There also may be future opportunities to reduce the trade imbalance and diversify Japan's sources of energy supply through increased shipments of liquefied natural gas from Alaska's North Slope.

Nuclear power is the fastest growing energy component in the forecast, rising at a rate of over 9 percent through this decade as new projects come on stream and then tapering off to a steady growth of about 3-1/2 percent a year throughout the decade of the 1990s and into the new century.

In the United States, nuclear power and electricity generation will increase at a rate of over 10 percent a year through the 1980s as the number of new plants that have long been under construction finally enter commercial service. However, after that, U.S. nuclear power generation is expected to level off and then decline during the 1990s. High construction costs, long lead times, uncertainty over future generation capacity needs, well organized opposition, and heavily publicized operating problems -- this is the sorry story of the nuclear power industry in the United States.

No new capacity has been ordered in the United States since 1978 and most plants ordered since 1974 have been cancelled. Japan, Western Europe and even the developing world, will be the source of new reactor orders in the future. I should add that one of the fears regarding nuclear energy in the United States concerns nuclear waste disposal. Yet liquid high level waste resulting from nuclear power generation can be made into a stable, immobile form of borosilicate glass -- eminently suitable for transportation and borrowing in deep geologically stable formations. As you well know, Japan is a leader in this technology. In the United States glassification is used for disposal of defense wastes, but it is not in commercial use to any significant extent. But it has some very appealing characteristics. For example, if all U.S. electricity were generated by nuclear power, and at the present time only 15 percent is, one person's annual share of the resulting waste in borosilicate form would be the size of a small button.

To round out the picture presented by our study, the beginning of the 21st century will see a reliance on several primary sources. Oil will still be the leadership position, accounting for 42 percent of the world energy demand as compared to about 50 percent currently. Natural gas will have 17 or 18 percent of the market at the beginning of the 21st century -- little change from its current position. Coal share will expand from 21 percent to 24 percent and nuclear power will almost double its share to 8 percent.

Into the 21st century, and into the longer reaches of time, we can already see the dim outlines of our energy uses. And I would stress that conservation and efficiency and better management will be in further demand and further required. But from the supply point of view in all likelihood we will surely see increased use of nuclear energy including further development of LWR technology as well as the development of new technologies, especially in those parts of the world that have dealt rationally with the problems of nuclear energy use. I hope that the U.S. will resume the track of rational development of this significant source of energy soon (2).

In the 21st century we will see greater use of coal, again assuming that the technical and environmental problems implicit in its present use can be resolved and surely they can be. We will see exploitation of new methods of oil recovery as various geophysical programs including deep sea drilling are exploited. We may see major advances in fusion energy, providing large scale physics and engineering problems can be resolved (3).

There are, in short, exciting developmental problems and there are important theoretical and basic research problems still not clearly defined but that will require our best efforts and our brightest people. It goes almost without saying that some of the most interesting opportunities lie in the development of new technologies for the conversion of energy in transportation, communication, and in air space conditioning. For Japan, the major industrialized country which continues to be most dependent on the import of primary energy sources, the opportunities are especially appealing.

But here lie the windows for the future. It is important, as national economies enjoy rapidly falling prices and likely lower plateaus of oil prices due to the present disarray of OPEC, that these windows are not shut. The old habits of profligacy and of waste must not return. Largely motivated by security and price, every industrialized country has made progress in conservation, none with a better record than Japan. That continued discipline of conservation must have a national, corporate and household commitment.

On an international scale, the test for now and for the next twenty years is whether we can press forward in research and development in research areas against the backdrop of a short-term siren attraction of cheaper oil prices. If we can, it will require, in my judgment, mixed organizational structures and solutions. Some projects can be pressed within individual countries and by individual companies, universities, industries and by associations like your own distinguished organization. Some projects, however, will be best pressed by new international organizations in international corporations. The research universities of the United States and Japan should surely see larger opportunities for collaboration and the science academies should play a much larger part. There is a good case for large scale collaboration where sizable funding is needed in fusion developments where the future outline is not yet clear. We have seen a recent good example in the Japan, U.S. and E.C. agreement for cooperation relating to three large Tokomac devices signed earlier this year, and I hope that these next years will include opportunities for research cooperation with Japan, the E.C., the U.S., and also the U.S.S.R. One thing is certain; each of these developmental and research areas, even though they operate in traditional arenas, will be dominated by high technology implications.

The commodity of energy supply, like the commodity of food supply, should be seen as an international problem that exposes our interdependencies and demands our joint efforts. There are good scientific reasons for such collaboration. No one nation can have the full scientific talent to deal with the science involved. There are good practical and economic reasons as well. No one nation can afford the full range of initiatives that should be pursued.

To further these great goals we have been given a window of opportunity. Your country, the great country of Japan, can play a special role. I would hazard the observation that if you are to play your full role, you will need to be even more forthcoming than you have been in the past. Thus, these new windows give us all a place on the team that can, I have no doubt, solve the set of complex energy issues before us. By the end of the 21st century, barring disaster, we should have developed sustainable supplies of energy along with a continuing collective commitment to the environment.

But the danger of the present time, if I may return to it, is clear also. This will take place as prelude to the future and it is the classic time of crisis -- a period of both opportunity and danger. If oil prices stay at recent low levels for a sustained period of time, there will obviously be some effect on oil supply and demand at some point. Also, the price of oil may have a bearing on the outlook for other forms of energy

For example, although coal prices are generally considered to be most influenced by the cost of production, interfuel competition is also an important consideration. Coal must be priced several dollars below oil on an energy equivalent basis because it is more difficult to handle and to burn. Natural gas must be competitively priced with oil and coal because all three share utility, industrial and commercial markets. And, of course, nuclear power is in competition with coal. The big strength of oil is that it is imbedded in industrialized societies in a variety of uses, most importantly in the transportation sector. For other energy forms to displace it in specific applications, they must offer substantial economic advantages in order to justify the cost of fuel switching. So the price of oil is a consideration, not only in the obvious relationship between oil supply and demand, but in the relationship between all energy forms. It is generally true that the higher the price of oil, the better the prospects for other fuels. And it is also generally true that the lower the price of oil the less bright the prospects for other fuels.

All of these factors are clearly understood by OPEC and most especially by Saudi Arabia -- the key player in the oil price picture. This is a nation with huge proved reserves of oil recoverable at probably around $1.50 a barrel and the ability to increase productions substantially at low cost using conventional technology. It is therefore in Saudi Arabia's best interests and perhaps within its capability to maintain the status of oil as a major energy source for many decades to come. Saudi Arabia's planners are well aware that there is a trigger price for oil which, when reached, sets off a range of responses -- investments in energy conservation, in nuclear power programs, in synthetic fuels, in renewable energy and perhaps, ultimately, in new technology which might make oil obsolete as an energy source. This, of course, would substantially reduce the value of Saudi Arabia's primary asset -- its oil in the ground.

Saudi Arabia has increased its production in recent months from 2.2 million barrels a day to about 4.5 million barrels a day in order to re-establish oil as the energy source of choice by bringing the price down. Another reason for its increased production is that Saudi Arabia grew tired of single-handedly trying to balance world supply and demand by reducing production again and again. The Saudis saw export revenues decline from a peak of $110 billion in 1981 to $33 billion in 1985. Where prices will settle depends to a large extent on what Saudi Arabia wants in terms of share of production; as one of the lowest cost producers it has considerable capacity to increase its market share by lowering prices.

The optimum condition for the oil exporting countries would be for prices to stabilize at a level high enough to meet their financial requirements but not high enough to encourage further investment in conservation, fuel switching, high cost production in non-OPEC countries, and further nuclear development programs.

Even at prices that prevailed before the decline in the first quarter of this year from the mid-$20's to around $15 a barrel on the spot market, synthetic fuels such as shale oil and liquids from coal had already been pushed out of the picture. Many of the smaller oil fields that have been economically marginal for development are also out of the picture.

Exploration is being reduced worldwide. Drilling in the United States has declined by more than 50 percent from the high point in 1981 and it is still falling. And yet another factor is that much of the non-OPEC production that was brought onstream in response to earlier high prices would have gone into decline in the 1990s even without the recent price slump.

On the demand side a very important consideration is the relative value of the U.S. dollar. In recent years, the dollar has been strong in relation to the currencies of Europe and Japan and this has largely offset the effects of lower dollar denominated crude oil prices. In local currencies, oil prices have remained high. But this year the dollar has weakened -- particularly against the yen and the mark; combined with lower dollar denominated crude oil prices, this is likely to have a stimulating affect on economic activity and energy demand. It is also likely to improve the competitive position of American industries in domestic and export markets, reducing the trade tension between the United States and Japan and diminishing the pressure in the U.S. Congress for protectionest legislation.

From the technological perspective, lower oil prices will effect the direction of research and development. Efforts will focus on methods to explore for and produce oil at the lower prices, and more expensive approaches will be laid aside until prices rise. Deep sea petroleum development may be delayed, although research is likely to continue on technology to replace the very expensive steel and concrete structures built from the seabed up that are the traditional means of offshore petroleum production. Now we are seeing new designs such as floating structures of various sizes and shapes and designs that enclose production facilities on the seabed.

High cost enhanced recovery projects to get more of the oil out of the ground will also be delayed, but research will be continued on the most promising cost effective methods of using thermal processes and injecting carbon dioxide in chemicals.

So far, the main effect of lower oil prices has been on oil itself -- principally in exploration and development.

Even at oil prices as low as $15 a barrel, there would be little effect on coal demand for many years. Except for a relatively small number of coastal, coal fired, coal power plants -- for example, in Northwest Europe and Japan -- utilities would not substitute significant quantities of oil for a coal based electricity generation at $15 a barrel. Coal plants substantially under construction would be economic to complete. In coal rich regions such as the United States, Canada, Australia, a few LDC's and parts of Europe, even completely new coal plants, might be economic at $15 a barrel for oil.

Nuclear power generation will remain competitive with oil at $15 a barrel based on operating costs. Perhaps in some cases nuclear plants would be competitive at lower levels, but you in Japan are in a better position to make that judgment.

So even with oil prices down to a level of $15 there would be little change in the outlook for other fuels. At levels below $15, however, oil could take a bigger share of the market at the expense of coal and possibly nuclear. The effect on oil supply would not be significant at first, even at prices below $15, because of the long lead times in petroleum projects. For example, funds committed ten years ago may now only be showing results in oil production. Thus in 1986 -- with low oil prices -- North Sea production is continuing to increase slightly as a result of projects started years ago. After an investment has been made -- has become a "sunk" cost -- the factor determining continued production is operating costs. At uneconomic price levels new investments are not undertaken so there is a future impact on output, but as long as prices remain above production costs, there is little impact on current output.

Cash operating costs vary widely in the oil business from region to region and even within the same region. Factors include geography, climate, depth and other geologic conditions, economies of scale and proximity to existing pipelines among other logistics. Thus, in the North Sea, cash operating costs range from $3 to $8 a barrel. In Africa the range is $1.50 to $5 a barrel. In Mexico, costs may range from $2 to $7. Conventional U.S. production costs range from $2 to $12 while enhanced recovery would be much higher. It is likely that the present level of world oil demand could be met for a short time with supplies that have outer pocket costs of $5 to $8 a barrel. However, prices would not remain at this level. Production rates would deteriorate and this, coupled with invigorated demand, would sharply raise the price of the last barrel supplied, bringing us back, probably, to a price in the range of $25.

The Conoco study emphasizes that the 1990s could be the crucial period in the world energy outlook and could set the pattern for the 21st century. Trends in the United States underscore this prognosis. For example, Alaskan production will decline as new output will not be sufficient to offset decline at the huge Prudhoe Bay fields. Increased production from the Gulf of Mexico and offshore California will not be sufficient to offset declines in the lower 48 states. In fact, U.S. oil output is expected to decline from about 11 million barrels a day to 9-1/2 million over the next fifteen years. At the same time, U.S. oil demand is forecast to rise about half a percent a year to 17 million barrels a day. This means U.S. oil imports will increase to 7-1/2 million barrels a day by the end of the next decade compared with 4-1/2 million barrels last year. This will create additional demand in world markets at a time when North Sea and most other non-OPEC production will also be in decline. These worldwide supply and demand trends may well put OPEC back in the driver's seat in the next decade. Certainly they suggest that the Middle East, which holds most of this planet's remaining oil reserves, will resume its importance as a supplier of oil to the world.

It is worth noting that the two energy crises that have occurred since the early 1970s, and which wrenched the economies of all oil importing countries, did not take place as a result of geologic shortage of oil; they both resulted from military actions -- first, the Arab Israeli war and then the revolution in Iran. Conditions for a similar disruption still exist; Arab Israeli hostility is unabated, and the Middle East is split by religious factionalism among the Islamic states themselves.

In conclusion it seems to me that all of the reasons why Japan and the other members of the OECD embarked on programs of energy diversification -- nuclear power, coal and natural gas as well as oil -- are as valid now as they have ever been and they will be into the future. Short-term, the outlook is for continued volatility, but long-term, beyond the smoke, dust and confusion created by present oil prices, another energy crisis is a possibility in the next decade and certainly beyond. The current period of surplus should be viewed largely as a reprieve and a period in which we can prepare together for the future. Let us not miss this opportunity as we see the 21st century looming ahead.

FOOTNOTES

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2. Richard K. Lester, "Rethinking Nuclear Power",. Scientific American, Vol. 254, No. 3, March 1986, p. 33 ff.

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JAPAN ATOMIC INDUSTRIAL FORUM

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"ENERGY OPTIONS AND THE GLOBAL ENVIRONMENT"

by

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1. ENERGY AND THE EVOLUTION OF INDUSTRIAL SOCIETY

It is quite timely for this meeting to focus attention on the long-term prospects for nuclear energy, and on the role that nuclear power - as one of several energy sources available to man - will have in the 21st Century.

As our industrialised society has progressed, its calls upon the energy system have changed in quantity and quality. I want to start therefore with a brief historical sketch of these developments to illustrate the importance of energy sources for both the prosperity and well-being of mankind.

Prior to the industrial revolution, the main energy sources were human and animal labour and the burning of wood. Given modest standards of living and small populations, energy needs were relatively low, and a society largely based on agriculture and handicraft activities could satisfy them from these sources.

With the industrial revolution, triggered essentially by James Watt's invention of the steam engine, it became necessary to make recourse to higher density and more abundant energy sources. Coal was then the obvious and most convenient solution, and its exploitation gave rise to the development of the industrial society of the 19th Century, and to a new process of urbanisation centred on coal-bearing regions: in the United Kingdom, continental Europe, the Eastern United States.

But coal possessed certain inherent limitations as an energy carrier. It was dirty, difficult to extract, costly to transport, and not very convenient for uses of high potential demand, such as road transport.

When oil was discovered in large amounts in America, Europe and Asia, a new energy source became available that was far more convenient and versatile than coal. Extreme ease of storage, low cost of transport, wide range of applications at all dimensions of final utilisation - from large centralised plants to small applications in industry, transport and domestic uses - are all elements that explain why oil replaced coal to become the main energy source of the 20th Century, spurring the emergence of a modern industrial society able to sustain socioeconomic development at unprecedented rates.

Oil's ease of transport has put an end to the geographical constraint of linking industrial centres to locally produced energy. In fact, industrialisation in an oil-dominated society has taken place typically in areas either central to consumer markets or along seaboards and therefore convenient for the transport of oil and oil products, as well as of other raw materials and industrial goods.

Without oil, the development of a modern society based on private transport systems and autonomous energy use would have been improbable, if not impossible. The modern chemical industry, capable of producing agrochemicals, plastics, solvents, synthetic rubber and fibres and a whole spectrum of specialty products, is due to the extensive application of oil. There are many other examples showing how easy was the penetration of oil, even under circumstances that on heat value calculations alone should still have favoured coal. The fact is that oil had a premium value, and this was the reason for its increased demand.

Then gigantic oil fields were discovered in the Middle East, South America, North Africa. This led our society into a phase of abundant and easily available oil at extremely low cost. The share of oil in the global energy market approached 50%, and oil became the hegemonic source, much as coal had been in the late 19th and early 20th Centuries. The exploration, production, transport and distribution of oil was all but left in the hands of the oil industry, more especially in those of the major companies which as early as 1928 had formed a powerful cartel, soon nicknamed the 'Seven Sisters'.

Many attempts were made to counter this cartel, by both producing countries and market outsiders. Favoured by the process of decolonisation then in full spate, in 1960 a dozen or so oil exporting developing countries came together in the OPEC cartel, in an attempt to appropriate a more substantial portion of oil revenues and hopefully to assume a role in the determination of prices.

But it was only in 1973, on the occasion of the Yom Kippur War between Israel and Egypt, that OPEC was able to impose its will on the oil market, trebling international oil prices. The repercussions of what is known as the first oil crisis are well known to all: inflation, economic stagnation, a widespread increase in unemployment, disequilibrium in balances of payments of consumer countries, increased indebtedness of less developed oil importing countries, constriction in world trade.

The sudden increase in the oil price generated by OPEC in 1973-74 convinced consumer countries of the need to give new impetus to action leading to the substitution of oil with other energy sources, as well as to the conservation of energy by the adoption of suitable technologies.

In the years immediately following this first oil crisis, there was a diffused belief that oil demand was virtually inelastic versus price; that is, that oil - in some ways like a drug - has to be available in the amount needed for a given economic activity, whatever its cost. The economies of the industrialised consumer countries gradually began to recover from the first crisis (the main victims of which were essentially the oil importing LDCs), and a situation developed whereby the interests of the oil producing countries and those of the big oil companies within consumer countries started to appear convergent.

In 1978 the explosion of the Khomeini revolution in Iran, followed in 1979 by the conflict between Iran and Iraq, set off a new steep rise in the price of oil. Consumer countries were shaken by panic. The fear that there might be a physical shortage of oil, and that this could paralyse the entire industrialised world, spread. Thus, the overall effects of the second oil crisis were of an even graver nature than those of the first.

Gradually, though, it became apparent that this situation could not last long. First of all, oil demand was revealed to be price elastic, and this fact alone led to a weakening of the oil market. Secondly, as time went by, the effects of the massive investments made especially by industrialised consumer countries to substitute imported oil and to save energy bore fruit. OPEC's market share in international oil trade dropped from the 86% of 1973 to 82% by 1979, to reach 55% in 1985.

In addition, important oil discoveries were made in consumer countries and - even though production costs were much higher than those of the major Middle East and other OPEC producers - at sustained high oil prices these fields appeared very profitable and rapidly expanded production.

Furthermore, enormous investments were made in infrastructures needed for long distance transport and distribution of natural gas, which thus became a new internationally traded energy commodity. The once primary fuel - coal - was the object of revived interest and its market share increased for the first time in 50 years, with increased applications in industry and in electricity generation.

Meanwhile, there was a new source of energy, one literally invented by man - nuclear power. From a first small ingenious prototype built by Enrico Fermi at the University of Chicago in 1942 to demonstrate the feasibility of achieving controlled nuclear fission, a whole spectrum of nuclear power generation technologies developed in the decades that followed.

When in 1955 President Eisenhower launched the "Atom for Peace" programme, it was already clear that the aim was to free man from his vulnerable dependence on non-renewable fossil energy sources. The market price of oil in those years was, however, very low - in fact, it was falling in real terms - and as a result the penetration of nuclear power was certainly not favoured by market forces.

Despite this handicap, a healthy nuclear industry developed, aided by an optimistic belief in man's capacity for technological achievement, a widely held sentiment in the 1950s and 1960s. Other valid considerations were at work, including the importance of making an energy supply available in industrial countries which could rightly be considered as "domestic", given that the cost of the raw material - uranium - was but a negligible part of the cost of producing energy and, moreover, the element is easy to store. The financial cost of keeping several year's supply in hand is acceptable and the space required not great. The real "raw material" input remains, in fact, the technology. A country able to master nuclear technology could feel itself secure and in control of the energy source. Furthermore, nuclear power was reliable, characterised by a stable and predictable price structure, and eminently suitable to produce the form of energy most in demand: electricity.

In fact, increased reliance on electricity has been one of the main characters of modern civilisation. As a vector, electricity is proving itself as ever more indispensable, being uniquely suited to drive applications of modern high technologies in such fields as microelectronics, information and communication technologies, industrial automation, robotics, and so forth.

It was thus natural that the oil price increases resulting from the 1973 crisis, and growing uncertainty as to future price and availability trends, should further stimulate efforts to accelerate development of nuclear energy. Meanwhile, however, resistance against the nuclear option - which, in the 1960s, had been confined to a relatively small circle of environmentalists - began to gain ground. The general climate of opinion changed, first and foremost in the United States, as a result of a loss of faith in centralised power structures and big business, with the end of the long-lasting honeymoon between society and science and technology. These shifts were also linked with disenchantment with American policy in South East Asia. Alternatives to nuclear seemed preferable, and for the United States at least, readily available. The powerful oil and coal lobbies had a relatively easy time in capitalising on this often emotive reaction.

As is apparent to us all, we have now entered into what I like to refer to as an oil counter-crisis. The present excess of supply over demand has triggered a steep fall in the price of oil on international markets. It is plain that the high oil prices of 1979-80 could not possibly endure, given diminishing world demand for oil.

Paradoxically, moreover, the cost of artificially holding up market prices in the early 1980's has been borne by the OPEC producers (and, within the cartel, particularly by Saudi Arabia - the country endowed with the biggest and lowest cost oil reserves). In a normal market situation, marginal producers would have been sacrificed first. But over the last few years, it has been Saudi Arabia which has progressively reduced its production levels, whilst other OPEC - and even more non OPEC producers (such as those in the North Sea and Alaska) - have kept pumping at high rates. In 1985, the production of oil from the North Sea exceeded that of Saudi Arabia; U.S. production was three times higher.

It is thus understandable that Saudi Arabia has taken the lead in precipitating this wave of price cuts, to try to bring order among oil suppliers in the hope of defending a price level which might come to be regarded as an acceptable compromise by both producers and consumers.

Unless agreement is achieved, it is likely that the months and years ahead will see a very unstable oil market characterised by low, fluctuating prices, and dominated by speculators. In other words, we are likely to be facing a highly uncertain phase in the energy system that in the medium term may well create conditions (perhaps on the occasion of another regional armed conflict) for a third steep rise in the price of oil.

From this sketchy picture - but even more from the basic consideration that oil is a non-renewable, precious energy source, difficult to substitute in special uses such as petrochemicals and road or air transport, that therefore it is irresponsible to continue to use it as a basic fuel, simply to burn it to obtain heat or electricity - stems the thesis I want to put forward strongly at this meeting. In looking at nuclear power and at the contribution it can make to mankind's supply of energy over coming generations, we must refrain from giving too much weight to short-term, narrowly economic factors or, as we shall see later, to essentially immotivated fears.

2. A NEW TYPE OF ENERGY TRANSITION

From the above, it is clear that each of the two energy transitions of the past (the first the emergence of coal as the dominant source, the second its displacement with oil) marked a switch towards an easier and more convenient energy system than that reigning before. Both transitions occurred naturally, without encountering serious obstacles, like a free-wheeling, downhill bicycle ride. An easier, more flexible, single major source proceeded to take over as chief energy vector from the preceding one.

Although the present oil glut could offer crumbs of comfort to those looking for a continuation of an easy oil-based energy system, this is not the time for us to be complacent. On the contrary, we must view this parenthesis in what is bound to be an established and natural trend towards higher energy costs as an opportunity to use the resources available to complete a new energy transition - this time away from the dominance of oil, with the aim, amongst other things, of preserving oil itself for nobler utilisations.

What we must recognise, however, is that unfortunately there is no single source as versatile, as easy to transport and to use or as cheap as oil was at the time it began to assert its dominance over the world energy economy. We must be ready to analyse our energy needs carefully, so as to apply ourselves to an assessment of the relative merits and demerits of the various available resources, with no easy solution on hand. This new transition is therefore likely to represent a long and strenuous uphill ride.

Whilst our production systems, distribution networks and infrastructures were modelled to be served essentially by an energy system based on oil and oil products (including oil-generated electricity), we must now face up to the problems deriving from the complexity of our society. The development of high technologies inevitably requires more electricity, and each source which can provide this energy carrier must be carefully assessed.

Natural gas is a relatively clean fuel, but its international trade requires truly massive investments in rigid infrastructures, and liquefied natural gas is not the safest of commodities to be shipped in bulk around the world. Coal too requires a complex and costly chain of infrastructures, and besides, without expensive and not always very efficient cleaning devices, coal plants are often responsible for high levels of atmospheric pollution - the most serious being acid rain. Mounting pressure for a reduction in SO_2 and NO_x emissions may soon inevitably put a question mark over more intensive use of this fuel, even in those areas where it still enjoys relative cost advantage.

When the amount of fossil fuels burned every year by man was small, photosynthesis by plants, as well as CO_2 absorption in oceans and generation of carbonate rocks, could re-establish equilibrium in the chemical composition of the air. But nowadays the amount of CO_2 produced in combustion processes is to be measured in terms of tens of billions of tons per year, and the above mentioned biological and geochemical processes are no longer sufficient to bring back CO_2 content to its original value. Increased concentration of CO_2, as is well known, is a cause of concern because of the so-called "greenhouse effect" - related to the rise in absorption of the infrared component of solar radiation and consequent temperature increase of the earth surface. This is a phenomenon that might have severe, if not yet fully predictable climatic effects, both at global and regional levels.

Hydroelectric power can be expected to play a significant role into the foreseeable future. Potential remaining untapped though is to be found largely in developing countries, and more in general in parts of the globe distant from existing demand for electricity. The harnessing of such power will thus require either considerable investment to bring energy-using industry to the power generation area or, alternatively, major advances in electricity transmission technologies, so as to enable the economic carrying of power over long distances without the high levels of transmission loss encountered today. This area of research offers considerable hopes in the long-term for a more rational approach to the generation of electricity in the future, decoupling the geographical areas of generation and consumption. Within the range of possibilities, might then be the transmission of electricity between time zones, thus meeting one area's peak demand from another's otherwise slack capacity.

In this survey of energy options now available to us, nuclear fission power represents a much more important alternative to fossil fuels than hydro. As I have said earlier, the real raw material of nuclear power is technology. To set up an efficient nuclear power utilisation system on a world basis, one must have available a complex of technologies, stretching all the way from extraction of the uranium ore to isotopic enrichment, to fuel fabrication, to the generation of electricity in nuclear power plants and on to the closure of the fuel cycle with reprocessing and disposal of radioactive wastes. In each phase, environmental protection and safeguarding of human health must be paramount. Similarly, a high degree of sophistication, both in technology and organisation, is needed in the management and control of the whole system.

Considering the uranium resources available at reasonable price, exploitation of nuclear power in light (or heavy) water-moderated reactors as at present represent an option which will be quite limited over time. But, fortunately, nuclear power has within it the possibility of making recourse to fast breeder reactors, multiplying by two orders of magnitude the amount of energy potentially available in the uranium ore, and hence able to supply abundant energy for many centuries to come.

The survey so far has not included renewable energy sources such as photovoltaic solar energy, thermal solar energy, biomass, wind, or the more "exotic" renewables, nor has it included geothermal power. Technologies to exploit these forms of renewable (or abundant, as in the case of geothermal) energy sources are available, but at the moment cost-performance is such as to make all these energies essentially non competitive, except for particular circumstances where the use-value of the energy produced justifies premium prices, or where specific local conditions allow energy generation at low cost.

This somewhat negative assessment should not discourage research and development aimed at promoting penetration of these energy sources. On the contrary, I believe that there is great scope, for example, in concentrating technological efforts on photovoltaic technology, which offers promise of competitiveness in decentralised uses thanks to low-cost modules based on amorphous silicon deposited as thin layers at the surface of a substrate structural material, and to a parallel development of flexible automation in the production of photovoltaic systems.

Another renewable energy that offers great interest for the future is biomass, be it wood or other energy crops, or agricultural byproducts and wastes. Now that agricultural productivity throughout the world has increased to such an extent as to create the premises for eventually abundant food production for all our planet's inhabitants, it is possible to think in terms of large agricultural areas being given over to products other than cereals and other food crops, able to make a non-marginal contribution to energy needs. Still, options of such a strategic dimension need time before becoming available to mankind.

This survey of future trends into the middle of the next century, would not be complete without mentioning an energy source the feasibility of which has as yet to be proven but which appears promising: nuclear fusion. The achievement of controlled nuclear fusion is an extremely ambitious target, the realisation of the dream of reproducing in relatively small machines on Earth nuclear reactions that occur on the surface of the Sun and stars.

International efforts at present are centred on, first, demonstrating the scientific feasibility of controlled nuclear fusion. Later, the time will come when technological feasibility will have to be proven, and farther still, after the accumulation of sufficient data, an assessment will be required of the economic convenience as compared to other sources, and environmental impact and safety.

Many opponents of nuclear fission look at nuclear fusion as a realistic, more benign, alternative. In my opinion, however, it makes no sense to put nuclear fission - based essentially on already proven technologies and a source for which solid assessments can be made in economic and environmental terms - on a par with nuclear fusion, which has still to prove itself as a realistic energy source.

3. A PLURALISTIC ENERGY SYSTEM FOR THE 21ST CENTURY

A pluralistic system is the best suited for the complex articulated society of the next century. Let us for a moment think that, in the middle of the 21st Century, advanced post-industrial societies - deriving their income essentially from exploitation of new knowledge available to man in such areas as information and communications, biology and related technologies, ocean and space exploration, development of new materials and so forth - will coexist with societies by then in a stage of fully fledged industrialisation, and with others that are still striving to solve primordial problems, and relying largely on agriculture and early-phase industrial activities.

This socioeconomic diversity will dominate a planet which, by the middle of next century, will have a population of about 8 billion inhabitants, almost twice that at present.

As I said earlier, the future organization of society will need both centralised and decentralised patterns of activity. Large industrial areas, big and powerful service infrastructures and a multiplicity of urban structures will coexist with wide rural areas where quite different life styles will predominate, and where community activities will largely be patterned on participative bottom-up organisation and power structures.

To serve a planet of such increased complexity with the energy it needs, in the right quantity and quality, shall not be easy. This is why I am a defender of a pluralistic energy system. Each country or region of the world will have to establish the most suitable mix of energy sources and carriers, according to its natural resources, endowment of infrastructures, socioeconomic and technological position, aspirations and needs of its urban and rural population. This energy mix will have to harmonise with technological developments, not only in the production and transmission of energy within the planet and possibly from space, but also in other areas of economic activity.

Allow me at this point, to illustrate a scenario representing the contribution of nuclear energy in the year 2050, based on certain hypotheses which I consider to be prudently realistic, if not conservative.

Table 1 illustrates my forecast concerning world population in the year 2050 and its distribution between the countries which are now already industrialised (in both West and East) - group one countries, and the now developing group two countries. It should be noted that population increase will largely take place in the now developing countries, some of which, however, by then will have joined the ranks of advanced industrial economies.

Table 2 shows per capita consumption of energy in the two groups of countries, now and in the year 2050. I have assumed that per capita energy consumption in present-day industrialised countries shall have the same value 65 years from now (and this in the presence of a substantial growth of income), thanks to the development of energy-saving technologies and, more in general, to the process of "dematerialisation", already visible in our economies and societies. Furthermore, some energy-intensive industries will by then have relocated in developing countries.

A further assumption in this table is that we will move from a ratio of 10:1 as regards per capita energy consumption for the two groups of countries to a ratio of 3:1. This is perhaps an audacious hypothesis, but if one thinks that it would be sufficient for just China and India fully to industrialise to achieve this improvement in ratio, then what may seem at first sight an ambitious goal, on closer analysis appears achievable.

Table 3 shows the penetration of electricity in the two groups of countries now and in the year 2050, expressed in primary sources. It is not necessary that I spend much time in convincing you all that electricity is bound to increase its penetration throughout the world. I believe that the values of 50% and almost 40% respectively for the two groups of countries are quite realistic.

Table 4 is of central interest to our meeting, dealing with the contribution of nuclear power to the generation of electricity in the two groups of countries now and by the year 2050. Although these forecasts seem to me to be quite reasonable, and perhaps conservative,I am making here an underlying assumption concerning the gradual acceptance of nuclear power by all sectors of society, with the fading of irrational attitudes that still prevail in certain countries and environmentalist circles around the globe.

From Table 4 it appears that we shall move from a production of nuclear-generated electricity of almost 1,500 TWh/y to one of 11,100 TWh/y, an increase by a factor of about 7.4. This means that, on a world basis nuclear electricity by the year 2050 will represent about one third of total electricity produced, a figure lower than some of you might have expected, but certainly much higher than that estimated in anti-nuclear circles: a flat zero.

Table 5 shows installed nuclear capacity in 1985 and an estimate for 2050. Assuming for the sake of simplicity a standard capacity of nuclear plants in 2050 equal to 1,000 mW, this is equivalent to 1850 power plants operating by then. A further assumption is that the average annual working time will be 6000 hours.

Figure 1 shows the nuclear capacity coming on line every year, both in now industrialised and now developing countries. The data are split between new and replacement capacity, assuming an average lifetime of 30 years for power plants. From these data, we have calculated the total number of plants to be replaced from now to 2050. This amounts to almost 1,450, a figure that, added to the 1,850 assumed, as shown in Table 5, to be functioning by the year 2050, brings the total number of power plants to be built up to then, both for replacement and generation of new capacity, to 3,300. These figures may seem high, but to cool your enthusiasm let me just add that the number of power plants starting up in the year 2050 will in our calculations be around 75, compared to 1985's 40 (to be corrected to 32 in order to normalise plant capacity).

This scenario is not based on explicit assumptions as regards the type of nuclear power stations installed: there are likely to be many technological developments and changes over the next 65 years. On today's knowledge, and given the long lead times involved in nuclear technologies, it seems reasonable to assume that light water reactors (LWRs) will dominate at least for the greater part of the period considered. Whilst large standardised units will in general prevail given associated scale economies and the advantage of exploiting available nuclear sites, it is likely that units of smaller size, characterised by greater flexibility and, hopefully, by easier operability, will also be developed especially to meet the needs of developing countries.

In industrial countries, fast breeder reactors (FBRs) are likely to appear on a commercial scale sometime after the first decade of the next century. If demonstration programmes now being carried out in Europe, the USSR and Japan are successful, the cost of energy produced by fast breeders is expected to be moderately higher than that from LWRs, at current uranium prices. FBRs may become more competitive should the price of uranium increase as a consequence of depletion of lower cost sources. In any case, FBRs can be considered as an insurance policy against an eventual unforeseen steep rise in uranium prices or difficulties in supply. This would enhance the qualification of nuclear power as a quasi-domestic source.

It seems reasonable to assume that a certain number of the nuclear power stations in industrial countries in operation after 2020 will be fast breeders. Although here too predictions are extremely difficult to make, it is conceivable that by 2050 20% of new stations (should we say, 10 per year) could be FBRs, and that, by mid-century, about 100 GWe of fast breeder reactor capacity will be supplying electricity. This estimate is quite compatible with projected figures for the availability of plutonium from thermal reactor fuel. Operations will require closure of the fuel cycle with the appropriate reprocessing and refabrication plants.

In Table 6 I have tried to give an indication of the likely turnover of the nuclear power industry in the years 2010 and 2050, split into turnover from power plant construction, power plant servicing, fuel cycle plant construction and related servicing. In the midst of the next century the total turnover on a world basis is a respectable 300 billion dollars (1985 value). This has to be compared with the present estimated turnover of $50 billion.

A lot of courage has been needed on my part to present before this distinguished and expert audience a set of assumptions and data which any of you have the capacity successfully to challenge: my purpose, however, is to supply orders of magnitude rather that precise figures, so as to supply the basis for a more informed debate.

Let us now return for a moment to the overall pluralistic energy scenario, to put the role of nuclear in the right perspective. As we have seen, on a world basis electricity has been assumed to be 43% of the total energy supply, and the share of nuclear electricity one third of that. This means that nuclear energy by the year 2050 is assumed to give a 14% contribution to the world energy supply.

Furthermore, if conditions facilitating the continued progress of the nuclear sector are not met in all major countries, my predictions will need revision. But even in the unlikely event that the country which is at the moment the industry's leader -- the United States -- should phase out nuclear power, the overall picture would not change drastically. Nuclear capacity in 2050 would still be in the order of 1,500GWe, with a nuclear industry worldwide having to meet the task of building 70 new stations per year.

On the other hand, one may well expect, after the year 2050, the rapid take-off of nuclear in many now developing countries, thereby leading, towards the end of the next century, to a much higher contribution of nuclear to the total energy supply. What I want also to stress here is that, with nuclear contributing 14% of total energy supply, there is more than ample space for fossil fuels and renewables (including hydro and geothermal) which must cover the remaining 86% of world needs in 2050.

I have left aside any contribution from nuclear fusion which I assume could become really significant only in the latter part of the next century.

In the concluding part of my lecture, let me make a few remarks on what I consider a pre-condition for the forecasts I have presented to become reality. I will therefore touch upon the delicate matter of how to dispel the clouds on the nuclear horizon.

4. DISPELLING THE CLOUDS ON THE NUCLEAR HORIZON

Since its beginnings, development of the nuclear industry has taken place with an unprecedented sense of responsibility, relying on a quality assurance methodology aimed at reducing to extremely low levels throughout the system the risk of major accidents, the happening of which in this case would have the peculiar characteristic of having long-term effects on both populations and environment. This concern for safety has also precluded for nuclear energy the acceptance of the environmental hazards universally encountered in the exploitation of all other sources. The priority granted to safety and environmental protection has led to the development of new technologies and to the adoption of a systems approach covering all aspects and phases of energy generation: from extraction of the uranium ores to the closure of the fuel cycle and disposal of radioactive waste.

I feel that we have still fully to appreciate the enormous importance of this approach for the overall technological development of our society, and not only for the energy sector. Nuclear industry has been the proving ground for many leading-edge technologies which are now making their contribution to advanced economies throughout the world. The level of scientific and technological excellence demanded by nuclear industry has stimulated academic and industrial circles in many countries, with a spill-over effect working its way throughout the wider community.

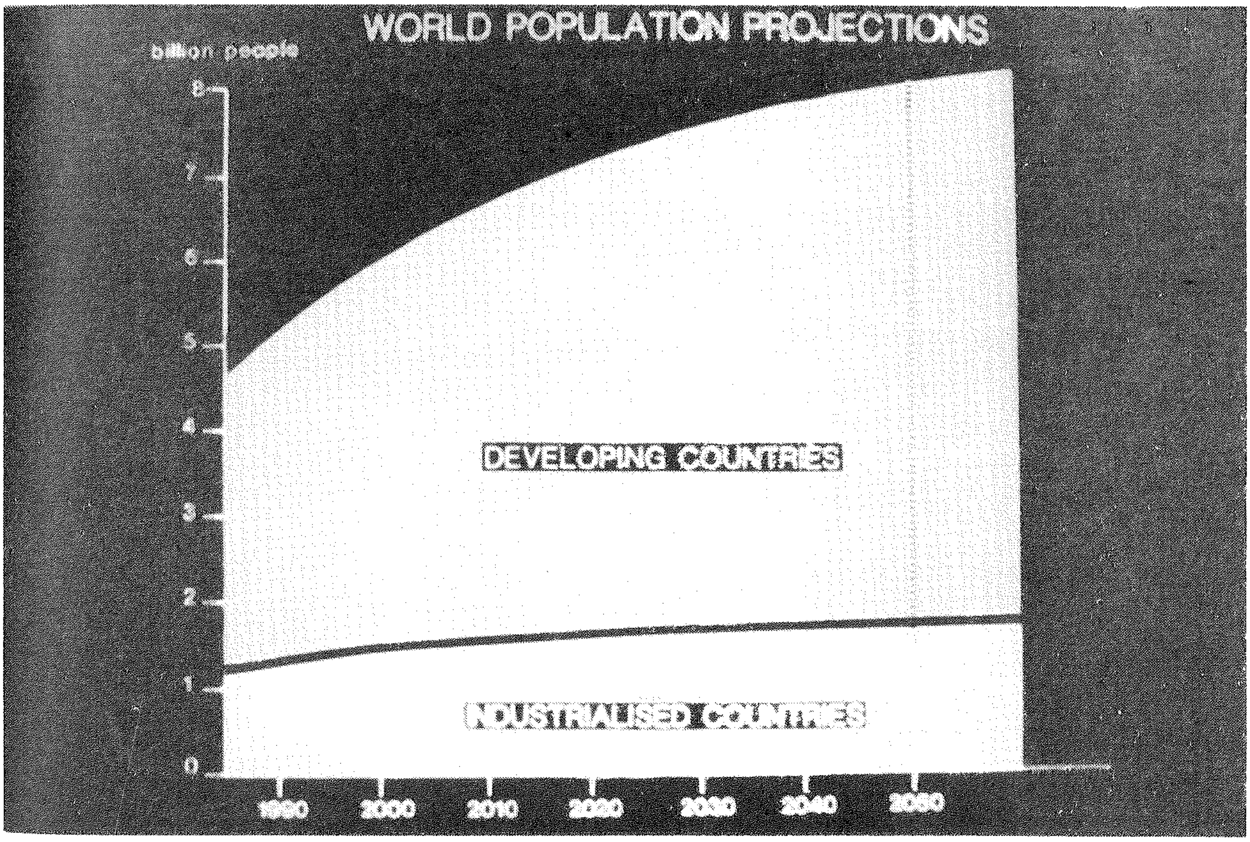
Yet nuclear suffers from one serious drawback and that is social acceptability. Despite continuous attempts to give scientific and political reassurance, in quite a few of the countries which have embarked on programmes - and paradoxically even in the country which generated most of the basic technology and which has the highest number of power plants in operation (the United States) - public opinion has yet to be fully convinced that nuclear energy offers lasting benefit to mankind. This problem should not be ignored, nor treated defensively: I believe we must face it openly, and get over it on the basis of comparative assessment with all other alternative energy sources.

The nature of opposition to nuclear power is based on several distinct elements. Certainly, unjust (and largely subconscious confusion) in the popular mind between nuclear power and nuclear weapons still has a

WORLD POPULATION DATA AND FORECAST

billion people

	1985	2050
INDUSTRIALISED COUNTRIES	1.15	1.50
DEVELOPING COUNTRIES	3.50	6.50
WORLD	4.65	8.00



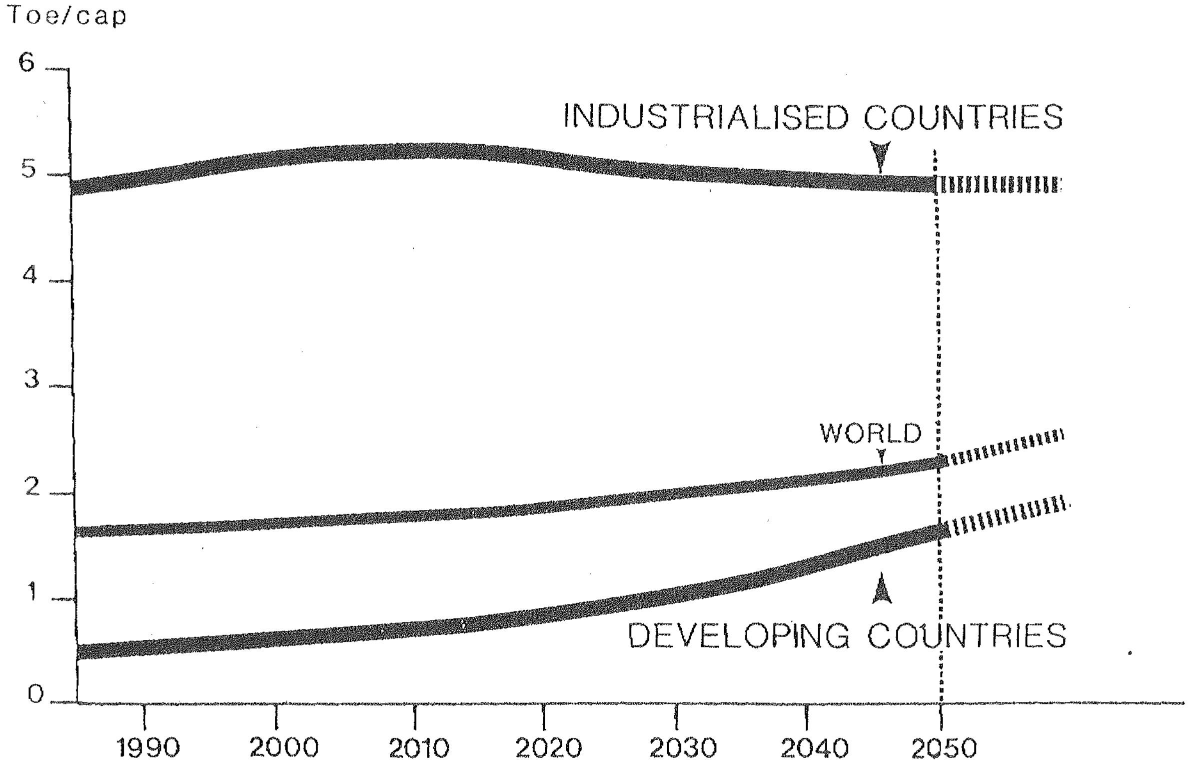
PER CAPITA ENERGY CONSUMPTION

Toe/cap

	1985	2050
INDUSTRIALISED COUNTRIES	4.9	4.9
DEVELOPING COUNTRIES	0.5	1.6
WORLD	1.6	2.2

TABLE 2

PER CAPITA ENERGY CONSUMPTION

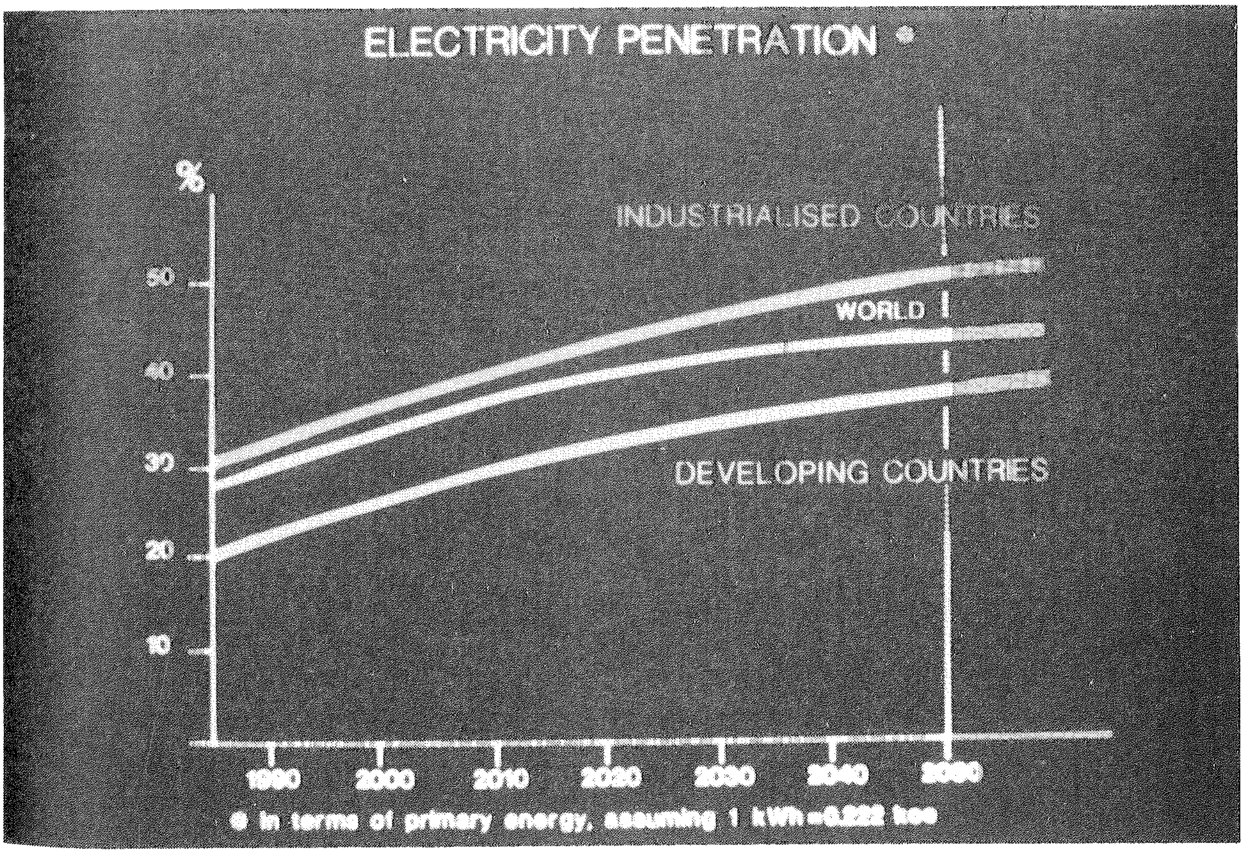


ELECTRICITY PENETRATION

expressed in percent of primary energy

	1985	2050
INDUSTRIALISED COUNTRIES	30.4	50.0
DEVELOPING COUNTRIES	20.3	38.0
WORLD	28.0	43.0

TABLE 3

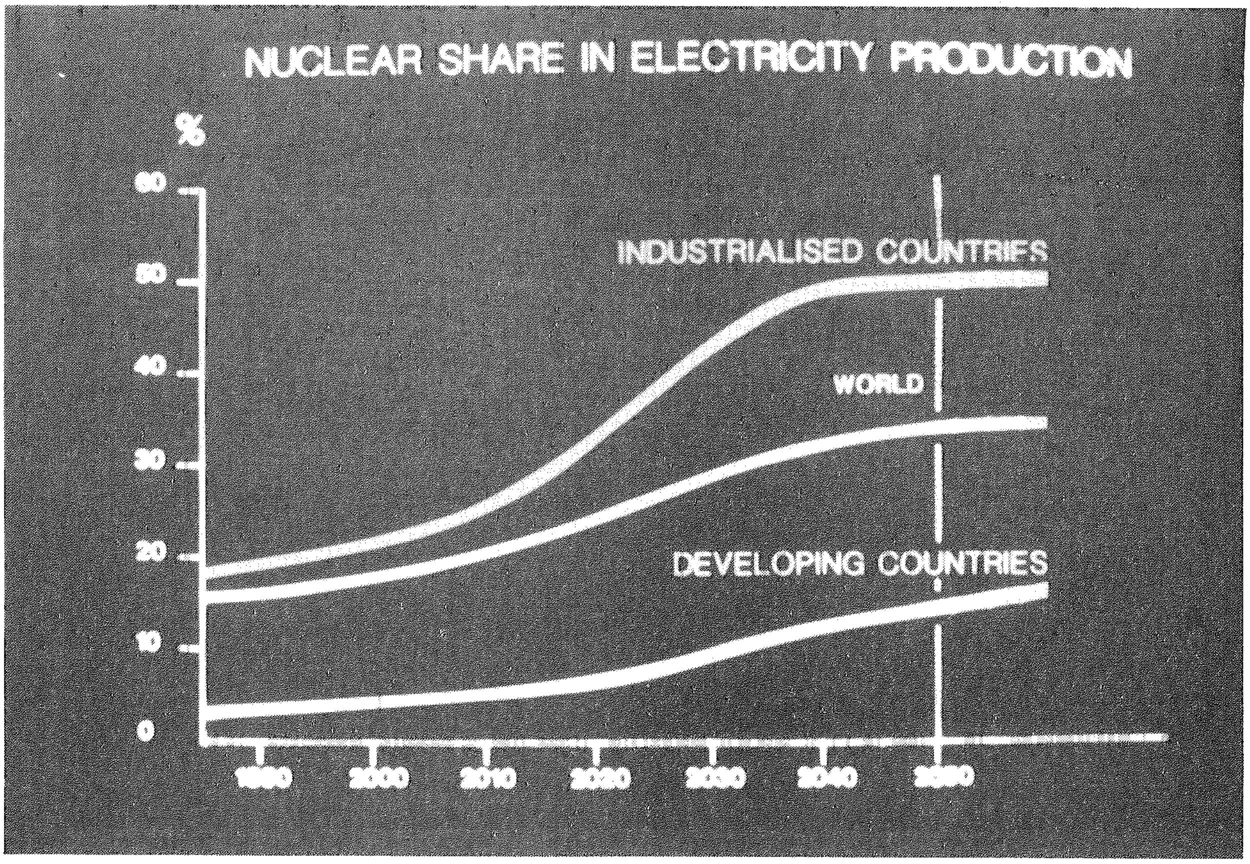


NUCLEAR SHARE IN ELECTRICITY PRODUCTION

in percent

	1985	2050
INDUSTRIALISED COUNTRIES	18.2	50.0
DEVELOPING COUNTRIES	3.7	15.0
WORLD	15.9	31.7

TABLE 4

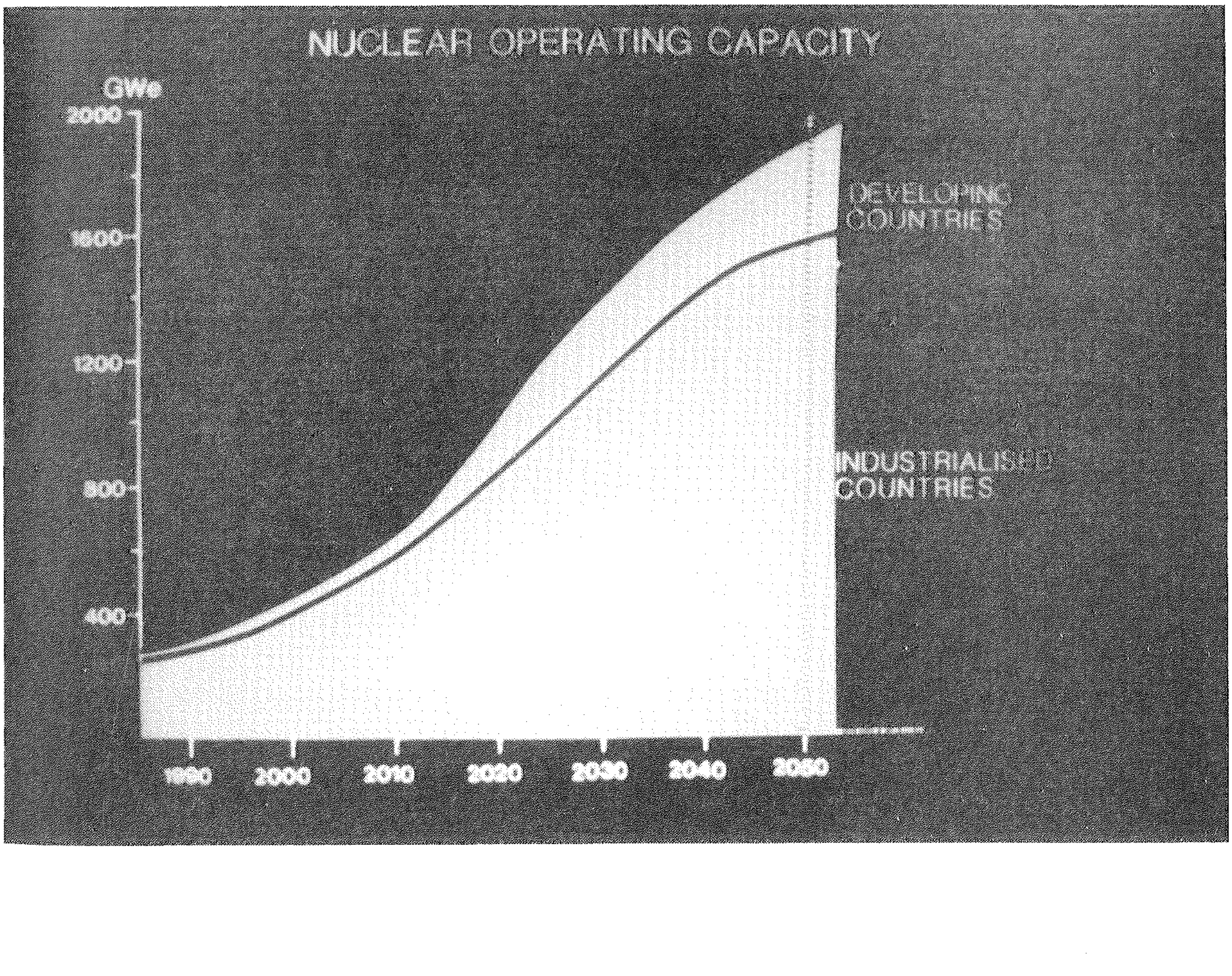


NUCLEAR OPERATING CAPACITY

GWe

	1985	2050
INDUSTRIALISED COUNTRIES	251	1390
DEVELOPING COUNTRIES	11	460
WORLD	262	1850

TABLE 5



ANNUAL NUCLEAR CAPACITY COMING ON LINE

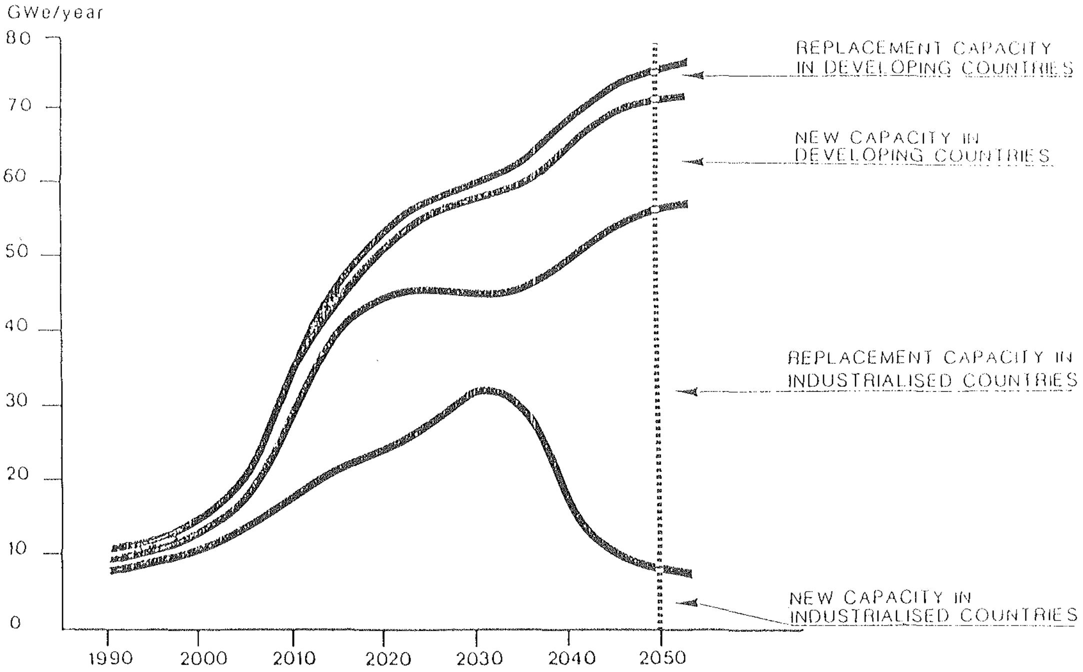


FIGURE 1

WORLD NUCLEAR POWER INDUSTRY TURNOVER

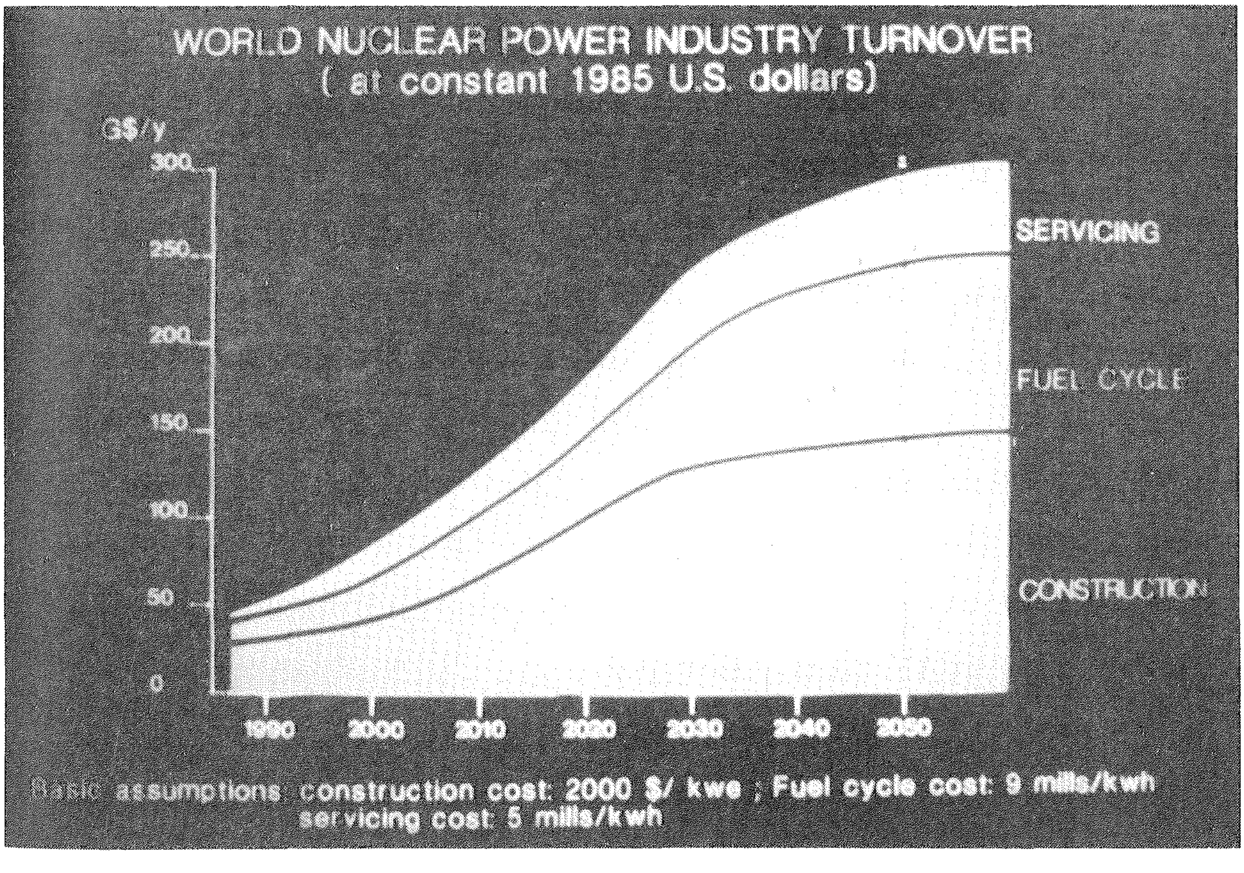
1985 billion dollars

	2010	2050
CONSTRUCTION	74	144
FUEL CYCLE	32	100
SERVICING	18	56
TOTAL	124	300

▸BASIC ASSUMPTION◂

- ▸Construction cost 2000 $/kWe
- ▸Fuel cycle cost 9 mills/kWh
- ▸Servicing cost 5 mills/kWh

TABLE 6



WORLD NUCLEAR POWER INDUSTRY TURNOVER
(at constant 1985 U.S. dollars)

Basic assumptions: construction cost: 2000 $/ kwe ; Fuel cycle cost: 9 mills/kwh
servicing cost: 5 mills/kwh

中国の原子力開発の基本方針

中国原子力工業大臣
蔣　心　雄

議長ならびにご出席の皆様：

原子力産業会議創立30周年を迎えるに当たり，中国原子力工業省代表団が科学技術庁，原子力委員会および原子力産業会議の招請により貴国を訪問し原産第19回年次大会に参加することが出来ましたことを大変嬉しく，ここに祝賀と感謝の意を表するとともに，会議に参加された世界各国，各地域の代表の皆様に心からご挨拶申し上げます。

日本は原子力開発先進国であり，原子力技術の自主的開発と厳格な品質保証の面で，成績が顕著であり，世界の原子力平和利用に貢献されております。中国の原子力工業開発も30年余の歴史があり，ウラン鉱石の採掘・製錬，ウラン濃縮，燃料製造，原子炉運転，再処理，廃棄物処理に到る一連の燃料サイクルシステムを打ち建てております。またウラン鉱地質，燃料製造，アイソトープ生産，原子力設備製造，原子力の研究設計，原子力工事建築から原子力安全防護まで，比較的まとまった原子力工業体系を打ち建てております。原子力工業省はすでに10基の研究炉あるいはその他の用途の原子炉を建設しております。しかしながら，さまざまな原因により，この10数年来われわれは原子力発電開発において先進国に大きく遅れてしまいました。今世紀末までに社会主義近代化建設という大きな目標を実現し，来世紀のエネルギー問題を解決するために，中国は固い決意をもって原子力開発を進めるつもりです。

今世紀内に原子力発電を発展させようというわが国の計画には変更ありません。原子力発電開発をより効果的に進めるために，今年から政府はまた新しい部門を設置し，1986年から1990年までの第七次五ケ年計画期間中に，重点的に，一歩一歩原子力発電所の建設を進めることを明確に致しました。エネルギー産業全体の発展は，電力を中心にしなければなりません。国は電力建設のために一定額の投資を増加させる予定で，計画されている各種発電所建設の規模は 5,400万ＫＷ，稼働する発電設備の容量は 3,400万ＫＷです。大，中，小型発電，水力，火力，原子力発電を並行して建設し，中央，地方，企業，集団の発電所建設も同時に行い，内資，外資による建設も併用していきます。今後わが国は二つのエネルギー省を有することになります。一つは水利電力省で火力発電と水力発電を所管し

ます。もう一つは原子力工業省で原子力発電を所管します。

わが国の原子力開発の基本方針は，自力更生を基礎に，外国の先進技術や主要設備を導入し，「対外協力はするが，自国を以て主とする」という原則によって原子力を発展させるというものです。これからはプラントを一括導入するとか，外国に請負わせて建設する方法は取りません。これは中国の原子力工業と機器製造工業にはある程度基盤があり，われわれは完全に外国の先進的な技術を吸収することができると同時に，原子力発電所を建設する能力があるからです。わが国が現在建設中の浙江省秦山原子力発電所はまさにこのようにして建設されるものです。この原子力発電所は上海原子炉工学研究設計院と華東電力設計院等の部門が設計したものであり，同時に外国の専門家を招聘してコンサルタントや評価を行いました。原子力発電所の設備は上海，西安，武漢，瀋陽，北京等の関係メーカーによって製造され，他の一部の設備と材料は外国のメーカーより購入しております。建設コスト低減，工期短縮のため，たとえ将来われわれに自力製造能力ができたとしても，必ずしも全部自力生産するとは限らないので，このようなやり方はある程度続くと思われます。われわれは自力更生，国産化を強調していますが，かたくなに100 パーセント国内生産を求めるものではありません。原子力発電所と密接な関係のある動力炉燃料の製造，使用済み燃料の再処理および放射性廃棄物処理についての科学的な研究，試験や拡張建設工事もすでに進んでおります。われわれは原子力発電開発と同時に原子力の研究を行い，同時に施設を建設するという方針をとっております。これも今後新しい原子力発電所の建設を速める基礎を打ちたてるためです。

これと同時に，われわれは一方で先ず，すでにある基礎の上に，60万KWの加圧水型原子炉を建設し，逐次標準サイクルを形成し，一定の段階に達するのを待って，さらに一段上げることとし，また，一方積極的に広東省大亜湾原子力発電所（すでに，三件の契約書，趣意書は全て調印され，正式着工に入る新段階に到っている。）の建設を行い，外国の先進的な技術の吸収，消化に努力します。このように，1995年以降には，中国の原子力発電建設は新しい局面を迎えるものと思われます。

原子炉熱併給（低温熱併給炉と高温熱併給炉を含む），高速増殖炉および制御核融合の研究について，われわれもある程度の基礎を有しております。今後さらに，国際交流を強化し，関係各国と共同研究を進めたいと思っております。さらに，原子力産業の経済効果を高めるため，わが国は現在ウラン同位体分離の新技術を研究開発しており，古い工場を技術改造中です。いずれも一定の進展を見せております。

原子力産業が国民経済に資するもう一方の広い分野は，すなわちＲＩ・放射線技術が直接工業，農業および国民の生活のために役立つことです。この分野において，われわれはすでに比較的顕著な経済効果と社会的効果を得ております。工業分野においては，現在放射線測定技術や関連ＲＩ計測器が鉄鋼，石炭，冶金，化学工業，石油，軽工業等多くの分野において有効に用いられており，かつ放射線加工を一つの新しい産業技術としてその利用を推し広めてきました。農業分野においては，われわれは放射線照射により194 の新しい作物品種を育成し，かつ1.3 億畝（約870 万ha）の農地播種を行いました。これらの優良品種は単位生産量を高めるだけでなく，品質，抗逆性等非常に多くの面において改善を見ております。昆虫の不生育，肥料の効果向上についての研究および食品照射鮮度保持技術面において良い成果をあげております。国際原子力機関と国際連合食料農業機構が現在上海で「アジア太平洋地区食品照射保存学術討論会」を開いており，食品の照射鮮度保持技術の開発推進が必ず促進されるでしょう。医学においては，わが国はすでに900 以上の病院がアイトソープ医薬品と放射線計測器を利用して検査，診断，治療をしたり，医学の基礎研究を行っております。放射性免疫技術は，肝臓癌等疾病に対する早期診断に顕著な効果を見せています。

中国は世界各国の原子力平和利用開発を積極的に促進し，広範な国際交流，協力を行うことを主張し，これには専門家の相互派遣，視察，講義，技術コンサルタント，技術導入を行うことを含みます。また，共同開発研究，共同設計，共同生産，合資経営および技術貿易結合，補償貿易等種々の方式を採用して二国間あるいは多国間との協力を行うつもりです。第三世界各国と地域に対して，われわれは平和利用の枠内において技術，工事建設の面で，できる限りの支援，援助，協力を行うつもりです。

今年は国際平和年です。現在一意専心社会主義近代化建設に力を注いでいる中国人民はことさら平和を求めております。われわれは平和でなければ社会の発展はないし，また，原子力事業の発展もないことをよく知っております。最近，趙紫陽総理が北京で開催された「中国人民の世界平和を擁護する会」において，中国政府の軍縮問題上の基本的立場と主張を述べ，かつ，「中国は今後再び大気圏における核実験は行わない。」と宣布しました。原子力政策上，中国は核拡散を主張せず，核拡散を行わず，他国の核兵器開発を支援しません。国際原子力機関の第29回総会において，われわれはすでに，中国政府は適当な時期に一部の民用原子力施設について自発的に国際原子力機関の査察を受けることを決定しています。

日中両国は一衣帯水の友好的な隣国です。日中原子力分野における交流と協力は既に数年の歴史を有しております。1981年にわれわれと日本原子力産業会議が交流協力覚書に署名して以来，両国間専門分野の交流視察，専門家の相互訪問が日増しに頻繁になっております。原子力の安全研究，放射性廃棄物処理処分の研究，放射線技術の応用およびアイトソープの生産等の分野において幅広い交流と協力が展開されております。両国は，わが国の雲南省騰冲地区で，ウラン鉱共同探査を行い，良好な進展を見せております。また，貴国のいくつかの企業，メーカーは秦山原子力発電所のために圧力容器等の設備や部材を製造しております。このことは，日中原子力協力がすでに良好に進んでいることを物語るものです。両国人民と科学者，技術者が科学技術の進歩と原子力協力の中でさらに大きく発展することを祈ります。

最後に議長ならびに各代表，各友人の皆様のご健康をお祈りすると共に，本年次大会のご成功をお祝い申し上げます。

有難うございました。

セッション1

原子力　－　回顧と展望

原子力平和利用の回顧と展望

国際原子力機関（ＩＡＥＡ）名誉事務総長
Ｓ．エクルンド

多角的展開を図るフランスの原子力産業

フランス原子力庁（ＣＥＡ）長官
Ｇ．ルノン

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原子力委員会委員長代理
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インターナショナル・エナジー・アソシエーツ社（ＩＥＡＬ）会長
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燃料サイクルのバックエンド　－　技術、供給能力、経済性

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原子力技術のポテンシャル

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Ｍ．レヴンソン

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NUCLEAR ENERGY: REVIEW AND FUTURE PROSPECTS

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International Atomic Energy Agency

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Administrateur Général
Commissariat à l'Energie Atomique
France

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Chairman
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OECD Nuclear Energy Agency

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Engineering and Construction Division
Electricité de France

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Federal Ministry of Research and Technology
F. R. Germany

"Nuclear Energy Potential"
Milton Levenson
Executive Engineer, Bechtel Power Corporation
Ex-President, American Nuclear Society
U. S. A.

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Check against delivery

Review and future prospects of peaceful uses of atomic energy

Sigvard Eklund
Director General Emeritus
International Atomic Energy Agency

The topic of my address today is what has happened to the development of atomic energy for peaceful purposes. Let me first distinguish between two topics: the use of atomic energy for the production of energy in the form of heat or electricity and the use of atomic energy in a wider sense, in the form of radiation for medical, agricultural or technical purposes or as an unsurpassed means for scientific or technical investigations.

I shall mainly speak about the use of atomic energy for the production of electricity. Last year about 15% of the electricity generated in the world was produced by nuclear means. How remarkable that 15% is would become evident if we were to try to find alternative energy sources for such an amount of energy. On the other hand 15% is a global average and at one extreme we have France where 65% of the electricity production was nuclear in 1985 and is expected to reach 75% in 1990, (perhaps then with 2 to 4 1.300 MW reactors more than would be strictly needed), Belgium 58%, Finland, Sweden and Taiwan in the 40-50% range. Japan and several countries about 25%. In the USA on the other hand only 15% of the electricity was of nuclear origin in 1985, in the USSR 11% amd Italy 3%. The USA nevertheless represents 1/3 of the world's nuclear capacity,

It must be recognised that nuclear power in an astonishingly short time has made a remarkable inroad in the conventional energy sources. At the same time we are aware of some of the reasons why the use of nuclear power has not advanced more quickly. First of all, our expectation after the 1955 UN conference on the peaceful uses of atomic energy were unrealistically high. The scientists were enthusiastic, the technical people believed that nuclear technology could easily be mastered, and the utilities were interested in a presumably cheap source of primary energy. At the next conferences in 1958, 1964 and 1971 a more realistic approach could be observed. It had become evident that there were unsolved technical problems and that utilities were organizations, which in fulfilling their task of providing customers with cheap and reliable electricity were inclined to considerable inertia which prevented them from rapidly turning to completely new solutions for their need of primary energy. They had to consider many different factors influencing their markets and they started to become aware of, for example the special restrictions which governed the acquisition of fuel in the uranium market. Those restrictions had been established in order to prevent proliferation of nuclear material for non peaceful purposes. They were faced with new safety requirements and the presence of regulatory bodies which made profit estimates uncertain, decision making difficult and some utilities having nuclear plants under construction - especially after the Three Mile Island event in 1979 - faced the danger of possible bankruptcy.

In this context it is important to recognize the continuous increase in power output in the nuclear power reactors designed and constructed during the last 30 years. The Obninsk reactor of 1954 had a generating capacity of 5 MW; the Grohnde reactor in FRG 1319 MW the last series of LWR, PALUEL in France has a rating of 1.300 MW and a new French design 1.450 MW. The capacity of the nuclear power station Ignalina in USSR is 1.450 MW. No wonder if there are some teething troubles.

This has given rise to world-wide scrutiny of reactor safety conditions, which certainly has led to a better understanding of the problems involved. It also had undesirable consequences, however, which for example in the USA, led to the requirement of questionable changes and back-fitting of already operating reactors, and of reactors under construction. It created a general uncertainty as to what ultimately is required of the designer, constructor, operator and regulatory bodies and where the ultimate responsibility for safety is located, with a tendency to have it in the regulatory agencies which became a paradise for lawyers. How safe is safe enough?. The consequences of this became, as we know, dramatic in the USA, the country which, up to then, had been leading in the use of atomic energy for the production of electricity. Costs and construction times increased exponentially and led to cancellation of a number of reactors under construction, not to mention the cancellation of plans to design and construct new reactor plants.

Fig.1 shows the annual status of the power reactors in the world. The increase in the time needed for construction between 1955 and 1985 is evident.

Fig. 2 shows the construction time for light water reactors in a number of countries. The reason for the astonishingly short and constant construction time achieved in France is to be found in the standardisation of reactors and reactor elements which has taken place there and lessons learned from well-filled order books.

A special tribute should be paid to Japan for the results achieved in the reactor field during the last ten years. Construction times for reactors in the 870-1100 MW bracket have been reduced to 55-57 months. Strict quality assurance programmes have resulted in increased reliability and load factors.

The 374 power reactors in operation in 26 countries represented at 31 December 1985, an accumulated operational experience of 3.500 reactor years. To this should be added some 300 reactor years emanating from shut -down reactors or, in total, over 3800 reactor years. From the 330 operating and 169 shut-down research reactors of various types a total operating experience of 8,000 reactor years has been accumulated. Let me in this context recall that research reactors to a large extent have been and are responsible for the use of atomic energy in wider sense which I mentioned a few minutes ago.

Although power reactors and research reactors cannot be compared with regard to the value of the technical experience obtained from operating them, it is nevertheless interesting to note that 43 years since the first man-made nuclear chain reaction was initiated more than 11.000 reactor years of experience have been accumulated. During this time not a single fatal accident caused by radiation has occurred in nuclear power plants for peaceful purposes. This safety record is the result of extensive and constant efforts made to improve the safety of nuclear plants. To the 11.000 reactor years can be added almost 3.000 reactor years of operating experience from only the USA naval nuclear propulsion programme. This is an impressive proof of the degree to which we have become accustomed to live with and manage the atom.

It goes without saying that the improvement of the availability of power reactors is a most important task.

Power reactors show unavailabity because of different reasons. Figure 3 shows a summary of causes of outages and it is remarkable that 70% of the unavailability through unplanned full outages is caused by equipment failure, half of which is in the conventional part of the plant. The importance of quality assurance is also evident in respect of the non -nuclear parts. Planned refuelling and maintenance account for 67% of the time lost. The introduction of robots and automation will certainly play an important role by facilitating maintenance work in radioactive areas.

Equipment failure is, as I have said to a large degree caused by failure of conventional equipment. Unfavourable statements in public media about nuclear power stations being unreliable usually refer to incidents which occur in the same degree in conventional power stations - without attracting the attention of news media.

Fig. 4 shows the increase in nuclear power generating capacity between 1954 and 1985 with extrapolation for the situation which is expected to be realized in 1990. An example from my own country, Sweden, is elucidating. Swedish hydro-electric power was developed over a period of 100 years to a capacity of around 60 TWh per year . The equivalent development of nuclear power was achieved in 20 years! The development in the nuclear field is very impressive even if it doesn't correspond, as I have noted, to what was originally expected in the 1950^s. What is striking, however, is the decrease in the number of reactors put in operation during each five-year period from a maximum of 90 between 1981 and 1985 to an anticipated number of less than 30 between 1986 and 1990.

Operating nuclear power reactors exist at present in 26 countries and in the next few years three other countries will enter this club bringing the total up to 29. Countries which have exported power reactors, are the USA, France, USSR, FRG, Canada, UK, and Sweden. Japan and India have proved their ability to manufacture and construct reactors in their own countries and other countries could also lay claim as Belgium and CSSR. The lack of new orders is a serious question for some of the manufacturers. The large capacity to which they have expanded in the past cannot be utilized now and the highly specialized and competent staff in the workshops have to be engaged less with new construction and more with backfitting jobs.

The rate of reactor construction in the future will depend on the need for electric power and on the development of reactor technology to cope not only with electricity production but also with production of low and high temperature heat. Japanese plans a few years ago regarding high temperature reactors for industrial purposes including metallurgy may eventually be realized as well as the Swedish concept SECURE for district heating purposes, a purpose for which reactors are built at present in the USSR. The HTGR project in Japan with a gas temperature slightly less than 950°C is another interesting development targeted to 1990. In the FRG interest and considerable efforts have been devoted to high temperature development.

The economic competitiveness of nuclear power with other energy sources is one factor to be considered when determining the extent to which nuclear power will be used to cover needs. In the sixties nuclear power was fighting against a moving target: the price of coal. A similar situation still prevails vis à vis coal and , at least temporarily, vis a vis oil,i.e. the utilities must make decisions which are completely different depending upon short or long term perspectives. It is interesting to see the possibilities which have been opened in Europe through an elaborate grid system to transfer considerable amounts of energy over large distances. Another factor to be taken into account is that nuclear energy is advantageous with its minimal ecological interference. Its rank can be kept, however, only if its safety record is kept at the present high level. Incidents involving safety could have disastrous consequences on the acceptance of nuclear power by the general public.

Nuclear power requires nuclear fuel, i.e. uranium, most often enriched. The uranium deposits which are periodically reported in surveys jointly issued by the Nuclear Energy Agency and the International Atomic Energy Agency are evidently so substantial that the supply of uranium is assured for at least the life time of the 500 power reactors which presumably will be in operation by the end of this century. Deposits in Canada and Australia are large enough to have caused the reduction in price to 16$/lb on the spot market which we are now witnessing and which has forced American uranium mines to close. The buyers market which seems to exist now will probably be strong enough to prevent drastic increases in the uranium price for a considerable time. The work in Japan on extracting uranium from the sea is another example on the importance countries pay to independence.

The availability of uranium and the price situation certainly does not promote the construction of breeder reactors. It must be hoped, however, that decision-makers will understand the fundamental importance of the breeder concept which must be applied in numerous installations in the 21st century if nuclear energy is to become more than a parenthesis. The construction of breeder prototypes should be supported in order to continue the development which was initiated by EBR II in the USA, and followed by the Dounreay breeder reactor PFR in the UK, the BN 600 in USSR and finally the Super-Phenix in France. The work done in the same field in the Federal Republic of Germany, India and Japan shows a laudible foresight.

The enrichment procedures used by the nuclear weapon countries were not declassified at the 1955 Geneva conference and it is not surprising that as a result methods for the enrichment of uranium 235 have interested and been studied and developed by a number of countries. Some of these efforts have been so successful that they have led to industrial production using new techniques even under the umbrella of an international undertaking: I am referring to URENCO, a joint British, Dutch and German undertaking. The laser method seems now to be so successful that the Americans do not intend to complete large scale production facilities for enrichment by means of centifuges which are under construction. The fact that enriched uranium can be supplied by at least four producers: the USA, USSR, France and URENCO; should be a guarantee against attempts to monopolization. Pilot plants in Japan, South Africa, Argentina and Brazil prove that many countries are very anxious to become self-supporting in this respect.

Reprocessing of used fuel means recovering uranium which has not been used and plutonium which has been generated during the burn-up period in the reactor. Reprocessing of fuel from military or civilian reactors is for the time being carried out only in Hanford and Savannah River in the US, in Sellafield and Dounreay in the UK, Marcoule and La Hague in France, in the USSR, in China, and India and some other countries. Large scale reprocessing facilities for civilian purposes are under construction or in advanced planning in Japan and the Federal Republic of Germany. Pilot plants have been in existence for a few years in these countries and in Italy and Spain or are under construction in some other countries.

Reprocessing is a controversial topic both from an economic and non-proliferation point of view. The economic motivation for reprocessing is questioned in some quarters whereas others are of the opinion that only through practical experience from at least an operating plant will it be possible to make a fair conclusion about the cost-benefit of reprocessing. Supporters of reprocessing take the same attitude as supporters of national enrichment: only through a full command of the complete fuel cycle is it possible to make a reliable estimate of the real cost of the nuclear fuel cycle.

Reprocessing plants have to be safeguarded in order to check that no proliferation of fissile material takes place. The difficulties involved in safeguarding a reprocessing plant in a satisfactory manner are recognized. The strict requirements concerning US prior consent in bilateral agreements between the USA and its customers have inevitably increased the interest in some countries in reprocessing. It must be regretted that the thorough studies made by the IAEA about regional fuel centres including fuel fabrication, reprocessing and storage of nuclear waste and products from reprocessing have not been met with greater interest. Unfortunately there doesn't seem to be any possibility of political acceptance for the time being of a regional reprocessing plant.

The American concern about reprocessing technology and the risk of a spread of reprocessing centres led President Carter to propose in 1977 a thorough international evaluation of the fuel cycle, INFCE. The study lasted until 1980 and unanimity could only be achieved by abstaining from making any recommendation.

The storage of radioactive waste (radwaste) is a topic often raised in the nuclear debate. Radioactive waste can contain highly radioactive non-reprocessed used fuel, or waste from reprocessed fuel, radioactive material and contaminated tools, etc. used in operating nuclear plants and low level active material and contaminated material in the form of gloves, protective clothing, and other items.

The storage of radwaste has been called by some a non-problem and it is deeply regrettable that up to now, even countries like the USA and UK, which have produced large quantities of radioactive waste - not in the least in connection with their manufacture of nuclear weapons - still haven't been able to get the necessary support and understanding from authorities at different levels for the construction of retrievable or non-retrievable underground storage for radioactive waste.

The intermediate, retrievable storage for spent fuel in Sweden located adjacent to the Oskarshamn Nuclear Power plant is an example of a possible solution, as is the final repository for reactor waste and waste from research, medical and industrial sources now under construction at another Swedish reactor site, Forsmark. The ultimate disposal of highly radioactive waste (used fuel) in Sweden is being studied by an international group under the leadership of NEA of OECD also including Japanese experts, working in an old iron mine (STRIPA) in Sweden. These studies have led to a much clearer understanding of the geophysical conditions which govern contamination of underground water streams, as well as other factors of importance.

The anxiety which people demonstrate with regard to disposal sites in their own vicinity does not make it very probable that a country would accept radioactive waste from other countries. There are exceptions however, for example the offer from China to accept radioactive waste on a commercial basis and the policy of the USSR to request spent fuel to be sent back .

Vast areas of our globe, uninhabited and of no economic importance, could certainly serve for depositing purposes. Unfortunately, up to now there has been very little political initiative taken in this direction. I think new attempts should be made when the matter has become more mature. The decommissioning of nuclear plants is an issue to which more attention will have to be given in the future. Already some experience is available even with regard to reprocessing plants. The tasks will undoubtedly be facilitated by expanded use of automation and robotnics and convenient design features.

By 1990 the number of power reactors for peaceful purposes in the world may be around 500 with a total generating capacity of 370 GW. Of the 500 the nuclear weapon countries (USA, USSR, UK, France and China) may operate some 300 reactors generating 230 GW for the civilian purposes.

The around 200 nuclear power reactors likely to be operating in 1990 in non-nuclear weapon states would have an electric power of about 140 GW and will, if we assume a load factor of 80%, produce 40 tons of plutonium per year. In nuclear weapon states power reactors will produce 60 tons of plutonium per year.

Nearly all of the non-nuclear weapon states have signed the NPT of 1970 undertaking not to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices. It is up to the IAEA to exercise safeguards in non-nuclear-weapon states party to the treaty for the exclusive purpose of verification of the fulfilment of their obligations under the treaty with a view to preventing diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices. Most nuclear weapon states have voluntarily accepted safeguards on part of their activities in peaceful uses of atomic energy.

It is obvious that the scope of the safeguards operation has grown very much and will have to deal with large quantities of plutonium produced annually in the nineties not to speak of the amount of plutonium accumulated since the fifties.

We are all fully aware of the importance of this control, partly by inspection which is part of the execution of the present safeguards surveillence but I think that the size of the task when the current plutonium production has grown and led to accumulation of the quantities mentioned, will require more emphasis to be given to the fundamental political undertaking which both nuclear-weapon states and the non-nuclear-weapon states have accepted and to which I shall return in a moment.

What are the future prospects for nuclear energy and what will be its role in future society?.

The 4.600 million people now living in the world and the 6.000 million expected by the turn of the century need continually increasing contribution of energy if only for maintaining their present standard of living. A fundamental condition for acceptance of more energy in developed countries is of course that the ultimate users of this increased amount of energy understand that this is for their good and not something which has been invented merely to give utility directors a more important role in society,- a comment I direct towards certain environmental groups. Nuclear energy which could supply this increased amount of energy is economic, certainly compared with prices of crude oil a few months ago, it is friendly to the environment as compared with the combustion gases from oil and coal-fired stations and the radioactive waste can be handled in a satisfactory way, especially if one compares the procedures to be used with those which has been permissable for decades for the chemical industry.

Much more than what is available to them now is needed in the developing countries if their standard of living is to be increased to approach what is prevailing in industrialized countries.

In developed countries nuclear energy could be an alternative energy source together with others such as hydro-power, power from fossil fuel where appropriate and available, and solar power, a domain where the last invention has certainly not been made. I personally do not think that nuclear energy is the panacea for developing countries which it is often claimed to be . The infrastructure, the power grid, the financial situation and the necessary political stability are often not available in developing countries which pretend that they want to go nuclear. Provided that they are fully supported by those developed countries which by expanding their nuclear power would lessen the pressure on oil and coal producers the developing countries would often be well advised to start their electrification programme and expand it by using conventional energy sources.

Even if we were able through education and perseverence to convince the public about the need to have an alternative energy source such as nuclear energy: which, I repeat, is economically competitive, reliable, safe and acceptable for the environment, another question would nevertheless remain as to how to handle the plutonium which will be generated during the operation of the reactors.

The management and eventual use of the plutonium generated is a question of fundamental importance for the further development and use of nuclear power. The plutonium production in the late 1990s will be of the order of magnitude of 100 tons per year. The accumulated amount of plutonium in nuclear fuel, in the non-nuclear weapon states alone, will in 1990 be a few hundred tonnes. Plutonium quantities of this magnitude raise vitally important questions about final disposal of used fuel - whether to store or reprocess. The problem of separating plutonium and how separated plutonium can be made available according to the customers' wishes must also be answered.

If the fuel undergoes chemical treatment in a reprocessing facility the safeguarding function becomes much more complicated, and the end product, plutonium, represents a material which although not ideal nevertheless is not far away from being a weapons material. A reprocessing plant requires large investments and must serve a large number of reactors in order to be used rationally. Sellafield and La Hague are a good example serving utilities in several different countries.

Another question is where the plutonium produced should be stored?. Is the material at the free disposition for the supplier of the used fuel for reprocessing?. These questions and many more have been under discussion by committees in the IAEA since several years without finding a definite solution. The regional concept I have mentioned earlier could be a solution but up to now the interest has been very scarce, although one would think that a regional facility in Western Europe would be ideal for fuel fabrication, reprocessing, plutonium storage and final deposit of radwaste and in the same way it is natural to think of a regional reprocessing centre in the Far East.

If so many difficulties are associated with reprocessing why doesn!t one skip that line and be satisfied with deposit of unreprocessed used fuel?.

The investment needed for a power breeder is so much higher than for a thermal reactor of the same size that it cannot be compensated by for example a doubling of the uranium price. But if the investment costs are brought down and if the uranium market is tight the breeder concept may become attractive again and create a market for the use of plutonium available. Mixed oxide fuel for thermal reactors will also consume plutonium and contribute to make reprocessing interesting from an economic point of view. As said before: development of the breeder is a must if nuclear reactors are to use more than a few percent of the energy contained in uranium.

I have a strong belief in man's imaginative mind and I am an optimist regarding the potential of nuclear power, first of all in the industrialized world. Our dilemma today has in other forms and circumstances been met by previous generations.

That is the reason why I hope that the work on reprocessing and I also include enrichment both from a scientific and technical point of view will continue, provided of course that the work is done under safeguards, even if its economic importance isn't obvious at present, . May I quote what Chairman Dr. Arisawa said a couple of years ago: "A glorious nuclear age will not open to us until we carry the backend of our nuclear fuel cycle to success".

We have said a long time now that nuclear energy has come of age; a conference was even arranged in 1976 with the motto that nuclear energy is mature, and this 19th annual meeting of the Japan Atomic Industrial Forum is celebrating the fact that is is now 30 years since Japan launched the peaceful uses of atomic energy development. I want to express my admiration and serious congratulations on the achievements reached in Japan in almost every branch of nuclear energy in these years. As an example of the beneficial international activity of Japan Atomic Industrial Forum I want to mention its support for the conference in Japan in 1988 on the Man-Machine Interface in the Nuclear Industry

It is appropriate to repeat here the most important issus in front of us in this field now.

I refer once again to the production of plutonium in the reactors for peaceful uses of nuclear energy. The policy initiated in the end of the seventies and followed since then has put a lid on a number of activities in which parties to the NPT were interested following their, as it is written in the treaty's Article IV, "inalienable right of the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination".

The activities of most immediate concern are enrichment, reprocessing and breeding, and I would like to say a few words about the two last items, reprocessing and breeding. Enrichment is, I have mentioned, taken care of by a number of fullscale plants in addition to pilot projects.

If the used nuclear fuel is disposed of in a final deposit, the use of nuclear energy as an alternative energy source will only represent a paranthesis, the length of which depends upon the prices of uranium from the reasonably assured and estimated additional resources but which will probably not extend over the end of next century.

If the plutonium is extracted from the used fuel by reprocessing, the material can be used for thermal reactor fuel in mixed oxide fuel whereby also higher actinides could be burnt. Another possibility is to use plutonium in breeding reactors. Only limited practical experience is available so far with moxfuel and still less with breeders. The economics of reprocessing and the use of recovered uranium and plutonium and the competitiveness of these materials with natural uranium is not precisely known at present. With this in mind an intensive programme should start to seriously assess the possibilities of an expanded use of plutonium.

Such a programme would fit well with the reduction of the number of nuclear weapons which is now under discussion. Already a reduction of the number with a factor of 2 would mean that weapons grade plutonium in the quantites of hundreds of tons would be available - for what use?

Under these circumstances a programme examining the introduction of plutonium in the energy production would become a very important, even indispensible link in nuclear disarmament efforts.

POWER REACTORS IN THE WORLD

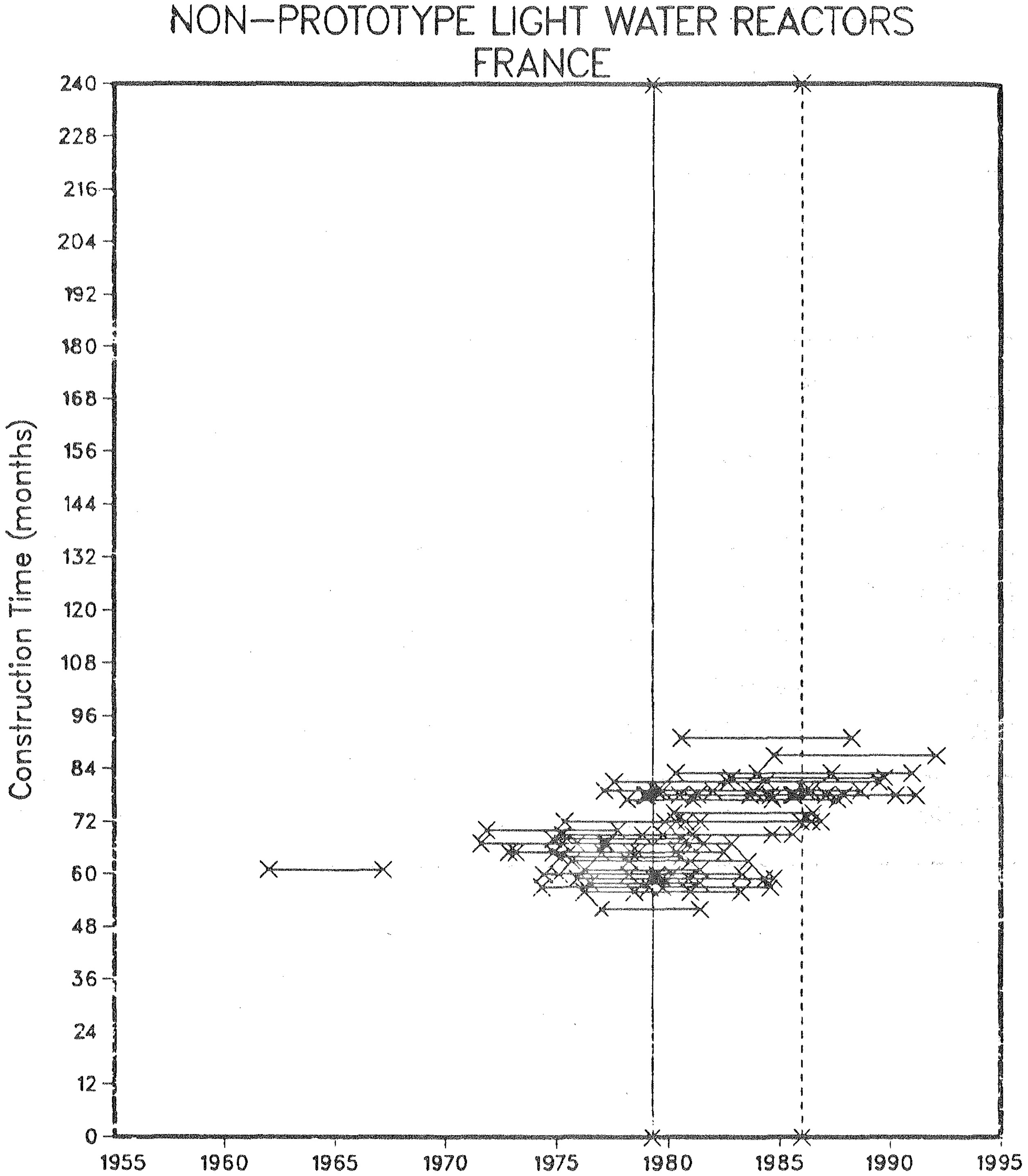
ANNUAL STATUS, 1961 TO 1985

	Under construction		*In operation*		*Shut down*	
Year	No.	MW	No.	MW	No.	MW
1951	1	5				
1955	11	754	1	5		
1960	35	4257	17	1145		
1965	41	10468	50	5277		
1970	133	86011	90	16524		
1975	203	171947	177	71848	6	300
1980	242	226089	255	135035	14	2295
1985	156	140492	374	249720	25	3305

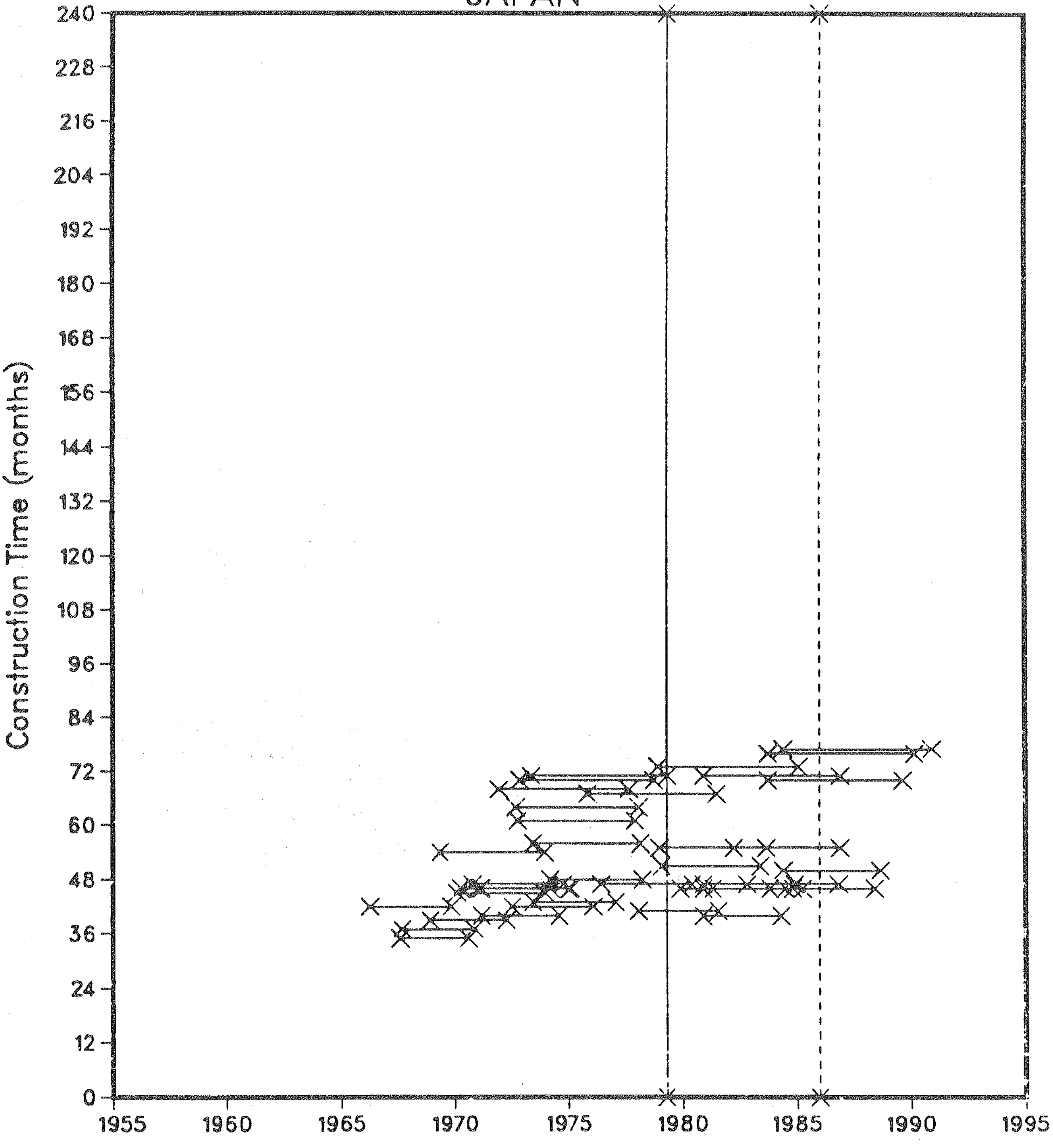
Source IAEA Power Reactor Information System, 1986-03-

NON-PROTOTYPE LIGHT WATER REACTORS, COUNTRY CONSTRUCTION TIMES

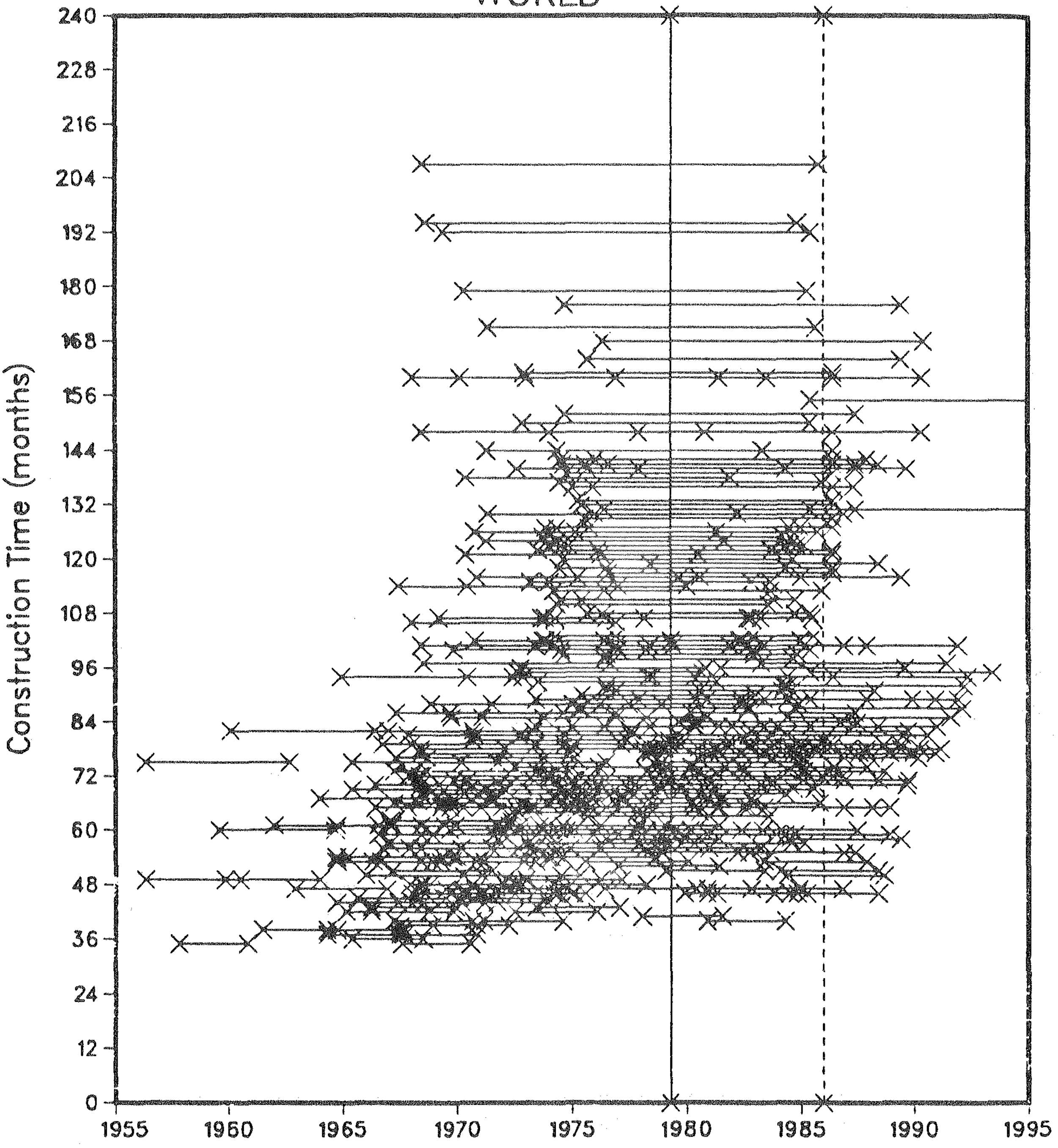
	Year of grid connection								
	Before 1979			1979 to 1985			After 1985		
Country name	No. of units	MW	Average months	No. of units	MW	Average months	No. of units	MW	Average months
Canada	9	587	69	7	632	96	7	804	92
Germany, FR	11	735	56	7	1203	97	4	1262	103
France	5	774	66	29	924	64	18	1243	79
Japan	19	690	49	10	834	51	8	909	62
USA	66	752	68	19	1061	125	26	1125	143
World	151	648	62	113	851	88	119	950	100


NON-PROTOTYPE LIGHT WATER REACTORS
FRANCE
Construction Time (months)
240
228
216
204
192
180
168
156
144
132
120
108
96
84
72
60
48
36
24
12
0
1955
1960
1965
1970
1975
1980
1985
1990
1995

NON-PROTOTYPE LIGHT WATER REACTORS
JAPAN



NON-PROTOTYPE LIGHT WATER REACTORS WORLD

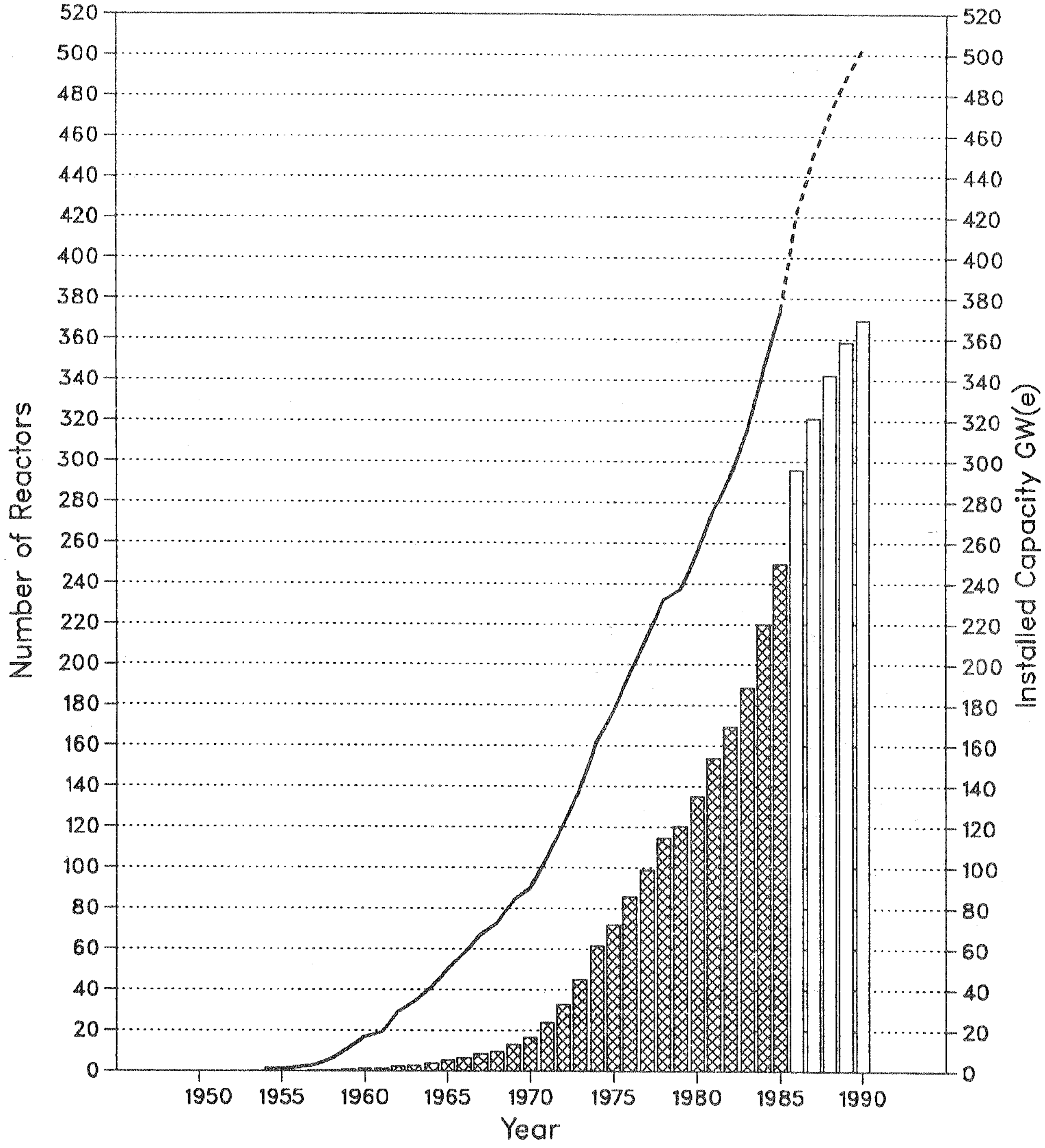


CAUSES OF UNAVAILABILITY, 1971 TO 1983

FOR NON-PROTOTYPE REACTORS

Outage Cause	**Planned Full Outages** *Time Lost (%)*	**Unplanned Full Outages** *Time Lost (%)*
Equipment Failure		70
Operation Error		2
Refuelling (Including Maintenance)	67	3
Maintenance & Repair	30	15
Testing of Plant		
Systems Components	1	1
Regulatory Limitation	2	5
Other Causes	0.3	5

Number of Reactors Connected to the Grid
1954 to 1990



THE FRENCH NUCLEAR INDUSTRY : ACHIEVEMENTS AND PROSPECTS

Gérard Renon
Administrateur Général
Commissariat à l'Energie Atomique
France

LADIES AND GENTLEMEN,

IMPLEMENTED WITH CONTINUITY SINCE THE FIRST "OIL CRISIS", FRANCE'S ENERGY POLICY HAS THREE MAIN OBJECTIVES :

- REDUCE ENERGY IMPORTS AND THEREBY IMPROVE BOTH BALANCE OF PAYMENTS AND SECURITY OF ENERGY SUPPLY,

- DIVERSIFY THE COUNTRY'S ENERGY SOURCES

- CONSERVE AND MAKE MORE RATIONAL USE OF ENERGY.

TO ACHIEVE THESE GOALS, FRANCE LAUNCHED A LARGE NUCLEAR POWER PROGRAM. TODAY, WE HAVE, BEHIND THE UNITED STATES,THE WORLD'S - SECOND LARGEST NUCLEAR POWER CAPACITY, WHICH MET IN 1985 25% OF OUR PRIMARY ENERGY REQUIREMENTS WITH LOW-COST, RELIABLE AND AVAILABLE ELECTRICITY. WE ALSO HAVE AN INDUSTRY COVERING ALL AREAS OF NUCLEAR POWER AND THE ASSOCIATED FUEL CYCLE.

THE FRENCH NUCLEAR POWER COMMUNITY BREAKS ROUGHLY INTO THREE MAJOR CENTERS OF COMPETENCE :

- THE NATIONAL ELECTRIC POWER UTILITY, ELECTRICITE DE FRANCE OR EDF, IS THE OWNER, ARCHITECT-ENGINEER AND OPERATOR OF NUCLEAR PLANTS IN FRANCE. IT IS THE LEADING UTILITY IN MARKET-ECONOMY COUNTRIES IN TERMS OF BOTH INSTALLED NUCLEAR CAPACITY AND OUTPUT,

- NUCLEAR TECHNOLOGIES ARE DEVELOPED WITHIN THE FRENCH ATOMIC ENERGY COMMISSION OR CEA AND ITS SUBSIDIARIES. THE CEA PERFORMS WIDE-RANGING RESEARCH AND DEVELOPMENT, WORKING HAND-IN-HAND WITH EDF AND INDUSTRIAL COMPANIES. IT ALSO SUPPLIES TECHNICAL ADVICE AND ASSISTANCE TO GOVERN AGENCIES IN CHARGE OF SAFETY,

- INDUSTRIAL COMPANIES MANUFACTURE AND SUPPLY COMPLETE REACTORS AND NUCLEAR STEAM SUPPLY SYSTEMS PLUS CONVENTIONAL EQUIPMENT SUCH AS TURBOGENERATORS, OR TAKE CARE OF FUEL CYCLE ACTIVITIES. THE INDUSTRY CONSISTS MAINLY OF THREE LARGE COMPANIES. NUCLEAR ISLANDS ARE DESIGNED AND SUPPLIED BY FRAMATOME, A SUBSIDIARY OF THE COMPAGNIE GENERALE D'ELECTRICITE (OR CGE) AND THE CEA. TURBOGENERATORS AND OTHER CONVENTIONAL EQUIPMENT ARE PRODUCED BY ALSTHOM, ALSO A MEMBER OF THE CGE GROUP. AND THE FUEL CYCLE IS THE BUSINESS OF COGEMA, A FULLY-OWNED SUBSIDIARY OF THE CEA.

I SHALL NOW PRESENT IN MORE DETAIL THE FRENCH NUCLEAR INDUSTRY AND ITS ACHIEVEMENTS DISCUSSING SUCCESIVELY, POWER PLANT EQUIPMENT, THE NUCLEAR FUEL CYCLE, NUCLEAR SERVICES AND MAINTENANCE, FAST BREEDER REACTORS AND NUCLEAR GENERATED ELECTRICITY.

I - ACHIEVEMENTS

I.1 PWR POWER PLANT EQUIPMENT

CONCERNING POWER PLANTS EQUIPMENT,FRAMATOME COMMISSIONED BETWEEN 1970 AND 1985, 39 PWR NUCLEAR UNITS IN FRANCE WITH A TOTAL CAPACITY OF 36 GWe, AND EXPECTS TO COMPLETE 14 MORE UNITS IN THE NEXT FOUR YEARS FOR AN ADDITIONAL 16 GWe. IT SHOULD BE NOTED THAT PWR's REPRESENT, WORLDWIDE, ROUGHLY 60% OF THE INSTALLED NUCLEAR CAPACITY.

FRAMATOME IS THE WORLD'S SECOND LARGEST SUPPLIER OF NUCLEAR - ISLANDS BEHIND WESTINGHOUSE. THIS POSITION HAS BEEN ACHIEVED THROUGH SUCCESSFULLY FACING THE CHALLENGE OF A LARGE HOME MARKET, THROUGH EXPORT VICTORIES AND THROUGH DEVELOPMENT OF AN INDEPENDENT REACTOR SYSTEM AND TECHNOLOGIES.

TECHNOLOGICAL INDEPENDENCE WAS THE FRUIT OF SEVERAL YEARS OF EFFORTS, LEADING IN 1981 TO RENEGOCIATION OF THE ORIGINAL LICENCING AGREEMENTS BETWEEN FRAMATOME AND WESTINGHOUSE, THE U.S. FIRM RECOGNIZING THE EXISTENCE OF AN ALL-FRENCH PRESSURIZED WATER REACTOR SYSTEM. IN 1984, EDF AWARDED FRAMATOME A CONTRACT FOR A NUCLEAR ISLAND WITH A RECORD THERMAL OUTPUT OF 4,270 MWth, EQUIVALENT TO AN ELECTRICAL CAPACITY OF 1,450 MWe, BASED ON THE TOTALLY FRENCH N4 DESIGN.

THE TURBOGENERATORS AND OTHER SO-CALLED CONVENTIONAL EQUIPMENT ARE DESIGNED AND PRODUCED BY ALSTHOM. THIS COMPANY HAS RECENTLY DEVELOPED THE ADVANCED 1,500 MWE ARABELLE TURBINE, AGAIN OF PURELY FRENCH DESIGN, FOR USE WITH THE NEW N4 DESIGN .ARABELLE IS ONE OF THE MOST POWERFUL TURBINES IN THE WORLD. COMPARED WITH THE 1,300 MWe TURBINES OF THE MOST RECENTLY COMPLETED NUCLEAR PLANTS, IT IS BOTH 15% LIGHTER AND 10% MORE COMPACT, WITH AN IMPROVED EFFICIENCIENCY.

AS FAR AS EXPORTS ARE CONCERNED, FRAMATOME HAS WON SINCE 1976 CONTRACTS FOR 6 REACTORS, NOT MENTIONING ITS INTERRUPTED CONTRACT IN IRAN. THIS MAKES IT THE WORLD'S MOST SUCCESSFUL NUCLEAR REACTOR EXPORTER, IN FRONT OF BOTH WESTINGHOUSE AND KWU. ITS LEADERSHIP HAS RECENTLY BEEN CONFIRMED BY THE SIGNATURE OF A LETTER OF INTENT FOR AN ORDER FROM CHINA CONCERNING TWO NUCLEAR STEAM SUPPLY SYSTEMS FOR THE DAYA BAY PLANT, WITH AN ASSOCIATED ORDER TO EDF FOR PLANT ENGINEERING WORK. THIS IS THE FIRST EXPORT CONTRACT AWARDED TO ANY POWER REACTOR VENDOR SINCE THE CONTRACTS IN 1980 FOR THE NINTH AND TENTH UNITS IN SOUTH KOREA, ALSO WON BY FRAMATOME, IN ASSOCIATION WITH ALSTHOM.

TECHNICATOME ANOTHER NUCLEAR ENGINEERING AND MANUFACTURING - COMPANY, ALSO A MEMBER OF THE CEA GROUP, DESIGNS AND SUPPLIES SMALLER POWER REACTORS. IT ALSO BUILDS NUCLEAR REACTORS FOR NAVAL PROPULSION AND HAS A LONG EXPERIENCE IN SUPPLYING RESEARCH AND TEST REACTORS, OR EVEN COMPLETE NUCLEAR RESEARCH CENTERS.

1.2. THE FUEL CYCLE

FRANCE'S LARGE NUCLEAR POWER PROGRAM OF 55 UNITS IN OPERATION OR UNDER CONSTRUCTION NECESSITATED THE BUILD UP OF A COMPLETE FUEL CYCLE INDUSTRY COVERING ALL AREAS OF ACTIVITY, INCLUDING URANIUM MINING AND CONVERSION, ENRICHMENT, FUEL FABRICATION, SPENT FUEL REPROCESSING AND RADIOACTIVE WASTE MANAGEMENT.

THIS MASTERY OF ALL OPERATIONS WHICH, TO A LARGE EXTENT, PROTECTS OUR FUEL PROCUREMENTS AGAINST WORLD MARKET OR POLITICAL DEVELOPMENTS HAS BEEN ACHIEVED LARGELY THROUGH COGEMA, THE WORLD'S ONLY INDUSTRIAL COMPANY ACTIVE IN EVERY AREA OF THE FUEL CYCLE.

COGEMA, A FULLY-OWNED SUBSIDIARY OF THE CEA, IS A COMPANY OF INTERNATIONAL IMPORTANCE. SOME 40% OF ITS TOTAL SALES ARE GENERATED IN FOREIGN MARKETS AND IN 1985 IT WAS FRANCE'S TOP EXPORTER TO JAPAN, THIS COUNTRY ITSELF BEING COGEMA'S LARGEST FOREIGN CUSTOMER.

IN NATURAL URANIUM EXPLORATION AND MINING , COGEMA IS THE WORLD'S BIGGEST OPERATOR IN TERMS OF PROSPECTING EXPENDITURES AND CONTROLLED MINING CAPACITY. OF ITS MANY SUCCESSES, PERHAPS THE MOST RESOUNDING IS THE 1985 DISCOVERY IN CANADA OF THE EXCEPTIONAL CIGAR LAKE DEPOSIT WITH ITS 150,000 METRIC TONS OF URANIUM IN VERY HIGH-GRADE ORE CONTAINING AN AVERAGE 10% URANIUM METAL.

IN ORE MILLING, OUR 1985 PRODUCTION EXCEEDED 7,600 TONNES OF URANIUM IN YELLOW CAKE. IN URANIUM CONVERSION, THE COMHUREX COMPANY, A SUBSIDIARY OF PECHINEY AND COGEMA, OPERATES FACILITIES ABLE TO CONVERT 13,000 METRIC TONS OF URANIUM TO URANIUM HEXAFLUORIDE EACH YEAR. THIS IS ONE-QUARTER OF TOTAL WORLD CAPACITY.

In URANIUM ENRICHMENT, FRANCE OWNS 34% OF THE MARKET-ECONOMY COUNTRIES' TOTAL CAPACITY FOR CIVILIAN APPLICATIONS. IT IS THE SECOND LARGEST ENRICHMENT OPERATOR, SUPPLYING ENRICHMENT SERVICES FOR ONE OUT OF THREE REACTORS IN THE WORLD. THE EURODIF COMPANY, WHICH IS 51% OWNED BY COGEMA, HAS AN ANNUAL CAPACITY OF 10.8 MILLIONS SEPARATIVE WORK UNITS OR SWU's.

IN FUEL FABRICATION , COGEMA AND FRAMATOME ARE PARTNERS IN THE WORLD'S LEADING INDUSTRIAL COMPLEX. DURING 1984, THE ROMANS PLANT OWNED BY FRANCO-BELGE de FABRICATION DE COMBUSTIBLE OR FBFC, A CONSORTIUM FORMED BY COGEMA, FRAMATOME AND PECHINEY, PRODUCED ITS TEN-THOUSANDTH 17x17 STANDARD FUEL ASSEMBLY FOR PRESSURIZED WATER REACTORS.

DURING 1985, EDF DECIDED TO PARTLY FUEL ITS PWR PLANTS IN FRANCE WITH URANIUM AND PLUTONIUM MIXED OXIDE FUELS. COGEMA AND BELGONUCLEAIRE HAVE THEREFORE AGREED TO JOINTLY MANUFACTURE AND SELL THE CORRESPONDING MOX FUEL. AS AN INITIAL STEP, A PILOT MOX FUEL FABRICATION WORKSHOP IS UNDER CONSTRUCTION BY COGEMA AND THE CEA AT CADARACHE TO SUPPLY THE FIRST FUEL LOADS, ALONGSIDE A SIMILAR UNIT OPERATED BY BELGONUCLEAIRE AT DESSEL IN BELGIUM.

MOREOVER, TO MEET EDF'S DESIRE TO EXTEND THE INTERVAL BETWEEN PWR REFUELING OUTAGES, IN ORDER TO INCREASE THE AVAILIBILITY FACTOR, THE FRAGEMA COMPANY, A JOINT SUBSIDIARY OF FRAMATOME AND COGEMA, HAS DEVELOPED THE ALL-FRENCH ADVANCED FUEL ASSEMBLY OR AFA FROM THE EARLIER 17x17 STANDARD ASSEMBLY.

IN REPROCESSING, FRANCE LIKE OTHER COUNTRIES SUCH AS JAPAN, THE FEDERAL REPUBLIC OF GERMANY AND THE UNITED KINGDOM HAS OPTED FOR SPENT FUEL REPROCESSING FOR MORE EFFICIENT AND SAFER MANAGEMENT OF RADIOATIVE WASTE PRODUCTS AND FOR IMPROVED UTILIZATION OF THE ENERGY IN NUCLEAR MATERIALS. THE UP-2-400 REPROCESSING PLANT AT LA HAGUE HAS SINCE 1976 PROCESSED MORE THAN 1,400 METRIC TONS OF SPENT

FUEL FROM LIGHT WATER REACTORS. IN 1985, THIS PLANT'S THROUGHPUT OF 418 METRIC TONS EVEN EXCEEDED ITS NOMINAL CAPACITY. THESE OUTSTANDING RESULTS ARE CLEAR PROOF OF THE INDUSTRIAL EXPERTISE ACQUIRED BY COGEMA AND THE CEA. THE LA HAGUE PLANT'S CONFIRMED TROUBLE--FREE OPERATION ALLOWS US TO CONFIDENTLY CLAIM THAT REPROCESSING COSTS ARE NOW UNDER CONTROL.

1.3. NUCLEAR SERVICES AND MAINTENANCE

THE FRENCH NUCLEAR INDUSTRY ALSO SPANS THE ENTIRE FIELD OF NUCLEAR SERVICES AND MAINTENANCE WHOSE MARKET, IT MUST BE STRESSED, IS OF THE SAME ORDER OF MAGNITUDE THAN THE FUEL CYCLE MARKET. THIS MARKET INCREASES STEADILY WITH THE NUMBER OF PLANTS COMING INTO OPERATION AND COULD FURTHER EXPAND SIGNIFICANTLY THROUGH EXTENSION OF THEIR LIFE-TIME. THE FRENCH COMPANIES INVOLVED IN THIS AREA ARE :

- FRAMATOME AND TECHNICATOME WHICH HAVE SPECIALIZED DEPARTMENTS FOR NUCLEAR MAINTENANCE AND RENOVATION, FOR SPECIAL WORK IN NUCLEAR ENVIRONMENTS AND FOR REACTOR DECOMMISSIONING OR DISMANTLING,
- THE SAME TWO COMPANIES PLUS INTERCONTROLE HAVE SUBSTANTIAL KNOW-HOW, RESOURCES AND EXPERIENCE IN NON DESTRUCTIVE TESTING,
- RADIOACTIVE WASTE PROCESSING AND PACKAKING IS A LONG-STANDING AREA OF BUSINESS FOR TECHNICATOME AND FOR SGN, A SUBSIDIARY OF COGEMA,
- AND THE STMI COMPANY IS SPECIALIZED IN WORK UNDER RADIATION DECONTAMINATION, AND WASTE PROCESSING AND STORAGE.

THE OBVIOUS BENEFITS FROM BUILDING SERIES OF STANDARDIZED PWR UNITS IN FRANCE HAVE BEEN MATCHED BY EQUAL BENEFITS WHEN DEVELOPING TOOLS AND TECHNIQUES FOR REACTOR MAINTENANCE. EXAMPLES INCLUDE SHOTPEENING AND ROTOPEENING FOR STEAM GENERATOR TUBES, AND WATER-LANCING FOR CLEANING THEIR TUBESHEETS. IN CONCRETE TERMS, WE HAVE BEEN ABLE TO REDUCE WORKING TIMES AND DOSES IN RADIATION AREAS FOR MAINTENANCE STAFF, AND ALSO AUTOMATE MANY MAINTENANCE AND INSPECTION TASKS.

1.4. FAST BREEDER REACTORS

CONSISTENT WITH ITS LONG TERM POLICY OF INCREASING THE COUNTRY'S ENERGY INDEPENDENCE, FRANCE HAS ALSO STEADILY PURSUED COHERENT EFFORTS TO DEVELOP FAST BREEDER REACTORS. COMING AFTER THE RAPSODIE 40 MWTH MATERIAL TESTING REACTOR AND THE PHENIX 250 MWe DEMONSTRATION PLANT, THAT OPERATED RESPECTIVELY FOR 15 AND 13 YEARS, THE 1,200 MWe SUPERPHENIX UNIT, THE WORLD'S LARGEST FBR POWER PLANT, WAS CONNECTED TO THE FRENCH NATIONAL POWER GRID IN EARLY 1986. IT'S NOW UNDERGOING POWER ASCENSION TESTING. BUILT ON A MULTINATIONAL EUROPEAN BASIS, NOTABLY BY THE FRENCH COMPANY NOVATOME, A SUBSIDIARY OF FRAMATOME, AND BY THE ITALIAN COMPANY NIRA, SUPERPHENIX IS A MAJOR MILESTONE ON THE PATH TO DEVELOPMENT OF FULLY-COMPETITIVE FBR PLANTS.

THE STRATEGIC IMPORTANCE OF FBRS HAS LED FRANCE TO PROMOTE CONTINUED DEVELOPMENT WITHIN A FRAMEWORK OF MULTINATIONAL EUROPEAN COOPERATION, ALSO OPEN TO OTHER INTERESTED COUNTRIES. DISCUSSIONS ARE UNDERWAY ON THE CONSTRUCTION OF THE NEXT FBR POWER PLANT AND ON A REPROCESSING PLANT FOR SPENT BREEDER FUEL.

1.5. NUCLEAR GENERATED ELECTRICITY

THE HIGH AVAILABILITY OF OUR NUCLEAR POWER PLANTS AND THE LOW COST OF PRODUCED ELECTRICITY ARE ALSO PROOFS OF SUCCESS FOR THE FRENCH NUCLEAR INDUSTRY.

BY THE END OF 1985, THE ON-LINE POWER PLANTS IN FRANCE, WITH A COMBINED CAPACITY OF 40 GWe, OPERATED AT AN AVERAGE AVAILABILITY FACTOR OF 81%. THIS EXCELLENT FIGURE IS DUE TO MAXIMUM STANDADIZATION OF PLANT DESIGN, CLOSE MONITORING OF PLANT OPERATION AND EFFICIENT FEEDBACK OF OPERATING EXPERIENCE. DEVELOPMENT OF THE REACTOR ADVANCED MANEUVERABILITY PACKAGE OR RAMP FOR PWR PLANT UNITS HAS ALLOWED THEM TO BE MANAGED WITH GREATER FLEXIBILITY THAN FOSSIL-FUELED POWER PLANTS. IT HAS ALSO HELPED INCREASE THE SHARE OF NUCLEAR POWER IN TOTAL FRENCH ELECTRICIY PRODUCTION TO 65%, A FIGURE SIGNIFICANTLY HIGHER THAN INITIALLY PLANNED.

THE ELECTRICITY PRODUCED BY OUR NUCLEAR POWER PLANTS IS ONE OF THE CHEAPEST IN THE WORLD. IN FACT, NUCLEAR-GENERATED BASE-LOAD ELECTRICITY IS, IN FRANCE, 30% CHEAPER THAN ELECTRICITY FROM COAL FIRED PLANTS.THIS ACHIEVEMENT IS DUE LARGELY TO THE EFFICIENCY OF THE FRENCH NUCLEAR INDUSTRY AND THE COST-REDUCING IMPACT OF BUILDING SERIES OF STANDARDIZED PLANT UNITS WITH SHORT CONSTRUCTION TIMES.

OUR NUCLEAR POWER PROGRAM HAS ALSO HAD GROWING BENEFITS IN TERMS OF FRANCE'S BALANCE OF TRADE. IN 1985, IT REDUCED ENERGY IMPORTS BY ABOUT 50 MTEP AND ENABLED US TO SELL TO NEIGHBORING-COUNTRIES,MORE THAN 20 TWh WHICH HAD A POSITIVE IMPACT OF ABOUT 4,5 BILLION FF ON THE TRADE BALANCE.

II - PROSPECTS

HAVING PRESENTED SOME OF THE MAIN ACHIEVEMENTS OF THE FRENCH NUCLEAR INDUSTRY, I SHALL NOW LOOK AT FUTURE PROSPECTS.

IT SHOULD FIRST BE REMEMBERED THAT ANY NUCLEAR POWER PROGRAM GOES THROUGH THREE PHASES :

- IN THE FIRST PHASE, IT AIMS AT REDUCING OR ELIMINATING THE CONTRIBUTION OF IMPORTED OIL IN ELECTRICITY PRODUCTION WHILE ALSO SATISFYING GROWING ELECTRICITY DEMAND,

- IN THE SECOND PHASE, IT IS GEARED TO MEETING EXCLUSIVELY THE CONTINUING GROWTH IN ELECTRICITY DEMAND,

- LATER, IT MUST NOT ONLY SATISFY GROWING DEMAND BUT ALSO REPLACE ANY EXISTING PLANTS NEARING END-OF-LIFE AND DECOMMISSIONING.

2.1. WORLD MARKET

IF WE NOW LOOK AT THE WIDER WORLD SCENE, WE SEE THAT THE CONTRIBUTION OF NUCLEAR POWER TO OVERALL ELECTRICITY PRODUCTION IS INCREASING ACROSS THE PLANET AS ADDITIONAL NUCLEAR PLANTS COME ON LINE.

CONSTRUCTION OF THESE PLANTS WAS DECIDED SEVERAL YEARS BACK AND MORE RECENTLY NEW PLANT ORDERS HAVE BEEN FEW AND FAR BETWEEN. THIS IS A DIRECT CONSEQUENCE OF THE CUTBACK IN EXISTING NUCLEAR PROGRAMS IN MANY INDUSTRIALIZED NATIONS, ITSELF TIED TO THE SLOWER-- THAN ANTICIPATED GROWTH IN ELECTRICITY DEMAND. BELGIUM, THE FEDERAL REPUBLIC OF GERMANY, FRANCE, AND JAPAN, FOR EXAMPLE, ALL NOW EXPECT THEIR INSTALLED NUCLEAR CAPACTIES TO GROW MORE SLOWLY THAN ORIGINALLY FORECAST. IN THE UNITED STATES, FOR REASONS SPECIFIC TO THAT COUNTRY, NO NEW NUCLEAR PLANTS HAVE BEEN ORDERED FOR SEVERAL YEARS. ON THE OTHER HAND, COUNTRIES SUCH AS HOLLAND, ITALY AND THE UNITED KINGDOM ARE SERIOUSLY CONSIDERING A RENEWAL IN NUCLEAR PLANT CONSTRUCTION IN THE SHORT TERM, ESSENTIALLY FOR BALANCE OF PAYMENTS OR OTHER ECONOMIC REASONS.

THE MARKETS FOR NUCLEAR SERVICES AND FOR FUEL PRESENT A VERY DIFFERENT PICTURE BECAUSE CLOSELY TIED TO THE NUMBER OF EXISTING PÖWER PLANTS. INDEED, THEY ARE VERY MUCH GROWTH MARKETS. INTERNATIONAL ORGANIZATIONS LIKE THE IAEA AND OECD FORECAST A TOTAL INSTALLED NUCLEAR POWER CAPACITY OF 340 GWe IN THE MARKET-ECONOMY COUNTRIES BY 1995, A CAPACITY ABOUT 50% HIGHER THAN TODAY'S FIGURE. NUCLEAR SERVICES, INVOLVE INCREASINGLY COMPLEX TECHNIQUES AND EQUIPMENT. THE HANDFUL OF REACTOR AND NSSS VENDORS WILL PLAY A LEADING ROLE BECAUSE THEY POSSESS THE NECESSARY KNOW -HOW AND ENGINEERING RESOURCES. THIS WILL PARTLY OFFSET THEIR BUSINESS SHORTFALL DUE TO THE SLOWDOWN IN ORDERS FOR NEW PLANTS.

FINALLY, THE RECENT DROP IN OIL PRICES DOES NOT OBVIATE THE VERY REAL DANGER OF OIL DEMAND AGAIN OUTSTRIPPING SUPPLY WITH AN IMMEDIATE EFFECT ON PRICES. MANY EXPERTS AGREE THAT THIS WILL OCCUR TOWARDS 1995 .IT IS THUS ESSENTIAL THAT WE THEN STILL POSSESS THE INDUSTRIAL RESOURCES TO SATISFY THE INEVITABLE UPSURGE IN NUCLEAR PLANT CONSTRUCTION.

2.2. THE FRENCH NUCLEAR POWER PROGRAM

THE FRENCH NUCLEAR POWER PROGRAM WAS LAUNCHED IN 1974 DURING A PERIOD OF FAST ECONOMIC GROWTH. THE SUBSEQUENT ECONOMIC CRISIS AND SLOWDOWN HAVE SINCE, HOWEVER, LED US TO REVISE OUR FORECASTS. THE SUBSTITUTION OF NUCLEAR ENERGY FOR FUEL-OIL IN PRODUCTION OF ELECTRICITY IS NOW NEARING COMPLETION. GROWTH IN ELECTRICITY PRODUCTION WILL BE FOR END-USE CONSUMPTION IN TRADITIONAL INDUSTRIAL AREAS WHERE ELECTRICITY IS IN DIRECT COMPETITION WITH OIL AND ALSO IN NEW DEVELOPPING AREAS.

AS FAR AS THE EXPORTS OF ELECTRICITY ARE CONCERNED, EDF WILL BE ABLE TO SUPPLY ITS EUROPEAN PARTNERS WITH 30 TO 50 TWh ANNUALLY IN THE 1990s. THESE EXPORTS TAKE INTO ACCOUNT TECHNICAL CONSTRAINTS SUCH AS THE LIMITED CAPACITIES OF INTERCONNECTIONS BETWEEN NATIONAL GRIDS.

CURRENT SCENARIOS SUGGEST A RISE IN FRENCH ELECTRICITY CONSUMPTION FROM 280 TWH IN 1984 TO 400 - 445 TWH IN 1995. COMPARISON BETWEEN SUCH FIGURES AND ACTUAL ELECTRICITY GENERATING CAPACITIES FOR THE CORRESPONDING PERIODS INDICATES THAT, ON AVERAGE CONSTRUCTION OF 1 OR 2 ADDITIONAL NUCLEAR PLANT UNITS SHOULD BE DECIDED IN FRANCE IN EACH OF THE NEXT 15 YEARS.

CONCERNING THE INFLUENCE OF OIL PRICES ON THE COMPETITIVENESS OF NUCLEAR POWER IN FRANCE, A DISTINCTION MUST BE MADE BETWEEN SHORT TERM AND LONG TERM COMPETITIVENESS.

IF ONE COMPARES THE OPERATING COST OF AN EXISTING OIL FIRED PLANT AND AN EXISTING PWR NUCLEAR PLANT OF EQUAL CAPACITY, THE PRICE OF OIL WOULD HAVE TO DROP TO ABOUT 6 DOLLARS PER BARREL BEFORE THE NUCLEAR GENERATED ELECTRICITY BECOMES THE MORE EXPENSIVE.

IN CONSIDERING CONSTRUCTION OF A NEW PLANT, THE PRICE OF OIL WOULD HAVE TO DROP TO ABOUT 10 DOLLARS PER BARREL TO MAKE NUCLEAR POWER UNCOMPETITIVE.

HOWEVER, ANY SUCH FIGURES ARE SIGNIFICANT ONLY IF REPRESENTATIVE OF OIL MARKET TRENDS OVER A LONG PERIOD. IT WOULD BE DANGEROUS TO DECIDE AN INVESTMENT SPANNING A PERIOD OF PERHAPS 10 YEARS EXCLUSIVELY ON THE PRICE OF OIL AT ONE POINT OF TIME, KNOWING AS WE DO THAT OIL PRICES ARE SUBJECT TO FAST AND SUBSTANTIAL FLUCTUATIONS.
AS A CONSEQUENCE, TODAY'S OIL PRICES DO NOT, FOR US IN FRANCE, FUNDAMENTALLY CHANGE THE CALCULATIONS FAVORING NUCLEAR ENERGY FOR ELECTRICITY PRODUCTION.

2.3. FUEL CYCLE

AS FAR AS THE FUEL CYCLE IS CONCERNED, THE CONDITIONS OF NATURAL URANIUM PROCUREMENT IN THE SHORT AND MEDIUM TERM APPEAR TO BE SATISFACTORY. NONETHELESS, THIS IS SUBJECT TO THE MARKET NOT BEING DISTURBED BY POLITICAL DEVELOPMENTS AND TRULY SECURE PROCUREMENT REQUIRES AN ADEQUATE DIVERSITY IN SOURCES OF URANIUM, TO AVOID A SITUATION OF DEPENDENCE ON A VERY SMALL NUMBER OF SUPPLIERS, PLUS ESTABLISHMENT OF LONG-TERM RELATIONS BETWEEN URANIUM PRODUCERS AND THEIR CUSTOMERS. IT MAY BE NOTED THAT BOTH FRANCE AND JAPAN HAVE ORGANIZED THEIR URANIUM PROCUREMENT WITH THIS IN MIND. TAKING A LONGER-TERM VIEW, CONCERN MUST BE EXPRESSED ABOUT THE COLLAPSE IN WORLDWIDE URANIUM EXPLORATION DUE TO THE DEPRESSED STATE OF THE MARKET. UNLESS SELLING PRICES INCREASE ENOUGH TO INDUCE MINING INDUSTRIES TO RESTART THEIR EXPLORATION PROGRAMS, THIS SITUATION COULD LEAD TO FUTURE MARKET INSTABILITY.

CONCERNING ENRICHMENT, THE AVAILABLE TOTAL CAPACITY OF ABOUT 34 M. SWUs PER YEAR AT THE END OF 1985 WAS FAR GREATER THAN THE ACTUAL DEMAND OF AROUND 25 M. SWUs, AND EXISTING STOCKS OF ENRICHED URANIUM ARE EQUIVALENT TO ABOUT TWO YEARS' CONSUMPTION.

THIS SITUATION LEADS TO INTENSE COMPETITION BETWEEN VENDORS OF ENRICHMENT SERVICES. HOWEVER, THE 10.8 M. SWUs PER YEAR EURODIF PLANT IS WELL PLACED BECAUSE IT BENEFITS FROM ECONOMIES OF SCALE AND NUCLEAR ELECTRICITY AT CONTROLLED COSTS. EURODIF IS THUS ABLE TO SUPPLY ENRICHMENT SERVICES TO UTILITIES UNDER HIGHLY SATISFACTORY CONDITIONS AND IS WELL POSITIONED IN THE MARKET UNTIL AT LEAST THE END OF THE CENTURY. IN ADDITION THE FRENCH NUCLEAR INDUSTRY WILL BE TOOLED TO IMPLEMENT NEW ENRICHMENT PROCESSES SUCH AS THE SILVA LASER-BASED PROCESS DEVELOPED BY THE CEA FOR USE BEFORE THE END OF THE CENTURY.

WORLDWIDE CAPACITIES IN SPENT FUEL REPROCESSING LAG BEHIND DEVELOPMENTS IN THE REST OF THE FUEL CYCLE. A FACT THAT IS CLEAR FROM A SIMPLE COMPARISON BETWEEN TODAY'S ACCUMULATED TOTAL OF OVER 26,000 METRIC TONS OF UNREPROCESSED SPENT FUEL AND THE AVAILABLE OR PLANNED CAPACITIES OF REPROCESSING PLANTS.

HOWEVER, IT IS ENCOURAGING THAT MAJOR INDUSTRIAL NATIONS SUCH AS THE FEDERAL REPUBLIC OF GERMANY, FRANCE, JAPAN AND THE UNITED KINGDOM ARE COMMITTED TO INDUSTRIAL-SCALE REPROCESSING. IN FRANCE, COGEMA IS INVESTING HEAVILY IN TWO LARGE PLANTS AT LA HAGUE. THESE INVESTMENTS, FOR WHICH CONSTRUCTION WORK IS PROGRESSING ON SCHEDULE, ARE :

EXTENSION OF THE EXISTING UP2 REPROCESSING PLANT TO INCREASE ITS THROUGHPUT TO 800 METRIC TONS PER YEAR. THIS PLANT WILL BE EMPLOYED MAINLY FOR SPENT FUEL FROM FRENCH REACTORS,

CONSTRUCTION OF THE NEW UP3 REPROCESSING PLANT, ALSO WITH AN ANNUAL CAPACITY OF 800 METRIC TONS, AVAILABLE TO FOREIGH CUSTOMERS FROM 1989 OR 1990.

AT THE SAME TIME, AN IMPORTANT MILESTONE IN FBR FUEL REPROCESSING IS THE CONSTRUCTION OF THE TOR DEMONSTRATION PLANT WITH A CAPACITY OF 5 METRIC TONS PER YEAR, NEARING COMPLETION AT MARCOULE IN FRANCE.

LASTLY, EXTENSIVE STUDIES HAVE BEEN ENGAGED IN FRANCE ON REPROCESSING AND STORING RADIOACTIVE WASTES. ANDRA, A SPECIALIZED BRANCH OF THE CEA, RESPONSIBLE FOR RADWASTE MANAGEMENT, HAS PROPOSED NEW SURFACE STORAGE SITES FOR SHORT-LIVED WASTES, TO BE OPERATIONAL TOWARDS 1990. ALSO, SINCE 1978, FRANCE HAS OPERATED AT MARCOULE AN ORIGINAL PROCESS FOR CONTINUOUS VITRIFICATION OF HIGH-LEVEL WASTES. TODATE, NEARLY 500 METRIC TONS OF WASTE GLASSES HAVE BEEN PRODUCED BY THIS PROCESS, WHICH HAS BEEN SELECTED FOR THE LA HAGUE PLANT OF COGEMA AND THE THORP PLANT OF B.N.F.L.

2.4. ADVANCED REACTOR

THE SUCCESS OF FRANCE'NUCLEAR POWER PROGRAM HAS NOT BLINDED US TO THE NEED TO AVOID DEPENDENCE ON IMPORTED URANIUM. THIS EXPLAINS THE IMPORTANCE ATTACHED IN FRANCE TO FAST BREEDER REACTORS. AS WELL AS TO ADVANCED PWRs.

FBRs ARE FUELED EXCLUSIVELY FROM NATIONAL RESOURCES ; THEY OPTIMIZE USE OF NUCLEAR MATERIALS ; AND THEY PRODUCE ELECTRICITY AT COSTS INSENSITIVE TO VARIATIONS IN URANIUM PRICES, THE STRENGTH OF THE DOLLAR OR POLITICAL CHANGES IN FOREIGN COUNTRIES. FBR TECHNOLOGIES DEVELOPED BY CEA AND BROUGHT TO MATURITY BY COMPANIES LIKE NOVATOME, AS DEMONSTRATED BY SUPERPHENIX, WILL HAVE TO GO THROUGH NEW DEVELOPMENT STAGES BEFORE THEY RESULT IN MAKING FBR PLANTS COST-COMPETITIVE WITH PWR UNITS, AT A TIME THAT SHOULD CORRESPOND ROUGHLY TO WHEN THE FIRST OF TODAY'S PWRs WILL REQUIRE REPLACEMENT.

ON THE OTHER HAND, COMPLEMENTARY WORK IS UNDERWAY IN FRANCE ON FURTHER IMPROVING THE PERFORMANCES OF CURRENT PWRs AND ON ADVANCED PRESSURIZED WATER REACTOR DESIGNS WITH ADVANTAGES IN TERMS OF BOTH COSTS AND URANIUM UTILIZATION. CONSTRUCTION OF THESE ADVANCED PWRs COULD BEGIN SOME TIME IN THE 1990s, AND R & D IS BEING PURSUED WITH THIS IN MIND BY THE CEA, FRAMATOME AND OTHER INDUSTRIAL COMPANIES.

CONCLUSION

BEFORE CONCLUDING, LADIES AND GENTLEMEN, I WOULD LIKE TO MAKE A FEW GENERAL REMARKS. NUCLEAR POWER IS TODAY A PROVEN SUCCESS FROM THE TECHNICAL, INDUSTRIAL AND ECONOMIC POINTS OF VIEW. IN BOTH JAPAN AND FRANCE, NUCLEAR-GENERATED ELECTRICITY COVERS A GROWING PROPORTION OF TOTAL ELECTRICITY CONSUMPTION UNDER CONDITIONS OF SAFETY, OPERATIONAL FLEXIBILITY AND COST COMPETITIVENESS THAT, ALREADY EXCELLENT, ARE BEING REGULARLY IMPROVED.

IN THAT CONNECTION, I THINK IT IS WORTHWHILE TO UNDERLINE THAT THE VERY GOOD SAFETY RECORD OF OUR NUCLEAR POWER PLANTS IS TO BE PUT TO THE CREDIT OF OUR NATIONAL SAFETY POLICY AND IN PARTICULAR TO THE EFFICIENT Q.A. STANDARDS ADOPTED BY OUR INDUSTRY. THE EFFICIENCY OF THIS SAFETY APPROACH HAS PROVED SO CONCLUSIVE THAT IT IS IN THE PROCESS OF BEING APPLIED TO OTHER BRANCHES OF OUR NATIONAL INDUSTRY.

OUR TWO COUNTRIES BOTH HAVE AN EFFICIENT INDUSTRY FOR NUCLEAR POWER PLANT CONSTRUCTION AND FUEL CYCLE OPERATIONS. MOREOVER, THE CLOSE COOPERATION BETWEEN OUR TWO NATIONS HAS ALLOWED US TO MUTUALLY BENEFIT FROM OUR COMBINED OPERATING EXPERIENCE, AND SURELY THE BEST CONFIRMATION OF ITS VALUE WOULD BE TO NOT ONLY PURSUE THIS COOPERATION BUT ALSO EXTEND IT TO ADDITIONAL AREAS.

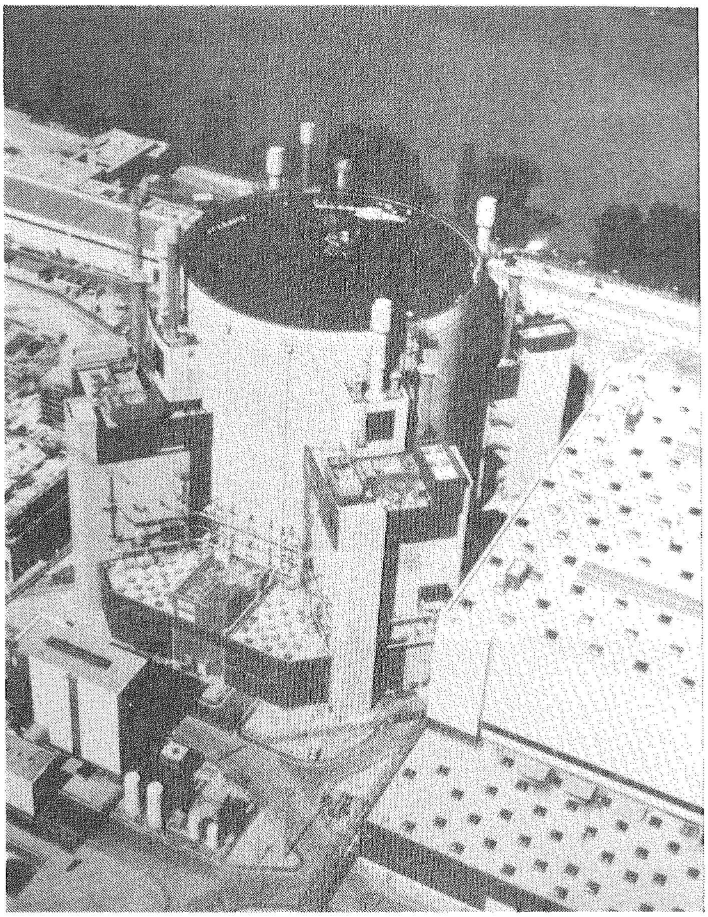
THE CONFIRMED SUCCESS OF NUCLEAR POWER ALONGSIDE THE RECENT SPECTACULAR AND TEMPORARY DROP IN OIL PRICES UNFORTUNATELY ENCOURAGES THE TEMPTATION TO FAVOR SHORT-TERM INTERESTS AND RELAX EFFORTS TO CONTINUE REDUCING DEPENDENCE ON OIL. FAILURE TO RESIST THIS TEMPTATION WOULD BE DANGEROUS FOR BOTH FRANCE AND JAPAN, NEITHER OF WHICH HAS SUBSTANTIAL DOMESTIC OIL OR COAL RESOURCES. IN THE MEDIUM OR LONG TERM, IT IS CERTAIN THAT THE PRESENT REDUCTION IN OIL EXPLORATION WILL TRANSLATE INTO RENEWED TENSION AND PRICE INCREASES IN THE OIL MARKET.

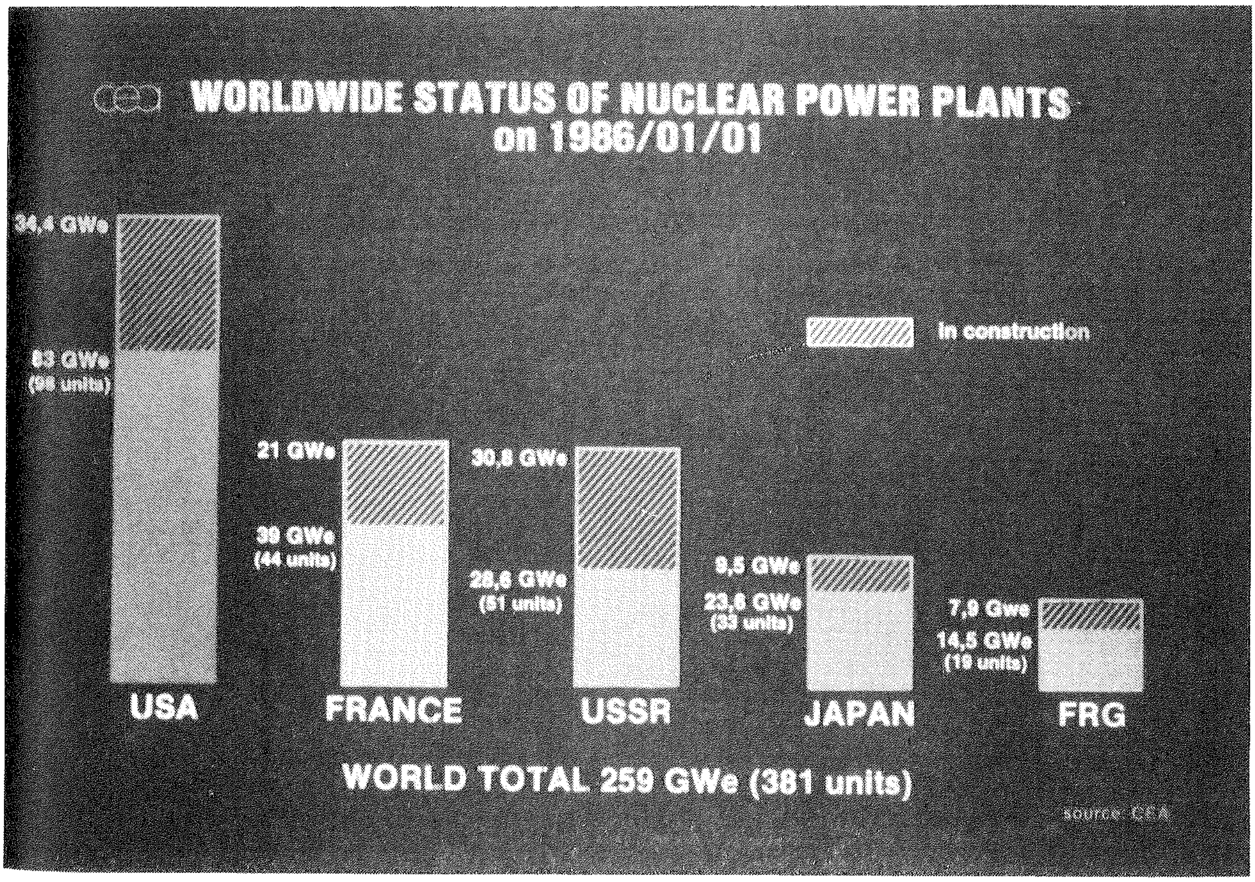
IN THE MEANTIME, EFFORTS ARE NECESSARY TO ADAPT OUR NUCLEAR INDUSTRIES TO CURRENT OVERCAPACITIES, ESPECIALLY FOR PLANT CONSTRUCTION. WE MUST PRESERVE OUR INDUSTRIAL CAPABILITIES IN READINESS FOR THE FORESEEABLE REACCELERATION OF NUCLEAR PROGRAMS BEFORE THE END OF THE 1990s.

WE MUST ALSO, RIGHT NOW, DEVELOP THE NEW TECHNOLOGIES THAT WILL MAKE NUCLEAR ENERGY THE ENERGY OF THE TWENTY-FIRST CENTURY. THE JAIF DECISION TO ORGANIZE THIS WEEK IN TOKYO AN INTERNATIONAL SYMPOSIUM ON ENHANCING LWR TECHNOLOGIES IS THUS MOST TIMELY.

BOTH COMMITTED TO IMPROVED UTILIZATION OF URANIUM AND PLUTONIUM, THE RAW MATERIALS OF THE NUCLEAR INDUSTRY, FRANCE AND JAPAN HAVE DEVELOPED, OFTEN TOGETHER, SPENT FUEL REPROCESSING, ADVANCED ENRICHMENT PROCESSES, ADVANCED PWRs AND FAST BREEDERS. DEPLOYMENT OF THESE TECHNOLOGIES IS CENTRAL TO ANY FORWARD-LOOKING POLICY OF ENERGY SOURCE DIVERSIFICATION IN WHICH NUCLEAR POWER IS INTENDED TO CONTINUE PLAYING AN ESSENTIAL ROLE.

TO CONCLUDE WITH, LET ME TELL YOU THAT I AM CONFIDENT THAT BOTH OUR NUCLEAR INDUSTRIES HAVE THE NECESSARY COMMITTMENT AND RESOURCES TO MEET THE PRESENT TECHNICAL AND ECONOMIC CHALLENGE, WHICH DOUBTLESS WILL EVENTUALLY TRANSLATE INTO SUBSTANTIAL BENEFITS : BECAUSE AS YOU SAY "AMÉ FUTTÉ JI KATAMALU".

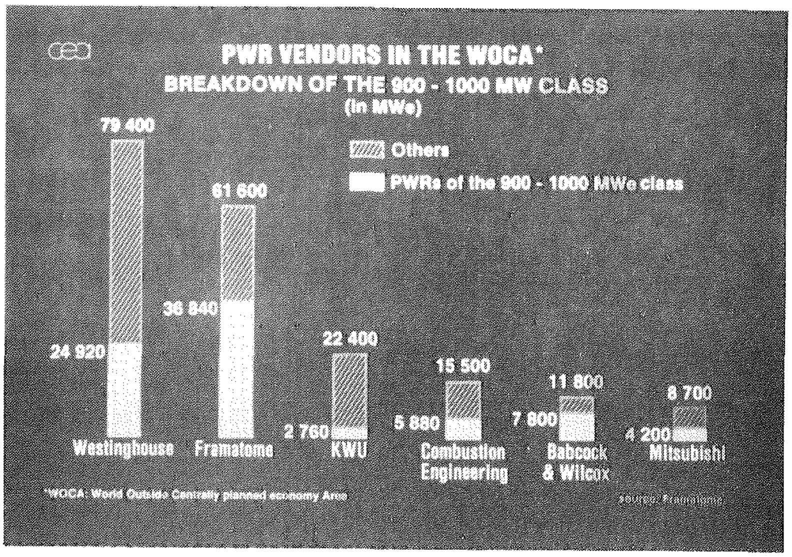




WORLDWIDE STATUS OF NUCLEAR POWER PLANTS on 1986/01/01

WORLD TOTAL 259 GWe (381 units)

source CEA



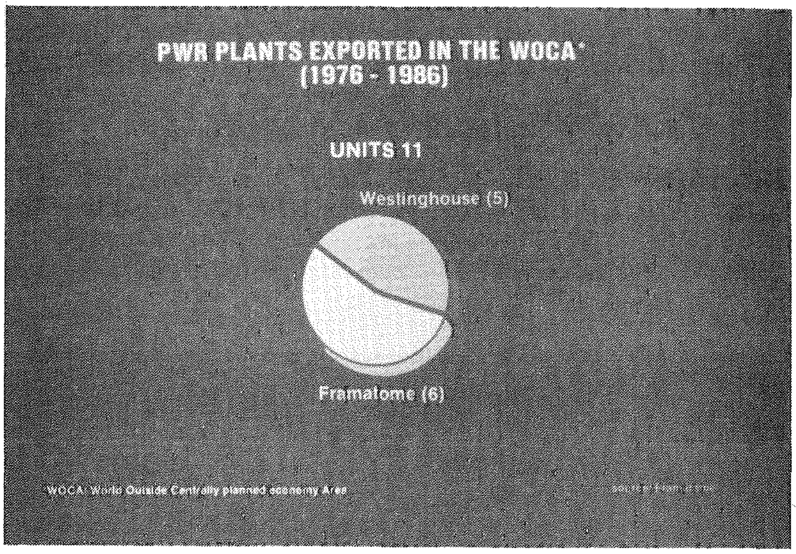
PWR VENDORS IN THE WOCA*

BREAKDOWN OF THE 900 - 1000 MW CLASS

(in MWe)

*WOCA: World Outside Centrally planned economy Area

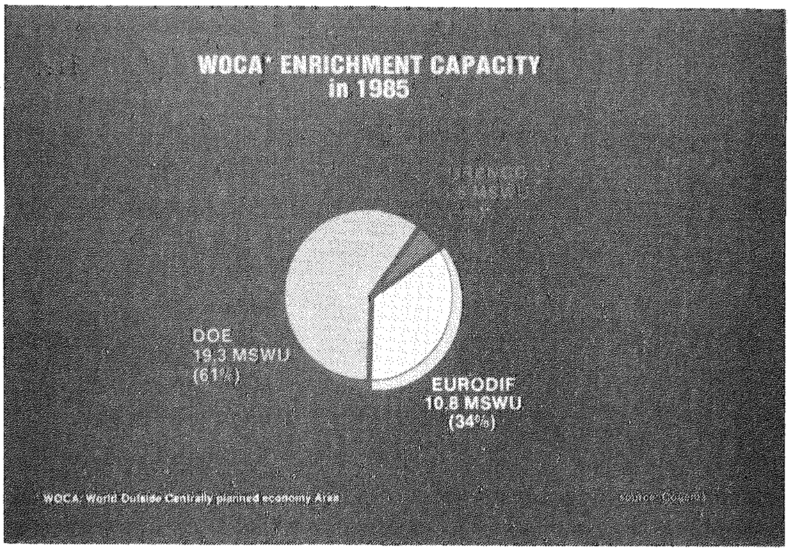
source: Framatome



PWR PLANTS EXPORTED IN THE WOCA*

(1976 - 1986)

WOCA: World Outside Centrally planned economy Area

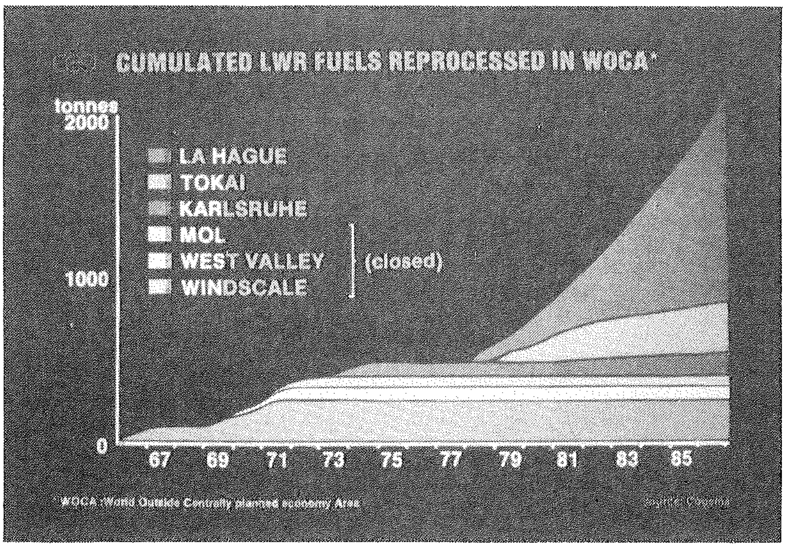


WOCA* ENRICHMENT CAPACITY

in 1985

WOCA: World Outside Centrally planned economy Area

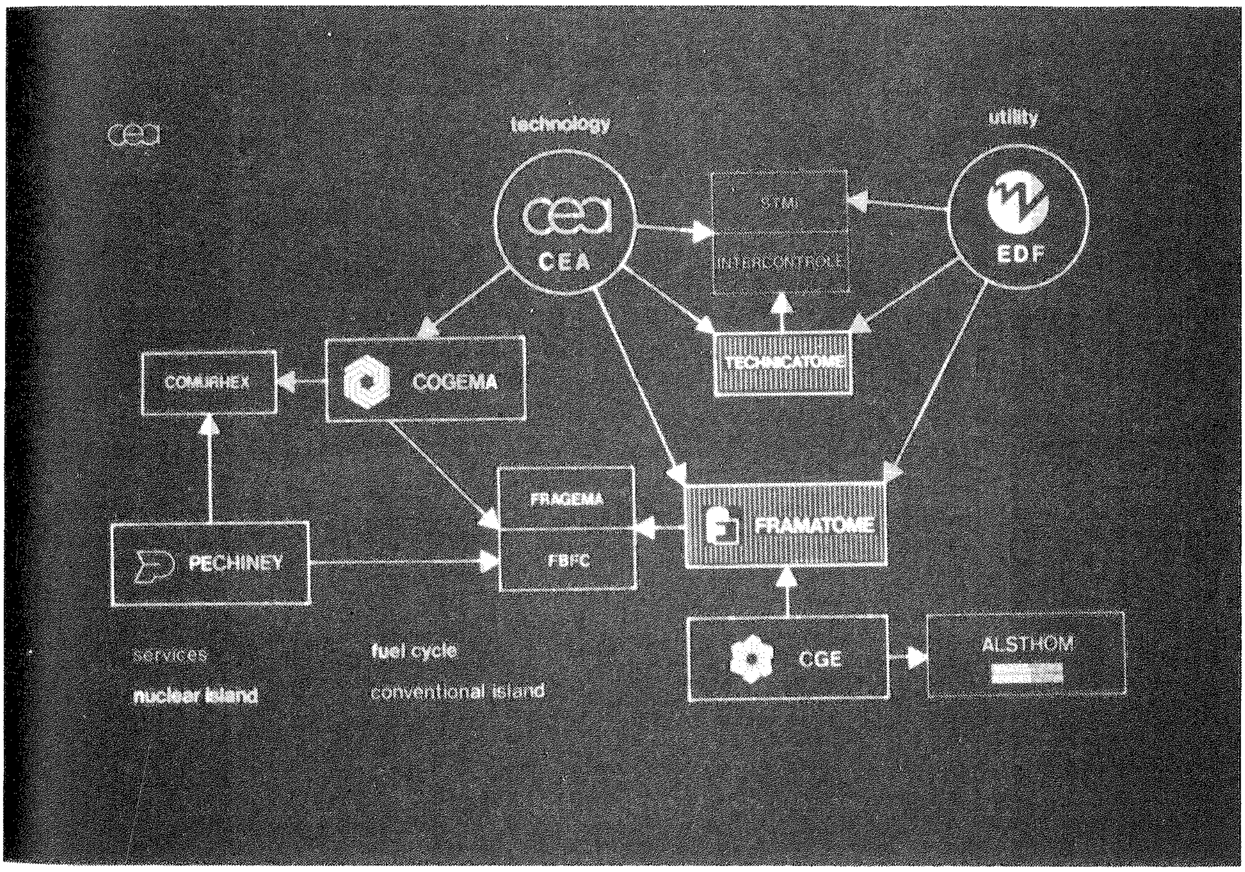
source: Cogema



CUMULATED LWR FUELS REPROCESSED IN WOCA*

* WOCA : World Outside Centrally planned economy Area

source: Cogema



technology

utility

CEA

EDF

STMI

INTERCONTROLE

TECHNICATOME

COMURHEX

COGEMA

FRAGEMA

FBFC

FRAMATOME

PECHINEY

CGE

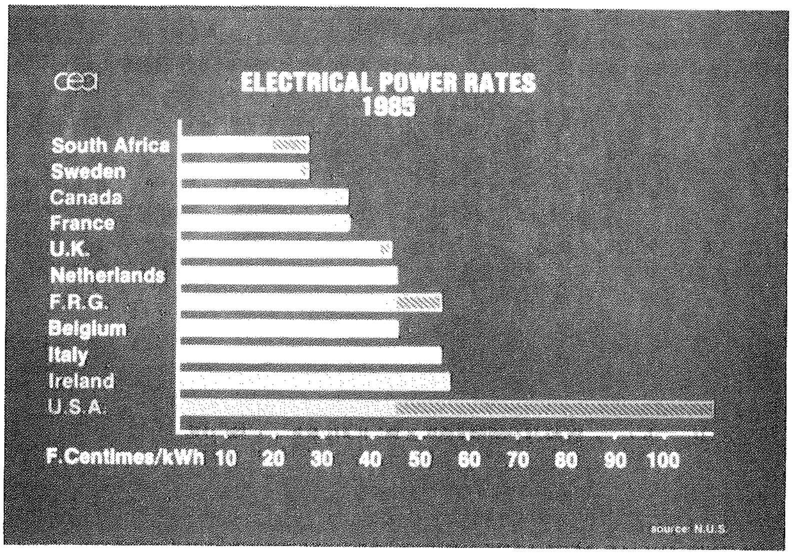
ALSTHOM

services

nuclear island

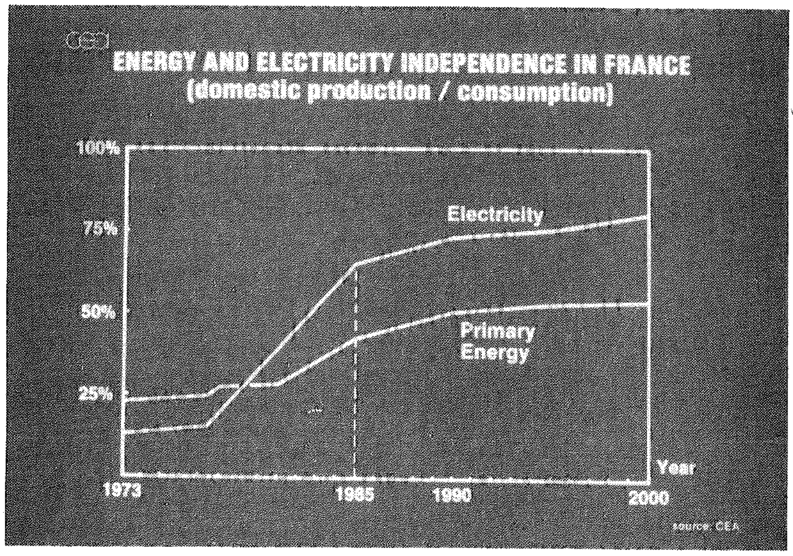
fuel cycle

conventional island



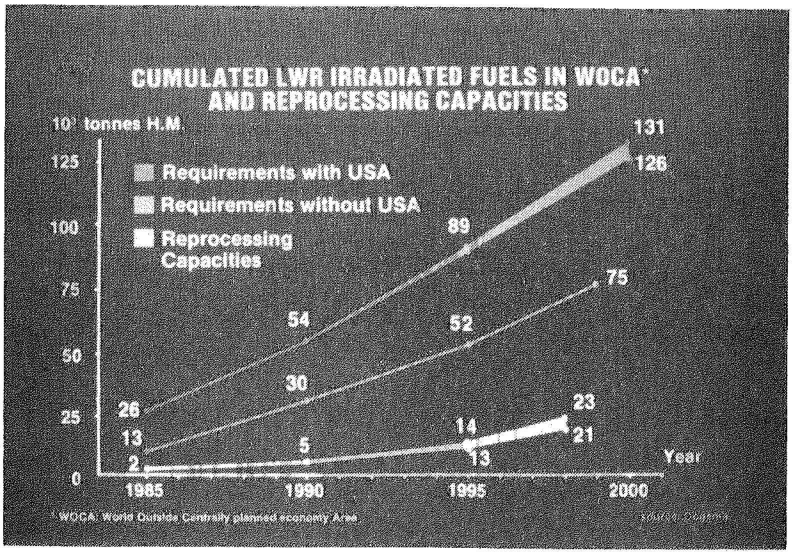
ELECTRICAL POWER RATES 1985

source: N.U.S.



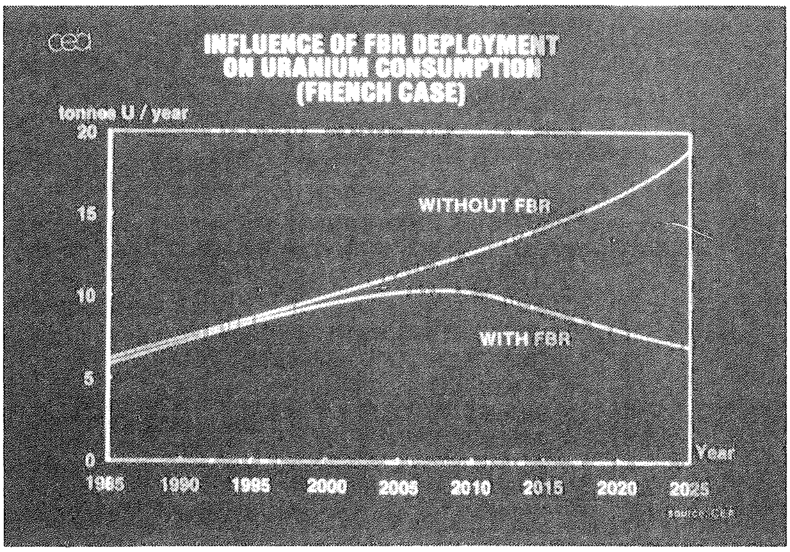
ENERGY AND ELECTRICITY INDEPENDENCE IN FRANCE (domestic production / consumption)

source: CEA

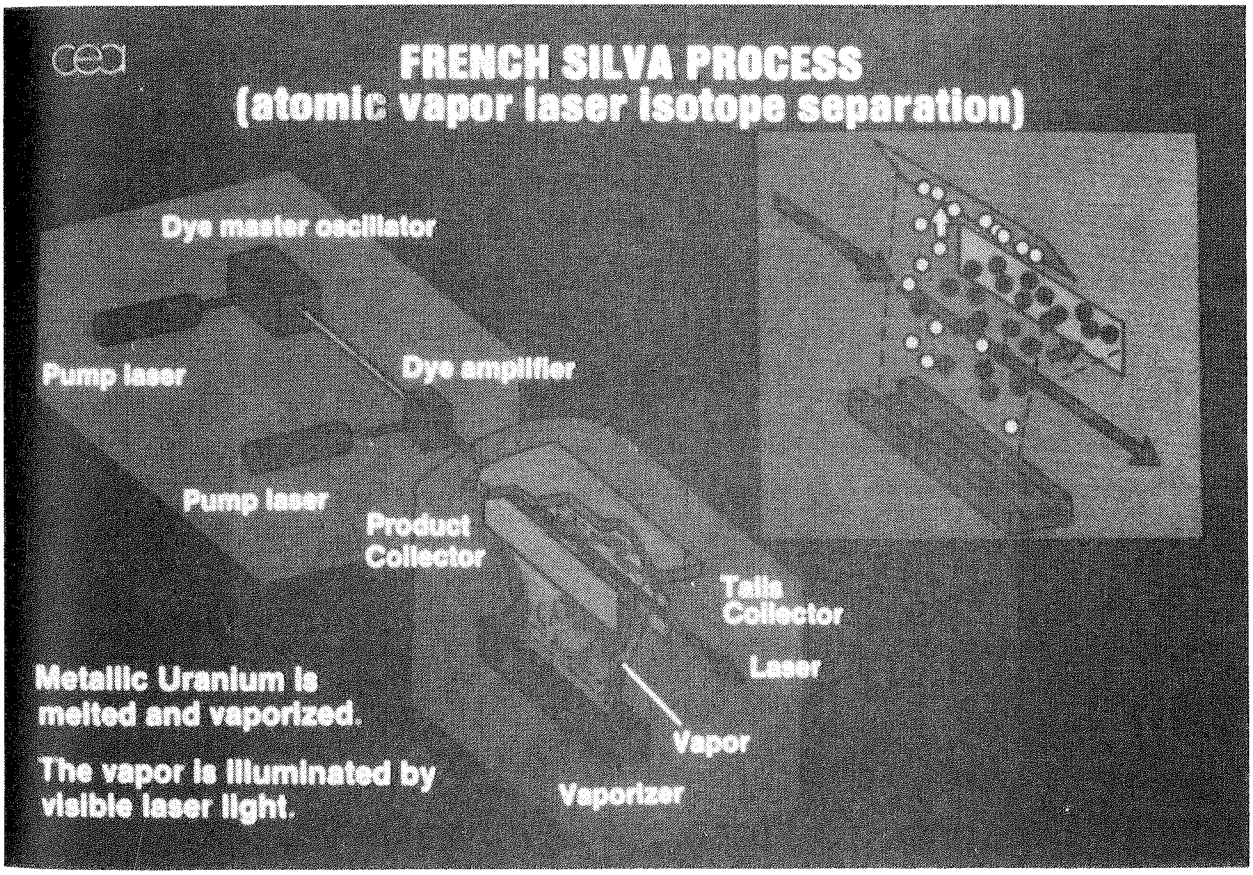


CUMULATED LWR IRRADIATED FUELS IN WOCA* AND REPROCESSING CAPACITIES

* WOCA: World Outside Centrally planned economy Area



INFLUENCE OF FBR DEPLOYMENT ON URANIUM CONSUMPTION (FRENCH CASE)

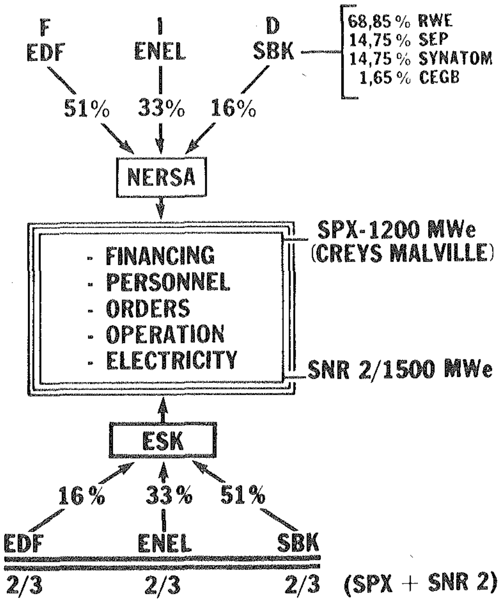


FRENCH SILVA PROCESS (atomic vapor laser isotope separation)

Metallic Uranium is melted and vaporized.

The vapor is illuminated by visible laser light.

THE EUROPEAN BREEDER COOPERATION



10 JANUARY 1984: EUROPEAN AGREEMENT OF COOPERATION ON FAST NEUTRON REACTORS (FBR)

COUNTRIES: FRANCE, BELGIUM, WESTERN GERMANY,
GREAT BRITAIN, ITALY

INVOLVES: OPTIMIZING OF R & D
AGREEMENT for DESIGN/CONSTRUCTION OF FUTURE FAST BREEDERS
COMPLETE EXCHANGE OF INFORMATION

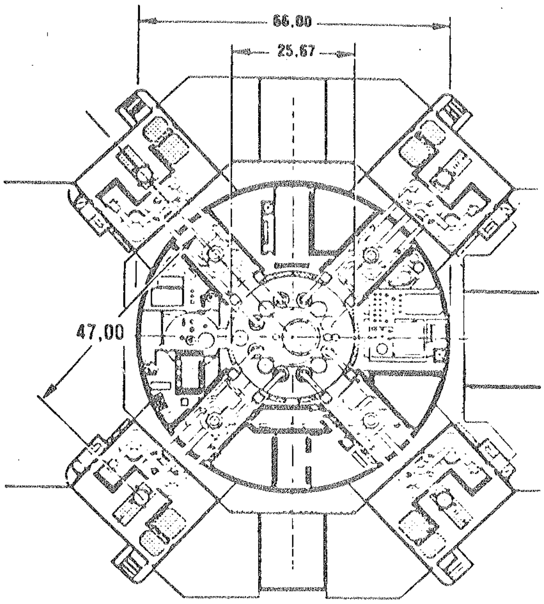
PROMOTION OF INDUSTRIAL COOPERATION

PROMOTION OF COLLABORATION BETWEEN ELECTRICITY UTILITIES

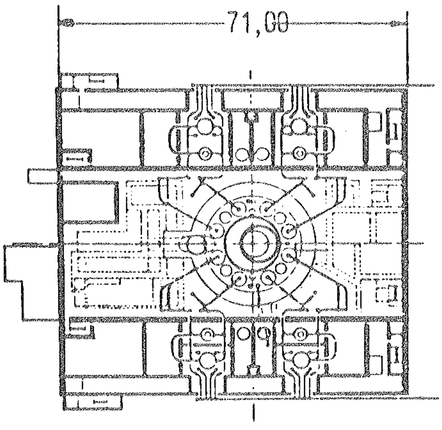
PUBLIC RELATIONS

ALSO INCLUDES THE FUEL CYCLE

Advantage of extending this cooperation to the United States and Japan



SUPERPHENIX 1



SUPERPHENIX 2

日本の原子力開発の原点と展望

原子力委員会
委員長代理　向坊　隆

ただ今はルノン長官から自信にあふれたフランスの原子力開発の状況をうかがいまして大変深い印象を受け，我々にとっても非常に刺激になったと思っております。今朝ほど有澤先生および原子力委員長が，いろいろ行き届いたお話をなさいましたので，委員長代理である私の話すことがなくなったんじゃないかと思って，実は困っている次第でございます。

御承知のように，原子力産業会議も原子力委員会も今年で創立３０周年を迎えますが，この３０年をふりかえって，いろいろと反省して，改めるべきところは改めて，今後の開発に資したいと，そういうちょうどよい時期でもあります。我が国では，だいぶ先の将来をながめて，それで１０年くらいの長期計画というものをたてまして，それを約５年毎に改定してまいったことは，御存知の通りでございますが，今年がちょうどまたその５年毎の改定の時期にあたっておりますので，この３０年の反省をふまえ，そうして現状，将来を見渡して，長計の改定作業に入ろうとしているところでございます。この機会に原子力産業会議で，このような盛大な大会を開いていただきまして，世界の情勢をうかがう機会が与えられましたことは，まことに我々にとってもありがたいことだと思っている次第でございます。

この長期計画の改定作業は我が国では，委員会組織をいくつもつくりまして大勢の方の意見を十分うかがいまして，それを最後に原子力委員会でまとめて長期計画という形で発表することになっておりまして，ちょうど５月頃からこの作業を始めることになっております。したがって，その作業を始める前に，私が何か具体的なことを申し上げるのも，あまりよくないことでありまして，その点からも私としてはなかなかお話をしにくいような気もするわけでございますが，大臣のお話ともなるべく重複しないように，そしてこれから始まる長期計画の議論にあまり余計な先見を与えることのないように，工夫しながら，ただ今考えていることなどを少し申し上げてみたいと思うのでございます。これはまだ委員会で議論しているわけではございませんので，委員会の意見としてではなく，私個人の意見ということで，お聞きいただきたいと存じます。

さて，この３０年前をふりかえってみますと，エネルギー資源のまったくない日本といたしまして，将来のエネルギーの安定供給を保証できるかもしれないというような期待をもたれて，この原子力開発が始められたわけでございます。その頃は石油の値段が今に比べれば非常に低い，１０分の１ぐらいの低い時代だったわけでございますが，そういう時期にあえて，この石油を置き換える一つの技術，非常に大きな技術体系として，これに取り組んだのでございますので，その時始められた方々の意気込みは非常に大きなものだったと思うのであります。その事業を始めるにあたりまして，いくつかの基本的な原則を当時の原子力委員会，国会，その他でたてられたわけでございまして，それを少しふりかえってみたいと思うのであります。

第１には，エネルギー資源のない日本の，将来のエネルギー供給の安定というものが目的で，原子力開発を始めるわけでありますから，一つの目標としては，できるだけ早く自立体制を確立することであります。外国に頼らないで，ウランが日本にありませんのでウラン鉱石を輸入するところは仕方ないとしても，それから先はできるだけ自立の体制を早く作り上げようという，非常にアンビシャスな計画があったわけであります。それから第２に，原子爆弾の被害を受けた国といたしまして，原子力はこれを絶対に軍事利用しないで，平和利用に厳重に限定していこうということが基本法則としてうたわれたわけでございます。第３に，これは非常に大きな計画でございますから，ばらばらに分散した力でやったのではとてもできないということで，国として計画的に進めていかなければなりません。それから原子力は核分裂を行った後は必然的に放射能の強い廃棄物ができますので，これを人間環境から厳重に隔離するなど安全性の問題を第一に大事な条件として考えていこうと，こういったようないくつかの基本線をはっきりとうたいました。

そして現在までのこの３０年間，この基本線だけはくずさないで進んできたと思っている次第でございます。その結果として，今どうなっているのかと申しますと，細かい数字の問題は別といたしまして，原子力発電は比較的順調に伸びまして，先程からたびたびお話が出てまいりますように，電力の４分の１ぐらいを提供できるようになりました。石油が今回非常に値下がりするまでは，石油よりもずっと安い電力コストで発電できるようになりました。それから発電所の稼働率もフランスにはまだ及びませんが，昨年度は平均して７６％の稼働率であったというようなことも発表されておりまして，一応の順調な成長をとげたわけであります。これにつきましては，電力，メーカー，規制官庁など非常に大勢の人たちの大きな努力によって，ここまできたわけでございまして，心から敬意を表し

たいと思うものであります。それから，その間，この平和利用に限定するという条件もきつく守られて今日にいたっておりますし，先程長期計画のことを申し上げましたけれど，十分とは言えないにしても，計画的に進めてきたということは言えるんじゃないかと思うのであります。

ただ，問題は，始めた最初の条件でありますところの，エネルギーの安定供給の骨組となるものとして，できるだけ早く自立体制をとりたいという意味から，日本の現在の状況を見てみますと，ルノン長官のお話にありましたように自信をもって言えるような体制は，残念ながらまだできておらないと言わざるを得ないわけであります。濃縮につきましては，９割ぐらいがアメリカに濃縮サービスを頼んでおりますし，１割ぐらいがフランスにお願いしております。再処理も，小さなプラントが東海で動いてはおりますけれども，発生する使用済み燃料に比べれば，自分でやれる量はきわめてわずかでありまして，大部分はフランスとイギリスに再処理のサービスをお願いしております。そういう風な状況を見ますと，これはとてもまだ自立体制に入ったとは言えないのであります。

しかし，今までのいろいろな努力のおかげで，基礎研究から一歩出まして，これから実用に向けて一段進んだ段階に入ろうとしております。そういう意味でも，一つの転換期と申しますか，次の段階に入ろうとしているところに来ているわけであります。濃縮プラントは，まだそう大きなものではございませんけれども，年に１，５００トンＳＷＵ程度の工場をつくろうとしておりまして，これはその頃の需要のおそらく６分の１ぐらいになるのでしょうか，その程度はできます。それから再処理の方は，またフランスの御協力を得ながらつくることになると思いますけれども，できるだけハードな部分は日本でつくるという努力をいたしまして，下北半島に年８００ｔのプラントを建てようとしているところでございます。

それから，日本ではエネルギーの元として，原子力をやる以上は国内に産出しないウランはできるだけ活用しなければならないというので，初めから再処理をして，プルトニウムを燃料として使うというプルトニウム・サイクルと申しますか，ウラン・プルトニウム・サイクルと申しますか，それを一つの基本線にしているわけでございます。そのプルトニウムの利用につきましても，今までできるだけの努力をしてきたわけでありまして，現在小型のものでありますが，敦賀で動いております新型転換炉原型炉「ふげん」は，ともかくプルトニウムを燃やしながら電力を発生しているわけでございますし，これの次の段階の２倍ぐらいの大きさのものをやはり東北の方にこれから建設しようとしております。

それから，高速増殖炉につきましては，かなり長期にわたりまして，１００ＭＷｔｈ程度の実験炉が順調に動いたものですから，今度は敦賀に実際の発電炉（原型炉）の建設が始まったところであります。

現在，いろいろな自立体制に向けてのプロジェクトが次の段階に入ろうとしているという意味で，一つの転換期でもあり，今度の長計は非常に重要な意味をもっておると考えている次第でございます。そこで最近，その長期計画をつくるのにあたりまして，いきなり長期計画に入るのではなく，少し前から今度の長期計画ではどういうことを議論したらよろしいだろうかということで，長期計画の準備委員会のようなものをつくりまして，約1年も前から作業を進めてまいりました。近いうちにその報告書が発表になると思いますが，かなり慎重にかまえて，一つ将来のために意義のある長期計画をつくろうという意気込みでいるわけでございます。問題はまだまだたくさんあるわけでございますけれども，その中のいくつかの重要な問題について申し上げて見たいと思うのであります。

第1は，原子力発電が２，５００万ｋＷという程度に非常に大きな，電力の4分の1も供給するような大きな規模になりましたのと，それから最近の石油の急速な値下がりがありましたのと，両方合わせまして，原子力の経済性をもっとよくしようという声が高まっております。これからは電力，メーカーを中心に軽水炉の改善にあたって，経済性が今までよりも重要視されるようになることは間違いないと思われるのでございます。これは当然のことでありますけれども，委員会の立場の方から考えますと，その場合に，いささかでも安全性を犠牲にして，経済性の方に力が行き過ぎないように，その点は十分一つ注意をしながら進めていただきたいと思うのであります。それから，この経済性についてのもう一つの問題は，本来原子力を始めたのは，国のエネルギー供給に関連しての，セキュリティーを重視して始まったものでございますので，この経済性だけを考えるのではなくて，この自立した，安定した供給を確保するという意味との兼合いのようなことを常に念頭におく必要があるのではないかと思います。これは数量でコストとして表すのは難しいかもしれませんが，その点を無視して経済性のみを追うということについては，慎重であってほしいと私たちは願っているのであります。日本の場合には，今でもフランスほどに全力投球と申しますか，国をあげて原子力に集中するというほどの集中の仕方をしておりませんでしたので，フランスほどの急速な発展は得られなかったのでございますが，これからもいろいろな点を慎重に考えながら進むとすれば，やはり２１世紀に向けても原子力が急速に増えるということは日本ではおこらないだろうと思うのですね。なんと申しますか，

ステディーな増加の仕方をしながら進んでいくと思います。ということは，やはり日本のエネルギーの供給については，これからも他のエネルギー源との，ベストミックスと申しますか，もっとも適切な組み合わせで，日本の需要を満たしていくという考え方をもつことになるだろうと思うのであります。

第2に，原子力は初めからそう短い寿命のものとも思っていなかったわけですけれども，最近になりますと，ますます軽水炉時代と申しますか，核分裂のエネルギーに相当なパーセントを頼る時代は相当長そうであるという見方が出てきているわけです。5年や10年の問題ではなくて，もっと長期にわたって日本のエネルギーで重要な位置を占めるということになりますと，基礎研究を改めて重要視していくということが大事なのではないかと思います。日本で原子力を開始しました時には，外国に遅れて始めましたし，基礎研究とそれから開発研究，実用化はアメリカから教わり，あるいはイギリスから原子炉を買うという風なことで進んだわけですけれども，基礎研究，開発，実用化というものをかなり平行的にすすめたのでありまして，その当時は基礎研究にもかなりの力が入っておったと私は思っているわけです。たまたま，私は初めの頃，原子力研究所と兼任しておりましたので，かなりの基礎研究に重点がおかれていたことは，よく知っているわけでございますが，だんだん開発が進んでまいりますと，実用化のために大事な開発研究が次から次へと出てくるものですから，限られた予算と人員がそちらへだんだんとられまして，基礎研究が少しおいていかれるようなことが絶えず私としては心配になってきたのであります。外国の先進国では，日本よりも先に始められたせいもありまして，基礎研究の方も非常にしっかりやってこられているのに比較して，どうしても日本の場合には見劣りがするのではないかという気がするのであります。

これほど原子力発電が進んで，いったい基礎研究があるのかという見方もあるのかと思うのですけれども，私は十分いろいろな基礎研究が残っておってですね，将来のためにそれらを，地味ではありますけれども，しっかりやっておくということは非常に大事なことではないかと思うのであります。それらには，たくさん挙げることも可能でございますけれども，高レベル廃棄物の処理にいたしましても，ただガラスに固めて地面の下に埋めるという道だけを探るんではなくして，もっとすすんだ高レベル廃棄物の処理というものを考えられないかどうかで，簡単に言えば半減期の長さによる群分離と称するもの，それから先につながるいろいろな基礎的な仕事がありうると思うのであります。それから，超ウラン元素についての基礎研究なども日本は大変遅れているのではないかと思うのです。す

ぐ実用につながるとは思いませんけれども，長い将来のためには必要なのではないかと思います。それから軽水炉があれだけ技術が進み，非常に進んだ装置になって，規模があれだけ大きなものになっていながら，炉の熱効率というものが，問題にされないというのは，私は熱機関の専門家ではないのでございますけれども，火力発電よりも１０％も低い効率のままで，これだけ大きな発電システムができつつあるというのはどうも不思議でしょうがないのであります。これを高くするということは，容易ではないということは，当然理解できるのですけれども，そちらに向けての基礎研究というものは，どれだけ行われているのか，私は少し心配しているわけであります。

そういったように，今度の長計にあたって，グループでも作って考えてみますと，基礎研究の重要な分野というものは，相当出てくるだろう思います。これはなにも基礎研究ですから，日本だけでやる必要はないので，おそらく国際的な共同研究として相当な部分が行われていいと思いますけれども，そういうものは是非やる必要があるのではないかと思うのであります。

それから第３に，日本の今まで進んでまいりました研究開発実用化というシステムが先程ルノン長官の御説明をうかがいましたフランスのシステムとは非常に違っておりますし，アメリカとも違っておりますし，いわば日本独自のシステムでやってきたわけであります。それには日本の背景を考えて非常によかった点も，もちろんよかったと思うのですが，これから将来のことを考えて今まで通りの進め方でいいのかどうか，研究開発実用化に向けての，この開発のシステムを，この機会に一つ皆さんで検討していただけたらいいのではないかという風に思うのであります。

それから先程の基礎研究とも深く関連しておりますが，人材の養成と，技術のレベルを高く維持していくという問題であります。これは，外国のことはなかなかよくわかりませんけれども，アメリカで最近新しい原子炉の注文がないということのために，相当の人間がやめさせられておるというような噂があるわけですね。世界のエネルギーの需要が厳しくなったり弱くなったりするにつれて，その製造業が大幅な人員の変動をおこしたりするようなことでは，長い将来をかかえた原子力開発にとっては非常に困ったことで，装置は場合によってはすぐ出来るかもしれませんけれども，人間はそう簡単に養成できるものではないので，人材の養成とその高いレベルを維持発展させていくための工夫というものも，長期計画に当然入るべきではないかと思うのであります。

第４は，パブリック・アクセプタンスといわれているものでございまして，日本の原子

力開発にあたりまして，今まで新しい施設の立地については，現場にあたっておられた方は絶えず反対運動や何かで非常に苦労されてきたわけでありますが，今後もそういうことは相当あるに違いないと思います。原子力発電の規模は通産省が中心になって絶えず見直しをやっておられますが，最近までの見通しとしては，紀元２０００年の頃には現在の発電規模の倍くらいにするという一応の目標がかかげられているわけです。そうなりますとまた新しい立地の問題もいろいろと起こってくるわけであります。それには住民の納得をえていくということが非常に大事なことなのであります。特にこのパブリック・アクセプタンスに関しては，政府も相当な予算をつぎこんで努力しておりますし，そのための機関もできており，電力会社も地方自治体も努力をしておられます。ところが，ある程度は効果があがっているのでしょうけれども，たとえばテレビでも，最近出てこられた人なんかもですね，「さっぱり分からないのだ，我々にもっとよく知らせてくれないから分からないのだ。分からないままに強行されるというのは……」，そういう意味の意見が多いのですね。十分努力をしておるにもかかわらず，効果があまり大きくないわけで，このパブリック・アクセプタンスを得るための努力の方法とか方向についても少し検討したらどうかと思っております。

最後に国際協力の問題であります。今後，原子力では核分裂，核融合をつうじまして巨大な装置を必要とする，あるいは巨大なプロジェクトというものが次々と出てまいります。それらについては他の国でもそうだと思いますけれども，我が国でも独力だけではなかなか進まないので，国際協力を大いに進めていかなければならないと思っております。そういう巨大プロジェクトのようなものをとりましてもですね，高レベル放射性廃棄物処理の問題など，世界に共通の課題としてこれから国際協力してよろしいというようなものがいくつかあると思うのであります。そういう国際協力は，これからいろいろと広がって行くだろうと思うのです。日本は今まで，国際協力といいましても，主として進んだ外国から学ぶという意味での協力が多かったわけでありますけれども，これからはそれだけでは済まないので日本より遅れてスタートした国との協力も非常に大事になってくるわけで，それにどう取り組むかということを，やはりこれからの問題として考えなければいけません。その場合に，どうしても核拡散防止の問題と，平和利用を進めていくという問題等が出てくるわけでございます。日本の立場としては，核拡散の防止については，今でも全面的に協力してきたし，これからもそれには努力します。しかし，核拡散の防止が，原子力の平和利用に支障をきたすような形で行われることは，日本として賛成できないわけでありま

す。核拡散の防止と平和利用の促進とが調和した形で進むように，日本なんかは一つ先頭にたって努力すべき大きな問題なのではないかと思うのであります。最近は，日本は貿易が大変うまくいっておりまして，貿易の黒字が多すぎて，世界各国から非難を受けているような状況になっているのであります。それに関連して，私なども国際会議にたびたび出る機会があるのですけれども，多くの場合に共通して批判される点は，日本は外国からいろいろなものを学んで，特に独創的な新しい知識を学んで，それを実用的な技術に育てあげる力は日本が一番強くて，それを直ちに輸出に向けてしまう。そのことが黒字の根本的な原因であってですね，その態度をこれから改めてもらわなければ困るという，これはまあほとんど共通してどこででも言われるところであります。原子力もそうだったと私は思うのですね。今まで外国から学んで，それを実用化する点では，日本は非常に強かったと思います。これからもそうだろうと思うんですね。しかし，これからはそれだけではすまないので，日本でもその基礎研究を中心にして新しい知識や技術を生みだして，それで世界に貢献するという気持での努力というものが必要なのではないだろうかと思うのであります。昨日たまたま，テレビを見ておりましたら，竹村さんというなかなか面白いことを言う人が，「日本は金を節約することばかり知っていて，使い方を知らない。これからは節約はほどほどにして，有意義な使い方をする工夫が大事だ」ということを面白く話しておられました。これもまったく同じことで，技術開発に広く適用される問題であり，原子力もそういった方向で一つこれから努力していかなければいけないのではないかと思うのでございます。

くわしいことはこれから１年をかけて，大勢の方のご意見をうかがいながら，なるべく有意義な長期計画を練っていきたいと思いますので，よろしくご協力をお願いしたいと存じます。どうもご清聴ありがとうございました。

Nuclear Energy: Present Situation and Future Prospects -- From Nuclear Fuel Supply Perspective

Remarks by
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I thank you for the invitation to speak at this conference. I have been asked by the organizers to review the world situation and prospects for nuclear energy from the perspective of supply of the "front end" of the nuclear fuel cycle.

First, and with regard to the world situation and prospects for nuclear power, I call attention to the fact that it was only slightly more than 30 years ago - in 1953, that President Eisenhower announced the U.S. "Atoms for Peace" program. This initiative, along with those of other

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nations, has resulted in the development and use of nuclear power on a global basis as a new energy supply, on a scale and at a rate without precedent. After these years, there are in operation, under construction, or on order, more than 400,000 megawatts of commercial nuclear electric generation capacity located in 35 nations, representing a total investment with a current value in the order of a trillion U.S. dollars. The situation is noteworthy in terms of (1) rate of technology development, deployment and transfer, (2) magnitude of the financial investments, (3) economic benefits, (4) favorable impact on public health and safety, and (5) the usual and positive character of cooperation among the government, industrial, utility and academic institutions of those nations with nuclear power undertakings.

Marchetti of IIASA, reporting in Nuclear Science and Engineering in 1985 on his study of historic and prospective penetration of nuclear energy concludes that "nuclear power . . .(as a new energy source). . . penetrates the energy market at a much faster rate than could be expected from the previous penetrations of coal, oil and gas." Thus, on a world scale, nuclear power has been, and continues to be, a true success story. Marchetti also noted "there have been the inevitable ups and downs." I expect that these will continue.

In considering the prospects for nuclear power, I anticipate that it will continue to increase in supply in all nations where demand for electric power warrants and nuclear generation is the economic choice. This, I believe, will be the case up to the point of "saturation" of electric power systems with nuclear, dependent on demand forecasts, retirement of old capacity, system load characteristics, and economically competitive choices for meeting base, intermediate and peak load demands. Although most nations are not close to this point, the very successful French program has been recognizing these realities for some time.

Also I continue to believe that the fundamentals of nuclear power generation - with regard to economics, safety, and environmental impact, are likely to favor increased use of nuclear - in Asia, in Europe and in North and South America. And I acknowledge that some difficulties must be overcome in order that these benefits are to be generally accepted and demonstrated and to be realized in future electric power supply decisions - especially in the United States. However, I also believe that the past 30 years has provided the lessons on what is to be done to improve further the technology, the economics and the safety of nuclear power; as well as defining the political and institutional issues which are to be resolved on both the national and the international level.

With regard to the situation and prospects for nuclear power in the U.S. market, the very large commercial nuclear program, now numbering one hundred nuclear power plants, has overall been quite successful. However, it has been somewhat diminished by certain financial, economic and operating performance, thought to result principally from what are called "institutional" factors. I believe that Mr. Walske later may discuss some of these factors.

My view is that the future prospects for nuclear power in the U.S. will be clarified, positively, when significant electric power demand growth is forecast and it is recognized more clearly that nuclear is a safe, economic and proper choice. This will happen, in my opinion, if the various U.S. electric utility and regulatory institutions behave correctly. We shall see in due course.

While discussing future prospects for nuclear power, especially with regard to the U.S., my view is that the U.S. supply system for nuclear power generation has inherent "staying power." This view is based on the number of plants still being constructed in the U.S.; plants of U. S. origin being constructed or ordered outside of the U.S.; service work on plants in the U.S. and abroad, and on the construction, operation and servicing of the U. S. Navy Nuclear Propulsion program. In many ways U.S. commercial nuclear power has derived from and continues to benefit from this Navy program.

The extent and character of this Navy propulsion program was described before the Kemeny Commission in 1979, following the T.M.I. accident. Admiral Rickover testified on the extent of the program as follows:

"Today (1979) 115 nuclear powered submarines are in operation; 41 of these are ballistic missile firing submarines and 74 are attack submarines. Twenty-three additional attack submarines and seven TRIDENT submarines are authorized for construction. We also have one nuclear powered deep submergence research and ocean engineering vehicle. Three nuclear powered aircraft carriers are in operation, and one more is being built. Eight nuclear powered cruisers are in operation, and one more is being built. Altogether, 127 nuclear powered ships are in operation. In addition, I am responsible for the Shippingport Atomic Power Station. Including nuclear ships, the naval prototype reactors, and the Shippingport station, I am responsible for the operation of 153 reactors."

He continued as follows: "There are two Department of Energy laboratories devoted to the support of the Naval Reactors program: one is the Bettis Atomic Power Laboratory in Pittsburgh, Pennsylvania which is operated by Westinghouse; the other is the Knolls Atomic Power Laboratory located in Schenectady, New York, which is operated by the General Electric Company. Since the USS NAUTILUS first put to sea in 1955, Naval nuclear powered ships have steamed over 40 million miles and have accumulated over 1800 reactor-years of operation. We have procured 508 nuclear cores, and have performed 166 refuelings. Some 300 large businesses and over 1000 small businesses produce equipment for the Naval Reactors Program."

This reference to the Navy program is made only to add to the understanding of nuclear power experience and capabilities in the United

States. Since this 1979 data it is my understanding that the U.S. Navy Propulsion program has continued both to grow and to be relevant.

I now present a perspective on nuclear power and the front end of the nuclear fuel cycle. I begin with the issue of what nuclear electric power demand may have to be fueled - on a world basis.

Slide 1 is a current NEA/IAEA projection showing forecasts from 1985 to 2025, for OECD - Europe and Pacific; OECD-America; Developing Countries, and Centrally Planned Economies.

The figures up to 1995 are based on reactors in operation, under construction or firmly planned. These NEA/IAEA figures for 1995 also correspond closely - within 5 gigawatts - to those found in Nuclear News, February 1986, for the same categories. The figures from 1995 to 2025 are based on an economic/energy model developed for the IAEA.

Slide 2 presents the same data for OECD-Europe, Pacific and America; for WOCA (World Outside Centrally-planned economies Area), and provides totals for the World.

These forecasts in turn establish the prospective demand for uranium, and for conversion, for enrichment services, for fuel element fabrication and for spent fuel storage. The demand forecasts for these, which I will present, are based on NEA/IAEA estimates for the WOCA - World Outside

Centrally - planned economies Area, except in some instances where I had access to other data which allows inclusion of the CPE's.

Slide 3 presents the projected uranium demand in WOCA - for the high nuclear generation demand scenario. Both annual and cumulative consumption are shown.

Slide 4 presents projected annual uranium production capability - from existing and committed and from planned and prospective production centers. Also shown are the total currently projected production capability and, the bottom line, new production required to meet projected demand. You will note that currently projected production capability is in excess of projected demand through 1995. Also, there are planned and prospective production centers, based on known resources, which can be expected to come on stream when the market develops. With this additional production, projected demand could certainly be met until the mid-1990s, even without drawing down the current stockpile. Since both the supply and demand projections up to 1995 are based on operations already in existence, under construction or planned, the conclusion that uranium supply will be adequate up to that time seems conservative.

Should a lower demand than that shown materialize due to lower nuclear capacity growth or significant deployment of reactors which consume less uranium per unit of electricity generated, the uranium production capability based on existing, committed, planned and prospective production centers might meet demand into the early years of the 21st Century. To meet the high demand projection shown, however, production from new developments, not yet in the planning stage, would have to be added by about the turn of the century. The amount of new capacity required by 2025 to meet this projection is very significant but the rate of increase appears manageable.

Slide 5 presents estimates of the uranium resource base with associated price levels. Comparison of the cumulative consumption and the known and estimated resource base shows that low cost known resources can be expected to supply cumulative demand for several years into the next century. In addition, the potential for new discoveries is very large. Thus, it appears that the resource base will not be a constraint on nuclear generation through at least the first quarter of the 21st Century. However, in order for this view to be correct, there must be exploration and discovery. The current level of exploration expenditures may be too low to assure this future supply.

Dr. Julian Steyn of IEAL has analyzed and presents the matter from a different perspective. Slide 6 presents IEAL estimates of uranium production capability by geographic region and projected demand figures through 2000. Shown are supply capability for the WOCA and a comparison of that capability to projected demand. The demand has been adjusted for 1985 excess inventory; it was assumed that about 70,000 STU_3O_8 of the approximately 250,000 STU_3O_8 current world inventory would be "consumed" over the next 10 years and that this reduction would reduce the need for production accordingly. The data project a conservatively estimated supply capability, which is shown here to be significantly in excess of demand.

Slide 7 presents IEAL's estimates of WOCA regional supply capabilities, with the total WOCA capability being indicated by the solid curve. Projected requirements are indicated by the dashed curve.

Then, assuming that future uranium production will come from the lowest cost producers, it is projected by IEAL that the distribution of geographic origin of uranium supply will be as shown in Slide 8. Thus, the bulk of WOCA requirements through the end of the century would be met by Canada, Australia, Africa, France and the U.S. This assumption as to origin could of course be upset especially by political factors, as well as the assumption as to amounts by the impact of laser technology on the completeness of separation of U-235 from natural uranium and thus on uranium production requirements.

Following the mining and milling of uranium, the ensuing steps of the front end of the fuel cycle are conversion, enrichment, fabrication, burnup, and spent fuel storage.

The supply/demand situation for the WOCA for conversion, enrichment and fabrication is shown in Slide 9. Currently, supply exceeds demand in all of these areas but by 1995 demand will have increased sufficiently to restore a reasonable balance. Looking beyond that period, since the lead times for increasing supply in all these areas are shorter than reactor planning and construction lead times, it can be expected that there will be a supply of these services at acceptable levels of access and price.

The only uncertainty in these areas is for enrichment supply and even this seems slight. There is now the potential and plans by the U.S. Department of Energy for a technological change to the use of lasers, which are believed to hold the promise of producing a cheaper supply of enrichment services than the current diffusion and centrifuge systems. Should the deployment of this technology, expected late in this century, be delayed for technological or other reasons, and should there be a reluctance to invest in expansion of current types of plants because of the risk of their early economic obsolescence when the laser systems are deployed, this could lead to a period of short supply. However, currently there are significant stockpiles of enriched material available in OECD countries which could be used to offset low production for a few years. In addition, mothballed diffusion plant capacity in the United States, not included in Slide 9, could likely be brought back into production if required.

It is also interesting to look at enrichment in terms of national origin of supply, technology of choice, and markets. Slide 10 presents world capacity by national, or in the case of Urenco multinational, capacities and technology choices. During the period shown there is the prospect of (1) major under-utilization of existing capacity even with some capacity on standby, (2) modest additions to world capacity on the part of Urenco, Japan, South Africa and Brazil, and (3) supply based on four nominally competitive technologies of choice.

While the U. S. Department of Energy has scrapped its centrifuge related development and production plans in favor of developing and later deploying the AVLIS laser technology, AVLIS economics are not proven. At the same time it is known that the existing GDP's are capable of providing a substantial additional quantity of SWU's at a relatively low marginal cost. Thus, while the AVLIS technology may be proven in a few years as more economic than even marginal cost diffusion, it must be significantly lower in cost in order to justify deployment. Marginal advantage is insufficient. As well there are many "institutional" uncertainties ahead for the AVLIS technology.

Slide 11 presents IEAL's estimate of the markets to be served by the various supply sources - in 1995. Note that the market demand is estimated to be in excess of the supply capability; that Urenco is estimated to have a significant share of the market, following U. S, DOE and Eurodif; that Japan will by then be providing a significant share of its own demand; and that the USSR has a supply role in a western energy market which itself has major excess capacity.

I also note that as one looks five years ahead, to the year 2000, not much changes. U. S. DOE remains the same, Eurodif increases to a total of 10.8, with added penetration of the European and "other" markets; Urenco increases to a total of 4.5, with added penetration of these same markets; the USSR drops to 1.5; Japan increases its own supply to 2.5; and "other" decreases supply to same by 0.2 Million SWU per year.

The last part of the fuel cycle that I will discuss is spent fuel storage and Slide 12 presents NEA/IAEA projections of Spent Fuel Arisings and Storage Capabilities in the OECD Countries to the year 2000. The projected storage capabilities are well in excess of the projected demand and spent fuel disposal should not be allowed to become a constraint at any time. With no permanent repositories yet in place there have been some public suggestions that disposal of spent fuel, or of high level radioactive wastes from reprocessing, could or should constrain nuclear deployment. However, spent fuel storage, with retrieval potential, does not appear to present any intractable technical or economic issues.

While the politics of spent fuel storage, retrieval, shipment, reprocessing, etc., does have a potential for introducing uncertainties, thus far these have been manageable to the extent that they have not, with one noteable exception, precluded construction <u>and</u> operation of commercial nuclear power generation. That one exception is the Zwentendorf plant in Austria.

I now summarize and conclude my remarks on the prospects for nuclear power from the perspective of the front end of the nuclear fuel cycle as follows: There appears to be ample supply capacity in being or planned or achievable to meet any currently foreseeable level of demand for natural uranium, conversion and enrichment, over the next 20-30 years, at acceptable economic levels. Natural uranium is available from diverse geographic areas, with Australia and Canada being the dominant sources. There is more than ample, diverse enrichment capacity in being or planned, with a broadening availability of enrichment technologies. It also appears that all spent fuel arising during the same period can be stored nationally without undue technical or economic difficulty.

This outlook for more or less plentiful "front end" supply presumes permissive political decision making on the part of many nations. Good political decision making is not always in plentiful supply. In order to have good prospects for nuclear power we need more of that supply everywhere.

Thank you for allowing me to present these remarks.

SLIDE 1

NUCLEAR GENERATION PROJECTIONS

(NET GIGAWATTS CAPACITY)

	1985	1990	1995	2000	2010	2025
A. OECD-EUROPE AND PACIFIC						
— HIGH	113	154	185	260	440	760
— LOW	113	154	185	220	270	320
B. OECD-AMERICA						
— HIGH	91	123	133	170	260	390
— LOW	91	123	133	150	190	230
C. DEVELOPING COUNTRIES						
— HIGH	15	20	27	70	170	410
— LOW	15	20	27	40	60	120
D. CENTRALLY PLANNED ECONOMIES						
— HIGH	28	49	73	150	300	610
— LOW	28	49	73	100	140	200

ERCI/IEAL

SLIDE 2

NUCLEAR GENERATION PROJECTIONS

(NET GIGAWATTS CAPACITY)

	1985	1990	1995	2000	2010	2025
OECD						
TOTAL (A & B)						
— HIGH	204	277	318	430	700	1,150
— LOW	204	277	318	370	460	550
WOCA (A & B & C)						
— HIGH	219	297	345	500	870	1,560
— LOW	219	297	345	410	520	670
WORLD						
— HIGH	247	346	418	650	1,170	2,170
— LOW	247	346	418	510	660	870

ERCI/IEAL

SLIDE 3

PROJECTED URANIUM DEMAND IN WOCA

(1,000 TONNES U/YR)

	1985	1990	1995	2000	2010	2025
ANNUAL CONSUMPTION	39	48	55	93	153	260
CUMULATIVE CONSUMPTION (FROM 1985)	39	256	513	981	2,232	5,375

ERCI/IEAL

SLIDE 4

PROJECTED URANIUM PRODUCTION IN WOCA

(1,000 TONNES U/YEAR)

	1985	1990	1995	2000	2010	2025
FROM EXISTING AND COMMITTED PRODUCTION CENTRES	44	48	46			
FROM PLANNED AND PROSPECTIVE PRODUCTION CENTRES	0	8	21			
TOTAL CURRENTLY PROJECTED PRODUCTION CAPABILITY	44	56	67	68	62	38
NEW PRODUCTION REQUIRED TO MEET PROJECTED DEMAND	0	0	0	25	91	222

ERCI/IEAL

SLIDE 5

ESTIMATED URANIUM RESOURCE BASE

(1,000 TONNES U)

	PRICE RANGE	
	UP TO $80/KG U	$80 TO $130/KG U
REASONABLY ASSURED RESOURCES (RAR)	1,600	600
ESTIMATED ADDITIONAL RESOURCES — KNOWN DEPOSITS (EAR-I)	900	400
UNDISCOVERED RESOURCES — AREAS OF KNOWN OCCURRENCES (EAR-II) OR SPECULATIVE RESOURCES (SR)	OVER 10 MILLION UNDER $130/KG U	

ERCI/IEAL

SLIDE 6

IDENTIFIABLE URANIUM PRODUCTION CAPABILITY BY GEOGRAPHIC REGION

(1,000 TONS U_3O_8/YR)

REGION	1984	1990	1995	2000
AUSTRALIA	5.6	6.1	18.9	24.1
CANADA	14.5	16.1	22.6	22.6
SOUTH AFRICA	7.5	8.4	8.0	8.0
OTHER AFRICA	10.2	11.6	14.6	9.5
FRANCE	4.1	5.1	5.1	5.1
UNITED STATES	7.4	13.6	19.3	19.9
OTHER	1.1	3.1	4.0	2.7
TOTAL:	50.4	64.0	92.5	91.9
DEMAND	NA	53	62	68

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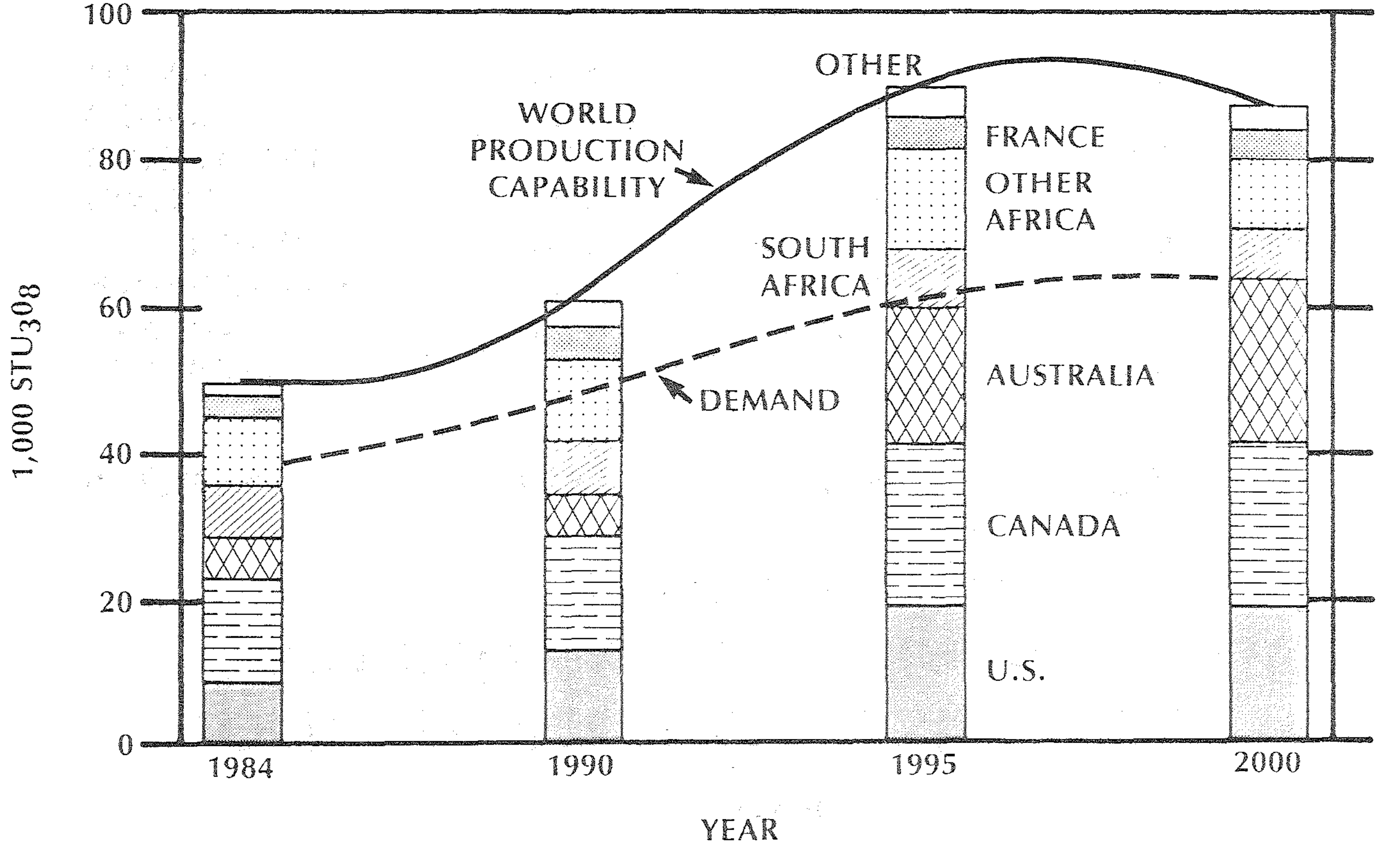
SLIDE 7

WORLD URANIUM PRODUCTION CAPABILITY BY GEOGRAPHIC REGION



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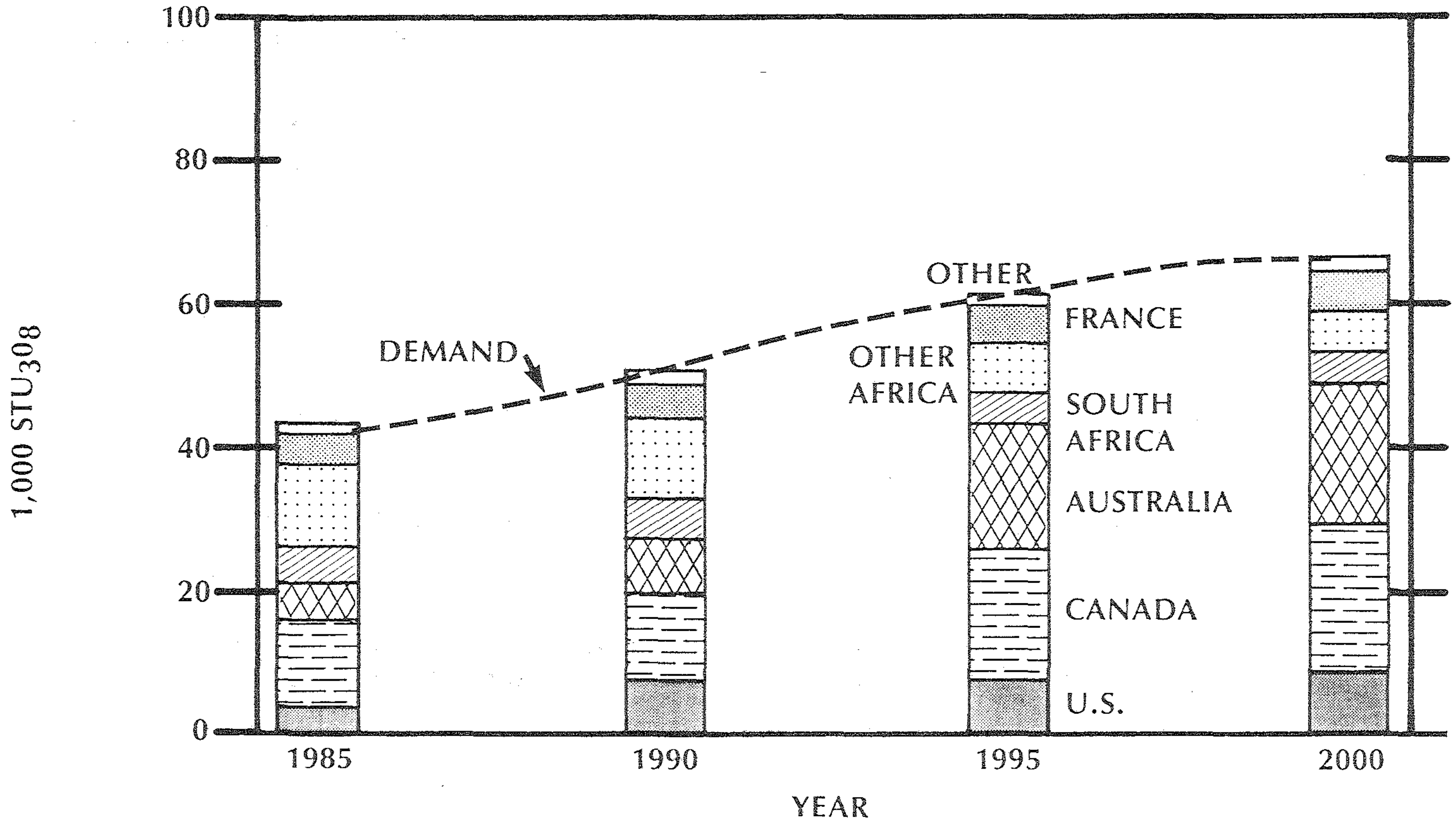
SLIDE 8

WORLD URANIUM SUPPLY PROJECTION BY GEOGRAPHIC REGION



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SLIDE 9

FUEL CYCLE SERVICES IN WOCA

	CONVERSION* (1,000 t U/YR)		ENRICHMENT (MILLIONS SWU/YR)		FABRICATION (1,000 t HM/YR)	
	SUPPLY	DEMAND	SUPPLY	DEMAND	SUPPLY	DEMAND
1985	56.8	33.3	32.0	23.2	14.3	6.6
1990	56.8	41.1	34.1	32.4	14.2	9.9
1995	56.8	50.6	36.3	38.3	14.4	10.9

*OECD COUNTRIES ONLY

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SLIDE 10

WORLD URANIUM ENRICHMENT CAPACITY EXISTING AND PLANNED

(MILLION SWU/YEAR)

	EXISTING 1985	PLANNED 1995	TECHNOLOGY
U.S.A.			
OAK RIDGE	(A)	(A)	DIFFUSION
PADUCAH	11.4	11.4	DIFFUSION
PORTSMOUTH	8.0	8.0	DIFFUSION
SUBTOTAL:	19.4	19.4	
EURODIF (FRANCE)	10.8	10.8	DIFFUSION
URENCO (UK/FRG/HOLLAND)	1.5	4.5	CENTRIFUGE
USSR(B)	3.0	2.0 (C)	DIFFUSION
JAPAN	0.05	1.5 (D)	CENTRIFUGE
UCOR (SOUTH AFRICA)	0.03	0.3	HELIKON
BRAZIL	--	0.3	JET NOZZLE
TOTAL:	34.8	38.8	

(A) 7.9 SHUTDOWN—ON STANDBY
(B) V/K TECHSNABEXPORT "CAPACITY"
(C) 2 TO 3 MILLION
(D) 1 TO 2 MILLION

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SLIDE 11

ESTIMATED 1995
MARKET SHARE DISTRIBUTION

(MILLION SWU PER YEAR)

	MARKET SECTOR TO BE SERVED				
SUPPLIER	U.S.	EUROPE	JAPAN	OTHER	TOTAL
DOE	10.0(A)	0.5	1.5	0.8	12.8
EURODIF	0.5	7.5	1.0	0.5	9.5
URENCO	0.5	3.0	0	0.2	3.7
USSR	0	2.0	0	0	2.0
JAPAN	0	0	1.5	0	1.5
OTHER	0	0	0	0.2	0.2
TOTAL	11.0	13.0	4.0	1.7	29.7

(A) DOES NOT INCLUDE U.S. GOVERNMENT'S REQUIREMENTS

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SLIDE 12

SPENT FUEL ARISINGS AND STORAGE IN OECD COUNTRIES

(TONNES HEAVY METALS—CUMULATIVE)

	1985	1990	1995	2000
SPENT FUEL ARISINGS				
— ENRICHED FUEL	28,900	53,000	86,000	124,000
— NATURAL URANIUM FUEL	8,100	15,500	25,000	36,000
TOTAL	37,000	68,500	111,000	160,000
STORAGE CAPACITIES(A)	111,000	159,000	180,000	190,000

(A) STORAGE CAPACITY INCLUDES AMOUNTS RESERVED FOR EMERGENCY CORE UNLOADING SO NOT ALL IS AVAILABLE FOR EXPECTED SPENT FUEL ARISINGS.

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BACK-END OF THE NUCLEAR FUEL CYCLE:
TECHNOLOGY, SUPPLY CAPACITY AND ECONOMICS

by

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Presentation to

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BACK-END OF THE NUCLEAR FUEL CYCLE:
TECHNOLOGY, SUPPLY CAPACITY, AND ECONOMICS

1. INTRODUCTION

Most of the nuclear spent fuel that is currently discharged from reactors in OECD countries is destined for long-term interim storage before final processing or direct disposal. There are at least three basic considerations affecting decisions on this spent fuel: first, there is currently insufficient capacity for prompt reprocessing in most cases; second, reprocessing is not considered urgent for either economic or plutonium availability reasons; third, there are technical and economic advantages in allowing the cooling of spent fuel (or separated high-level wastes) in controlled storage before final disposal.

On the other hand, some spent fuel arisings are already being reprocessed, and a major part of the spent fuel that is now in storage is intended to be reprocessed eventually. The basic technology has been commercially available for several decades, but political problems and the lack of immediate incentives for reprocessing have thus far slowed the build-up of new capacity. As long as there is perceived to be no immediate need for the separated plutonium, postponing reprocessing can be considered as technically reasonable to avoid problems related to plutonium storage.

Some OECD countries do not include reprocessing in their plans for spent fuel management but instead are planning to condition the spent fuel elements for direct disposal. Research in this direction is going on in several countries. In fact, repositories suitable for final disposal of spent fuel or separated high-level radioactive waste will be needed irrespective of whether the reprocessing or direct disposal option is chosen, but neither technical nor economic factors are creating pressure for their rapid development.

In this paper, the current outlook for the fuel cycle back-end will be reviewed stage by stage, with attention paid to status of technology, supply and demand for services, and costs. The emphasis will be on developments during the remainder of this century. Finally, some comments will also be made on the overall economics of the back-end.

2. STORAGE AND TRANSPORTATION OF SPENT FUEL

Technology

Over forty years of experience in spent fuel storage technology has demonstrated the relative ease, safety and low cost of storing spent fuel in water filled pools. Many countries will use such pools for storing spent fuel for periods as long as 20 to 50 years.

Some dry storage techniques are claimed to offer economic and safety advantages, particularly for relatively long-term storage of fuel which has first been cooled for a few years in water storage. These are likely to attract more interest in the future.

The safe transportation of spent fuel has been well demonstrated. Over the past thirty years more than 15,000 movements of spent fuel have been made in Europe and North America over road, rail or water. Further development in this area is likely to be directed towards optimizing designs for ease of handling and for shipping of larger fuel volumes. Substantial interest is being shown by some utilities in the concept of extended interim storage in specially designed shipping casks.

Supply and Demand

With increasing nuclear electricity generation, increasing amounts of spent fuel are being unloaded annually from the world's nuclear reactors. In the OECD countries alone the annual arisings will approximately double during the next ten years (1). Since most of the oxide spent fuel that is currently placed in storage will still be there after ten years, the total amounts of stored spent fuel will inevitably increase in the years to come. It is estimated that by the year 2000 about 160,000 tonnes of spent fuel will have been generated. Recognizing that less than 50,000 tonnes of fuel is likely to be reprocessed by that date, storage space will be required for at least 110,000 tonnes of spent fuel in OECD countries as shown on Figure 1.

Figure 1 also shows that the total storage capacity in the OECD countries is projected to be near 200,000 tonnes by the end of the century, well in excess of the estimated requirements. However, a part of the total capacity serves as an emergency unloading reserve so it is not all available for routine spent fuel discharges. Moreover, such a comparison of total supply and demand does not reveal possible local imbalances. Since storage services may not be readily available on the market, some utilities may have to construct new storage capacity during this time period. However, construction times for storage facilities are relatively short, and supply of new capacity, if needed, should not pose serious problems.

Costs

The costs of storing spent fuel at reactors or at reprocessing plants are difficult to separate from other capital and operating costs at these facilities. For separate storage, the responses to a questionnaire sent out in the context of an NEA study on fuel cycle economics (2) indicated a cost range of $50 to $200 per kilogram of heavy metal stored (Jan. 1984 U.S. dollars). The figure used as a reference value for water pool storage consisted of a fixed part of $40/kgHM and a part proportional to the length of storage period, adding $4/kgHM for each year of storage. Storage for ten years in water pools would then cost $80/kgHM while another ten years would add 50 per cent to the costs.

Some dry storage techniques are claimed to offer economies, especially in the case of small facilities and long storage periods, but there is still little actual experience with these techniques. It appears that it will be some years before dry storage is utilized on a large-scale, commercial basis.

The costs of spent fuel transportation also depend on factors specific to each power plant considered, for example, the means and distance of transportation. A considerable part of the costs is due to the transportation casks and other special equipment that may be needed. The corresponding fixed capital cost per shipment naturally depends on the total number of shipments made using the equipment. In the NEA study mentioned above, the reference value for spent fuel transportation costs was $40/kgHM for the average spent fuel shipment within Europe (2).

3. REPROCESSING

Technology

Reprocessing is, as we all know, a proven technology which has been used on a commercial basis for more than thirty years, with the majority of this experience having been obtained in France and the United Kingdom. Considerable reprocessing experience has already been obtained in Japan as well. By far the greater part of the experience is with the PUREX process, and, indeed, future commercial reprocessing operations are likely to be based on this process, or slight modifications of it. Solidification of high level reprocessing wastes by vitrification has also been developed on a commercial scale. This stage of the process can be considered as having a demonstrated solution. Future reprocessing development will likely focus primarily on cost reductions, improvements in equipment maintainability, reduction of effluents, treatment of wastes, and steps to lower worker exposure and environmental impact.

While there has thus far been relatively little experience in shipping reprocessing waste, the requirements are similar to those for spent fuel and should not present any great difficulties.

Supply and Demand

According to known plans or intentions, a considerable part of the present spent fuel arisings await reprocessing in the future. The metallic fuel from gas-cooled reactors is normally reprocessed within a few years from unloading, and adequate capacity exists for this purpose. For the oxide fuels from the light water reactors, the situation is different. In the OECD countries, present reprocessing capacity for oxide fuels will accommodate less than 15 per cent of the corresponding annual spent fuel arisings. Consequently, in most cases fuel can be reprocessed only after a prolonged interim storage period.

Only a few countries are actively working to increase their domestic reprocessing capacity. One of them is Japan, where site surveys for the construction of a new 800 tonne reprocessing plant have already begun. In France and the United Kingdom some capacity is being built for foreign customers. Several countries have already contracted for reprocessing some of their spent fuel in these facilities, but in many cases the question of reprocessing is still left open. According to our projections, in 2000 there could be reprocessing capacity for about 4,500 tonnes of spent oxide fuel in the OECD countries (Table 1). If all plants operate at their nominal capacity from the date of first operation, about 45,000 tonnes of LWR fuel could be reprocessed in the OECD countries by the year 2000. This would be about one third of the total LWR spent fuel arisings by that date .

Costs

During the last ten years, the cost of reprocessing has had approximately a five-fold increase in constant money, if estimates are based on price information about commercially available services. This cost increase may be attributed to two principal factors: first, the technical difficulties encountered when the process was adapted to handle relatively high burn-up oxide fuel; and second, the current tighter safety standards and environmental release restrictions. However, the costs appear now to be stabilizing, and in spite of the rather limited supply of commercial services, some believe that the price for such services may even come down in the future (2).

In an NEA study of fuel cycle economics, the OECD countries' original estimates for reprocessing ranged from $640 to $950/kgHM (2). These estimates include the vitrification of waste and the storage of vitrified waste up to the time of final disposal. The more detailed estimate made by the United Kingdom for this study indicated a range of $570 to $1000/kgHM, depending on the assumed return on investment, size of facility, and contingency allowance. The reference value selected by the NEA expert group for its report was $750/kgHM, including vitrification and waste storage. However, a relatively large uncertainty range of ± 33 per cent was considered in sensitivity studies.

4. WASTE DISPOSAL

Technology

Virtually all OECD countries with operating nuclear power plants are investigating the disposal of high-level radioactive wastes in deep geological formations. In general, the research is aimed at finding a balance among the various chemical effects of radionuclides, waste matrix, canister materials, backfill and additives, and the natural geochemical environment. The goal, of course, is to minimize the release of radiologically significant nuclides. The disposal concept is founded on a system of multiple, relatively independent barriers, designed to isolate the toxic radionuclides from man and his environment until they have decayed to levels which will present no unacceptable risk to future generations.

On the basis of extensive study and research, there is an expert consensus that the techniques which are currently being developed provide a feasible means for the safe disposal of both reprocessing waste and spent fuel. Safety assessments for repositories indicate that they would present no greater long-term risk to man and the environment than that allowed by current radiation protection standards or from radioactive materials occurring naturally in the earth's crust. Research and predictive analytical studies are continuing to further improve the already significant level of knowledge about the long-term behaviour of geologic repositories and to facilitate selection of suitable disposal sites.

The development of technology for waste disposal has benefitted from extensive international research co-operation in the area. This includes both model development for safety assessments and experimental work on repository characteristics. An outstanding example of the latter work is the OECD/NEA Stripa project in Sweden in which many OECD countries are actively participating. In this project, the properties and behaviour of granite bedrock are being studied under simulated disposal activities and tests are made with various techniques needed in disposal operations.

Supply and Demand

Irrespective of the decision on reprocessing, facilities appropriate for disposal of highly radioactive waste will be needed in the future. The vitrified waste from reprocessing generally takes a smaller volume than the original spent fuel elements, but the most important characteristics with regard to repository design are broadly similar. For instance, the heat output of waste at the time of disposal is largely determined by the fission product contents which are the same in both cases. Though some of the waste characteristics on the very long term are different, the total repository space requirements are similar in both cases.

In the United States, the site for the first repository is expected to be selected in the early 1990s and the repository could be in operation by the end of the century. An operating repository might also be possible in the Federal Republic of Germany by the year 2000, but in most countries the plan is to cool the spent fuel or vitrified waste for several decades in retrievable storage facilities before the start of final disposal operations. This means, generally speaking, that large-scale disposal activities are not expected before the second decade of the next century.

Costs

The cost estimates for disposal and the required conditioning include large uncertainties since the technology actually used several decades from now may well be different from what is presently envisaged. Current estimates are intended to show at what cost the operations could be accomplished if based on technology that is available now. The NEA study on fuel cycle economics adopted the same value of $150/kgHM in spent fuel for the reference disposal cost, for both the vitrified reprocessing waste and the conditioned spent fuel. In the case of direct disposal, the reference conditioning cost selected was $200/kgHM. This is the same as the cost assumed for vitrification in the reprocessing cycle. For total direct disposal costs a range as large as $150 to $550/kgHM was considered in the sensitivity studies (2).

5. BACK-END COSTS IN PERSPECTIVE

A summary of the reference unit cost assumptions used in the NEA study (2), is given in Table 2. Table 3 shows these costs in comparison with the total fuel cycle costs and, moreover, with total generating costs. According to the study, the share of the back-end in the total levelized fuel cycle costs is expected to be betweeen 10 and 20 per cent. The calculations based on the reference values shown indicate that back-end costs for a once-through cycle would be lower than back-end costs for a cycle with reprocessing, but in total levelized fuel cycle costs the difference between alternative fuel cycles was only about 10 per cent. Of the total electricity generation costs, the back-end options account for about 3 and 5 per cent, respectively. Therefore the impact of the choice of back-end options on the cost of electricity generation will be only about 2 per cent. A micro-economic effect of this size may well be offset by other strategic considerations.

Uncertainties in the unit costs of the back-end stages have little effect on the total fuel cycle costs. The most important single uncertainty is with the reprocessing price. A drop or increase of $250/kgHM from the reference price of $750/kgHM would lead to a change of approximately 10 per cent in the total levelized fuel cycle costs. Other uncertainties in the back-end are less important. For example, the uncertainty range studied for the disposal costs led to a change of only a few per cent in the total fuel cycle costs.

6. CONCLUSIONS

Many parts of the back-end of the fuel cycle have well-demonstrated solutions based on years of experience and, in some cases, on commercial operations. There is a consensus among the experts that those aspects not yet demonstrated are technically feasible. The principal problem, perhaps, is obtaining the public confidence in the technical solutions which will be needed for proceeding smoothly with disposal plans.

Some OECD countries have already made a decision to reprocess part or all of their spent fuel. Other countries will postpone their decisions for some time since extended spent fuel storage is safe and relatively simple. In finally deciding which option to choose, countries will take into account strategic factors as well as economics. The choice, even for the long term, will not, of course, necessarily be the same for all countries.

The costs of spent fuel management can be thought of as either high or low, depending on the perspective. For those involved in the business of the back-end, the cash flow is very large indeed. For example, NEA estimates show that in the OECD area alone over 2 million GWh of nuclear electricity will be generated in the year 2000 (3). At a back-end cost of about 1 to 2 mills per kWh this implies a commitment of some 2 to 4 billion 1984 U.S. dollars for all back-end activities associated with the spent fuel arising from that year's generation. That _is_ a large number, and provides a substantial incentive for research and development to reduce the costs.

On the other hand, for an electricity consumer, the back-end cost represents only about 5 per cent of generating costs, perhaps only 2 or 3 per cent of delivered costs. From this perspective the cost of the back-end of the fuel cycle is already low and further improvements, though always welcome, will have little real impact.

In summary, there is apparently no economic or technological reason why the back-end of the fuel cycle should constrain further deployment of nuclear power. While the costs of these activities appear high in absolute terms, they should be relatively low per unit of electricity generated. Beyond this, given the requisite determination, there is no reason why the fuel cycle cannot be closed.

REFERENCES:

1. Spent Fuel Management; NEA-OECD, to be published in 1986.

2. The Economics of the Nuclear Fuel Cycle, NEA-OECD, 1985.

3. Summary of Nuclear Power and Fuel Cycle Data in OECD Member Countries; NEA-OECD, 1985.

Figure 1. **Cumulative spent oxide fuel arisings and projected spent fuel storage capacities in OECD countries. The amount shown to be reprocessed is calculated assuming that all plants operate at their nominal capacities from first operation (1).**

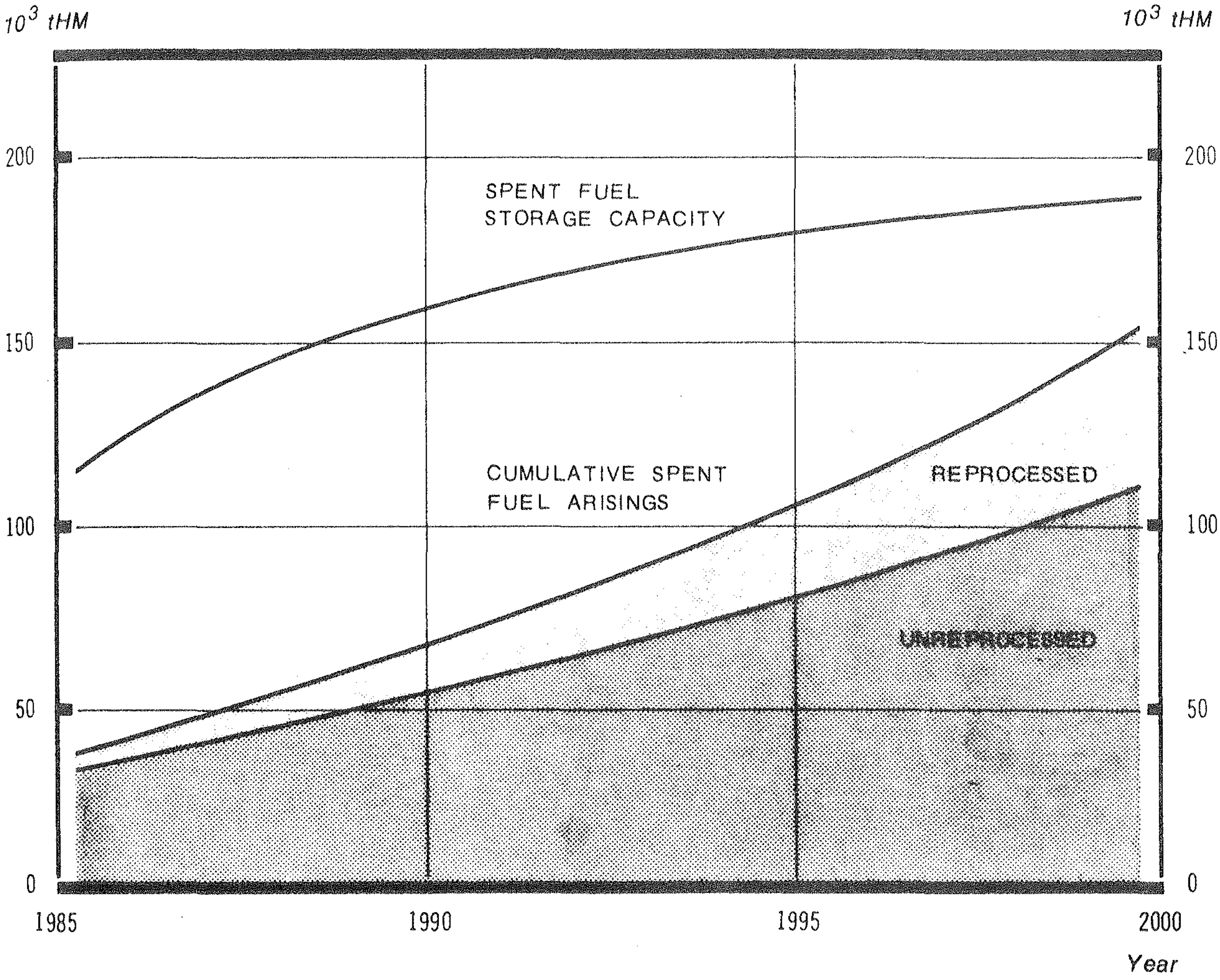


TABLE 1

Spent Enriched Oxide Fuel Arisings, Reprocessing Capacities and Maximum Quantities Reprocessed in OECD Countries
(tHM; Ref. 1)

	1985	1990	1995	2000
Spent Enriched Oxide Fuel Arisings				
- Annual	3 500	5 600	7 000	8 000
- Cumulative	28 900	53 000	86 000	123 600
Reprocessing Capacity	480	2 030	4 450	4 450
Maximum Cumulative Quantity Reprocessed*	1 800	8 100	24 300	46 500

* Assuming that all plants operate at their nominal capacity from first operation.

TABLE 2

Reference Back-end Cost Assumptions of the NEA Study
(Jan. 1984 U.S. dollars)

BACK-END	REFERENCE UNIT COST	RANGE OF NATIONAL ESTIMATES
COMMON COSTS		
Storage	\$40/kgHM + \$4/(year·kgHM)	\$ 90 - \$200/kgHM
Transportation of Spent Fuel	\$40/kgHM	\$ 28 - \$ 47/kgHM
ONCE-THROUGH CYCLE		
Conditioning of Spent Fuel for Direct Disposal	\$200/kgHM	\$128 - \$380/kgHM
Disposal of Spent Fuel	\$150/kgHM	
REPROCESSING CYCLE		
Reprocessing (including waste vitrification)	\$750/kgHM	\$640 - \$950/kgHM
Disposal of High-Level Reprocessing Waste	\$150/kgHM (in spent fuel)	\$ 72 - \$322/kgHM

TABLE 3

Back-end Fuel Cycle Costs in Perspective
(Back-end costs in Jan. 1984 U.S. mills/kWh)

OPTION	BACK-END COSTS (mills/kWh)	PER CENT OF TOTAL FUEL CYCLE COSTS*	PER CENT OF TOTAL GENERATING COSTS**
ONCE-THROUGH	0.97	12	3
REPROCESSING CYCLE	1.72	20	5

* NEA reference estimates for total fuel cycle costs were:

- once-through	7.78 mills/kWh
- reprocessing	8.56 mills/kWh

** According to the NEA study, the range of total generating costs in OECD countries was 20.3 - 43.8 mills/kWh (Japan: 31.6 mills/kWh). Here the median value, 32 mills/kWh, has been used as a reference.

DEVELOPMENT OF FAST BREEDER REACTORS IN THE WORLD

Rémy CARLE - Electricité de France

ORAL PRESENTATION

Pioneers in the field of nuclear energy very early perceived the strong possibility of using - in reactors - nuclear fuels whose neutrons strike the fissile and fertile materials in the fuel at a very high speed.

Enrico FERMI's famous declaration in Los Alamos in 1945 that the first country to develop fast breeder reactors would have indisputable advantages was based on the discovery, before the end of the Second World War, of the laws of physics which made it possible to describe the phenomenon of breeding, i.e. the recovery of the plutonium consumed by converting uranium into plutonium ; this conversion ratio is greater than one.

This rate of regeneration is far superior to that one finds in other types of nuclear reactors, and gives fast breeder reactors a decisive advantage, the potential of converting all the uranium 238 found in natural uranium, i.e. 99.3 % , into a fissile element, plutonium, which has properties comparable to that of uranium 235 for producing energy by fission.

All these predictions have been verified ; the French PHENIX reactor has indeed confirmed that the process described by physicists worked correctly : the plutonium breeding ratio (1.16) is slightly higher than predicted by the calculation and the plutonium is regularly recycled after irradiated fuel reprocessing. All in all, the fuel cycle consumes less than 200 kg of natural or depleted uranium every year, while generating 1.15 TWh (billion kWh) of electric energy.

This is the fundamental reason for the size and constancy of resources that all countries concerned with future energy requirements continually devote to this type of reactor.

The FBR system has been developed progressively and steadely, with all the necessary prudence.

1 - STAGES OF DEVELOPMENT

The difficulties of using plutonium in a very concentrated form in the core, and the necessity of using liquid metals as a coolant, made development of new technologies inevitable ; this development could only take place in stages :

- the preliminary stage aimed at confirming that reactor physics permitted praticable and safe reactors to be designed,
- the stage of experimental reactors, providing knowledge of basic sodium and fuel techniques,
- the stage of demonstration reactors prior to large demonstration plants,
- the full-power prototype reactors aimed at demonstrating both industrial competence and cost control.

All countries involved in the development of fast breeder reactors have followed, or plan to follow, those four stages.

You will find in my written paper a description of the steps in the different countries. The slide reminds you the main steps placed along the time.

Instead of describing in detail this history, let me insist on a few points related to the actual situation.

All this technological development was persued by a sort of international community having many scientific links and exchanging experience. This has led us to a convergence of the main choices which is quite remarquable : same fuel, same coolant, same components, broadly speaking.

Only one breeder technology exists today.

Even the difference between the pool type and the loop type must not be overestimated. The technological difficulties are quite similar in both cases. The only difference is the installation and arrangement of the primary components.

Of course, French specialists consider that the pool design is better thant the loop one : we have experienced in PHENIX that this arrangement reduces the radioactive doses that the maintenance people are exposed to, and that could be very important for the future. But it must be emphasized that a common trend in development and technology is dominant.

Is this current breeder technology the best one ? I do not know. It has been proven feasible. It is probably a little too costly. Is it the final one ? Certainly not. Breeder technology is a young one and we must improve it.

Of course, the experience acquired in the various countries is different. To roughly summarize, I shoud say :

United States have starded the first with EBR 2. They spent a lot of money in R and D work. They still spend much money in laboratories research centers, and also engineering work. They have a splendid research reactor, FFTF. Unfortunately, they did'nt succeed to build a demonstration reactor : CLINCH RIVER was abandoned in 1979. And utilities and industries have no pratical experience.

USSR made great achievements, both in R and D and by building demonstration plants, BN 350 and BN 600. Despite the fact that we do not know in detail the performances of those units, they seem to operate in a rather constant way and certainly produce a lot of experiences in all technological aspects.

Japan put JOYO in service in 1977 and begins now the construction of MONJU, demonstration plant of 300 MWe. This effort must be underlined as a very important contribution to the development of fast breeders. In particular, it will allow an interesting comparison between designs different from the european ones, in particular with regard to the primary loop circuits and also to the seismics conditions.

Europe made a strong effort in the breeders field since 1960, first in Great Britain, then in France, in Germany, in Italy. Clearly, Europe is the leader now for the breeder technology ; maybe because independant sources of energy are particularly valuable for this part of the world.

Without describing again the successive steps accomplished in the european countries, I shall give a few minutes to the most important achievement, for the moment, in Europe, which is SUPERPHENIX.

2 - SUPERPHENIX

The CREYS-MALVILLE nuclear power station -"SUPER-PHENIX- was built and will be operated within a European cooperation framework.

In 1971, the three largest utilities in continental Europe - EDF (France, ENEL (Italy) and RWE (Germany)- had decided to build jointly two prototype industrial size power stations equipped with breeder reactors using plutonium as fissionable matter and sodium as coolant. They signed a convention on December 28, 1973 putting this intention into concrete form. It planned for the construction of two power stations of about 1000 MWe. The first one in France, based on the "POOL" design of the Phenix démonstration plant. For this project, "SUPER-PHENIX", the French company NERSA was formed in 1974 (EDF 51 %, ENEL 33 % and RWE 16 %). The second one in Germany, based on the SNR 300 "LOOP" design as another European development. For this project, "SNR II", the German company ESK was formed (RWE 51 %, ENEL 33 %, and EDF 16 %). At a later date, RWE transferred its rights to SBK, a German company comprising other European utilities beyond RWE (68,85 %) : SEP /Netherlands (14,75 %), SYNATOM/Belgium (14,75 %), CEGB/ United Kingdom (1,65 %).

For SUPER PHENIX, in line with the agreements, the following items were shared in proportion to the utilities' participations : the cost of construction and operation, the engineering staff, the equipment orders, and the energy produced. Each partner has 100 % access to the experience obtained.

The international aspect of this project gave rise to efficient and concrete cooperation between neighbouring countries. Contracts were distributed among the partner countries by direct orders or subsequent sub-contrats. Thus, the plant was not ordered as a turnkey but broken down in a great number of individual system and component orders.
The largest single item, the Nuclear Steam Supply System (NSSS), representing approximately 2/3 of the value of all orders placed with the partners' industries, was awarded to a group consisting of the French NOVATOME and the Italian NIRA (today ANSALDO, NIRA Division). For the Balance of Plant (BOP) the choice of constructors and suppliers was made after invitations to tender, taking into consideration technical and economical criteria. Thus, for example civil engineering was contracted to a French-Italian-German Group (Fougerolle, Condotte d'Acqua, Philip Holtzman), the two turbo-generator sets to Ansaldo (Italy) and electrical equipment, instrumentation and control to CGEE (France), BBC, Siemens, Hartmann und Braun (Germany).

The slide shows a longitudinal cross section through the most important nuclear and conventional buildings.

The reactor unit (slide) is characteristical for the "POOL" - design.

The reactor vessel and the surrounding safety vessel are suspended from the roof slab, which is supported by a concrete cylinder and includes 2 rotating plugs and the core cover plug. Two zones are distinguished :

- below the roof slab, the reactor vessel encloses the core and the primary circuit components, primary pumps and IHX's, all immersed in 3,500 tons of sodium.

- above the roof slab, an accessible area bounded by the dome, contains the upper structures of the IHX's, the primary pump motors, the control rod drive mechanisms and the fuel handling machines.

The core support structure, welded to the bottom of the main vessel supports the core, the inner vessel, and the eight discharge pipes from the primary pumps which supply cool sodium to the diagrid.

The cost of the plant appears to be approximately 2,3 times the cost of the french PWR of same size.

Important milestones of the plant construction period were :

- main equipment orders (NSSS, turbine, generator, Civil Works) : early 1977
- on-site fabrication of large NSSS components .... : mid 1978 to late 1981
- reactor unit erected .... : early 1982
- primary and secondary circuits erected . : mid 1983
- sodium filling of circuits .... : 2nd half 1984
- start of fuel loading .... : July 20, 1985
- First criticality .... : September 7, 1985
- First supply of electricity into the grid : January 14, 1986

The main events of the commissionning period are generally divided into three main stages :

- the individual test stage which began with the first tests performed on the sodium unloaded facility in 1981, and ended with the achievement of the in-air overall fuel handling system tests and the NSSS qualification for its main systems sodium filling.

- The unfuelled NSSS tests stage,; called the isothermal stage, achieved concurrently with overall electricity generating plant tests, using test steam.

- The fuelling stage, followed by neutronic tests and power buildup.

The main problem that emerged during this startup up to now lied in the abnormally high vibrations observed in the thermal shields, separating hot sodium from cold sodium in the primary vessel, and in the cold sodium spillway, keeping the main vessel upper part cold.

The roots of such a phenomenon were quickly identified as an hydro-elastical excitation of some thin structures, due to the too important drop height of the above-mentionned cold sodium, occuring during this sodium restitution towards the main vessel lower part.

The solution consisted in modifying the leakage flow at the bottom of some subassemblies, after achieving numerous on-site tests in order to improve this phenomenon knowledge and to confirm the efficiency of the results brought about by these changes.

The criticality confirmed the neutronic calculations made by the physicists.

We have now reached 30 % of the nominal power. The power buildup is slow because of the interest of many measurements made at various levels and also because of some small defects inherent to any protocype (most of them appear in the "conventional" part of the plant). None of these defects now appears to be a serious difficulty on the way to normal operation.

So we hope SUPERPHENIX will confirm in a few months the validity of the technical choices made. The operation will be observed with much attention to draw all experience available.

This will represent the most valuable experience in the breeders field.

Let me underline also the importance of gaining experience regarding fuel reprocessing. It's clear that for PWR or BWR you may reprocess or not. For breeders you need reprocessing of both LWR fuel and FBR fuel.

The CEA (French Atomic Energy Commission) will soon put into service a demonstration plant for the reprocessing of breeders fuel. This plant is called TOR (which stands for fast oxide reprocessing in French) ; it has a capacity of 5 tons/year. It is a reprocessing technical demonstration plant just as PHENIX was a demonstration power plant.

It is difficult to estimate the real cost of reprocessing since it would require an industrial-capactity plant, which will be economically justified only when the fuel to be processed will be in sufficient quantities. The construction of this plant will only be started during the next power plant phase. Let us recognize it is very important to include it in the global approach of the breeders.

3 - PREPARING THE NEXT STEP

Once the technical feasibility has been demonstrated through the realization of projects in a growing number of countries, efforts must be concentrated on plant design in order to simplify the product and reduce the cost ; similar efforts must be made on the fuel cycle.

A careful examination of SUPERPHENIX shows that there is considerable potential for simplification and cost reduction of fast breeder reactors, particularly in those parts of the NSSS for which the first priority was given to demonstration of the industrial and functional feasibility and not to a search for low cost.

It is with this is mind that EDF launched, in july 1983, detailed preliminary project studies on the SUPERPHENIX 2 reactor, with an electrical output of 1,500 MWe and for which investments for the whole of the plant could be reduced in comparison to investments made for SUPERPHENIX 1.

The reduction of the weight in the reactor block, the circuits and the maintenance system is on average 45 %. This improvement and many others prove the possibility of reducing costs and approaching better competitivity.

To improve the product, to reduce the consts, to approach competitivity we nedd more R and D work, we need also an industrial objective in a not too far future.

The return we can hope from the breeders is too big to be jeopardized by the short term evolutions of the oil market or the uranium market.

But we know we have time before the commercial era, twenty, twenty-five years. We must organize this time gap to proceed in a coherent and systematic way by the construction of three or four demonstration plants.

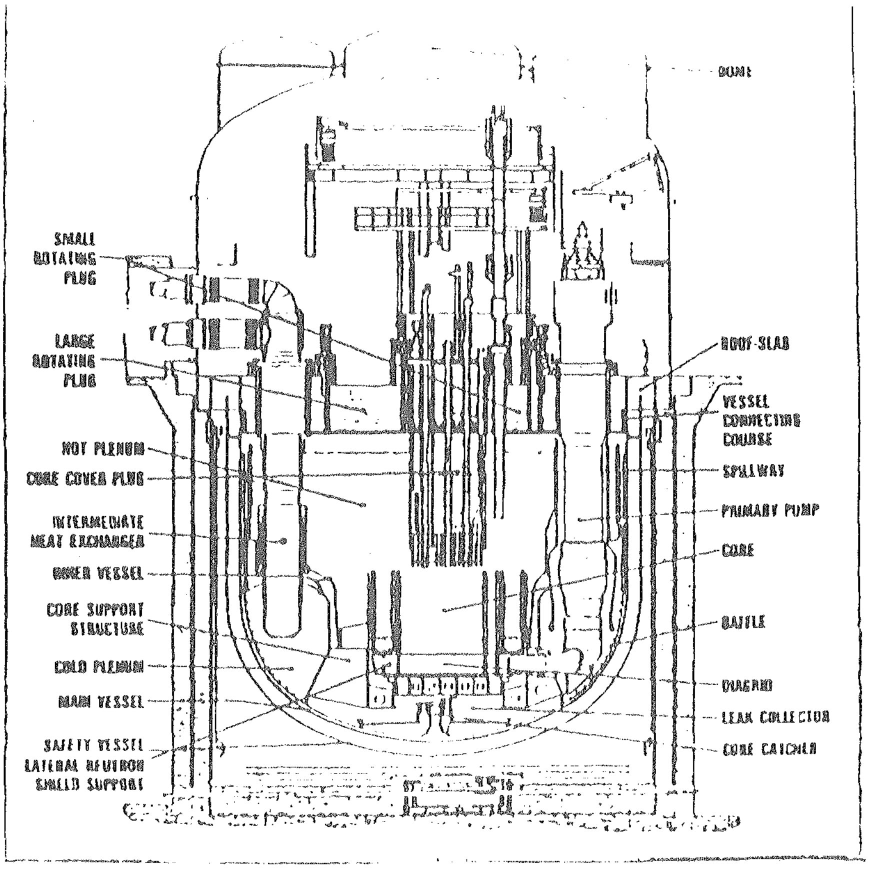
The overcost of these plants will represent a burden we must share between the interested countries, I mean the most interested in the existence of proven breeders. The European countries are in this situation, and probably also Japan.

This policy, expressed in Europe in the Memorandum of Agreement, signed in Paris on January 10, 1984, among the governments of Western Germany, Belgium, France, Great Britain and Italy, emphasizes the willingness of European governments, signatories to the agreement, to undertake long-term cooperation and to unite their efforts in this field of advanced technology ; they know it is a field which can be of major importance to their future energy policies, where they hold an undisputed lead. This agreement entails collaboration between industries, electric utilities and centers responsible for R & D programs to unite their efforts and facilities.

Discussions are now underway between the principal European electric´utilities ; they want to decide when, where and how to build the plant that is to follow Superphénix. As we have said previously, this phase should also include the construction of a reprocessing plant, which will give a good idea of the reduction in corresponding costs.

Unifying european efforts does'nt preclude external support and we should certainly favor interest of Japanese utilities or government in a form to be defined.

Japan and European countries are determined to prepare their energetic future by the way of this revewable, domestic energy which the breeders represent. Current achievements show the validity of this way, technically and even economically : a factor of two, at this stage of development is more a promise than a obstacle. We are ready to define this future in common.



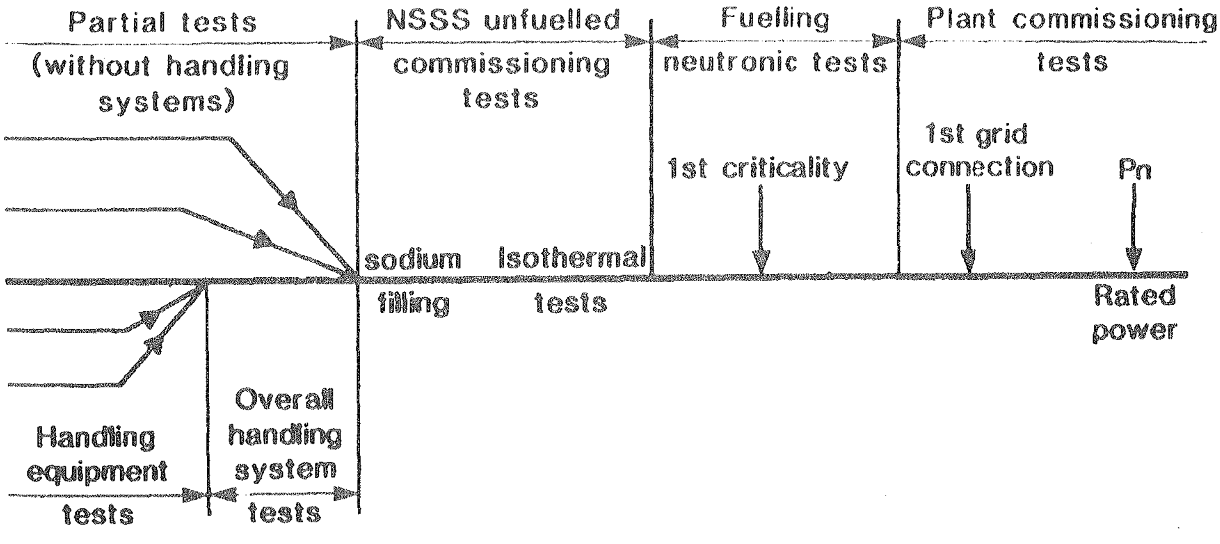
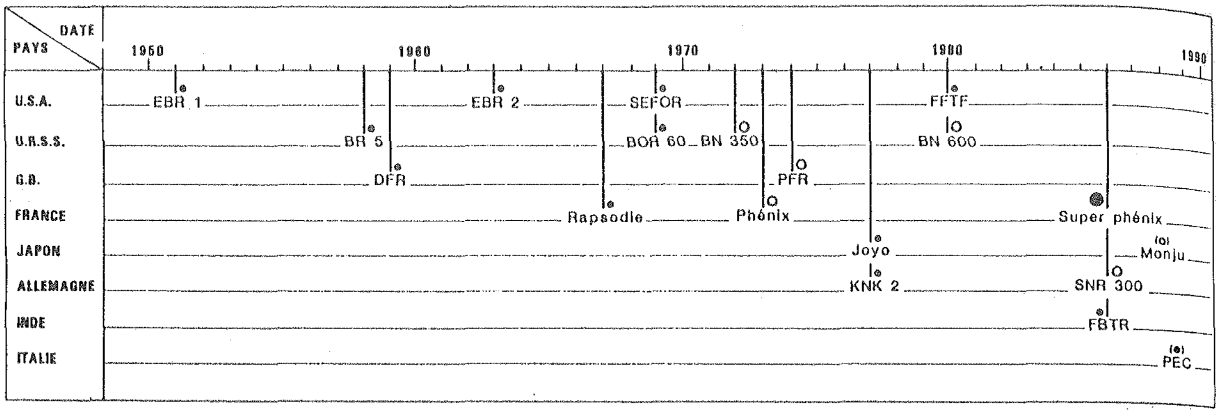


Fig. 1 – COMMISSIONING TEST FLOWCHART

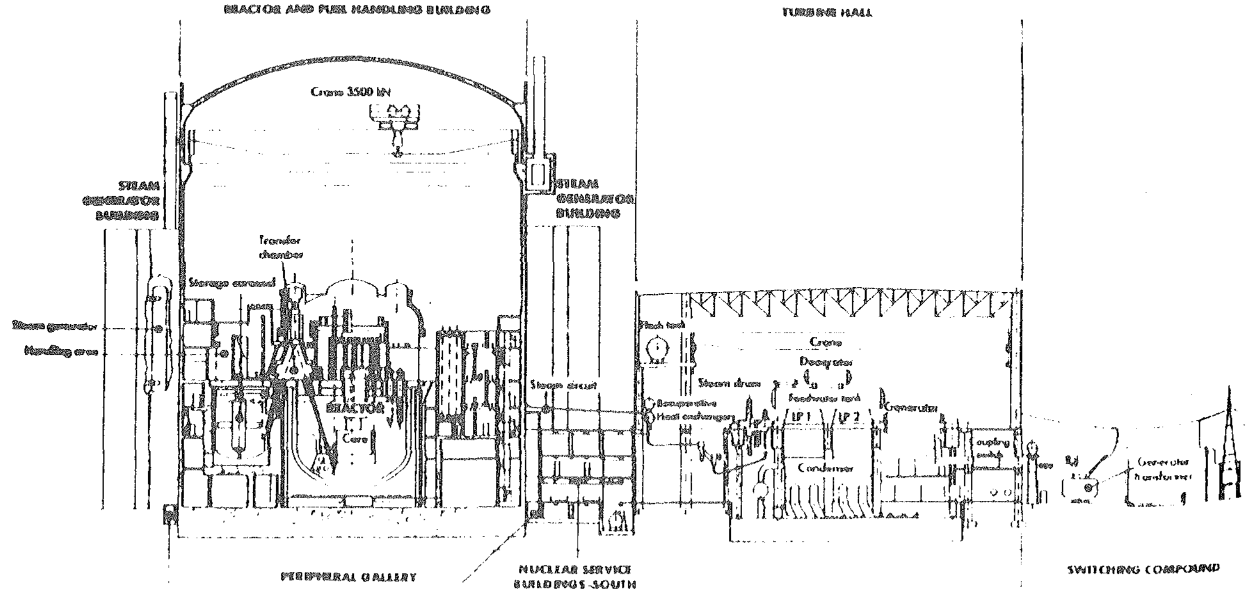
CRITICALITY DATE OF THE MAIN REACTORS
ALREADY BUILT OR UNDER CONSTRUCTION



KEY

- • Test or experimental reactor
- o Demonstration power plant
- ● High power prototype plant

longitudinal cross section



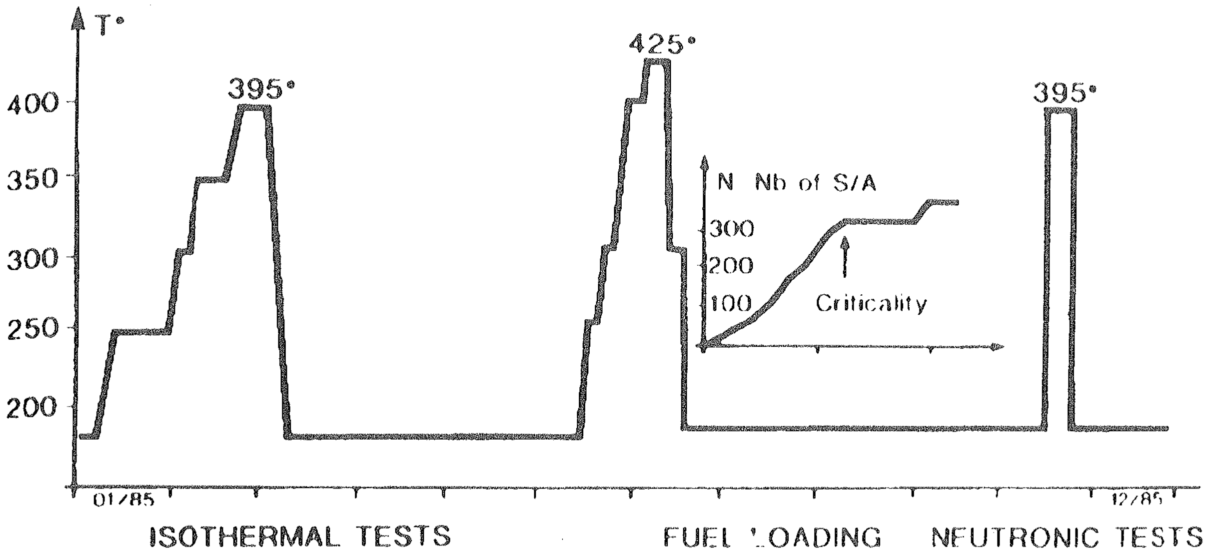


Fig. 2

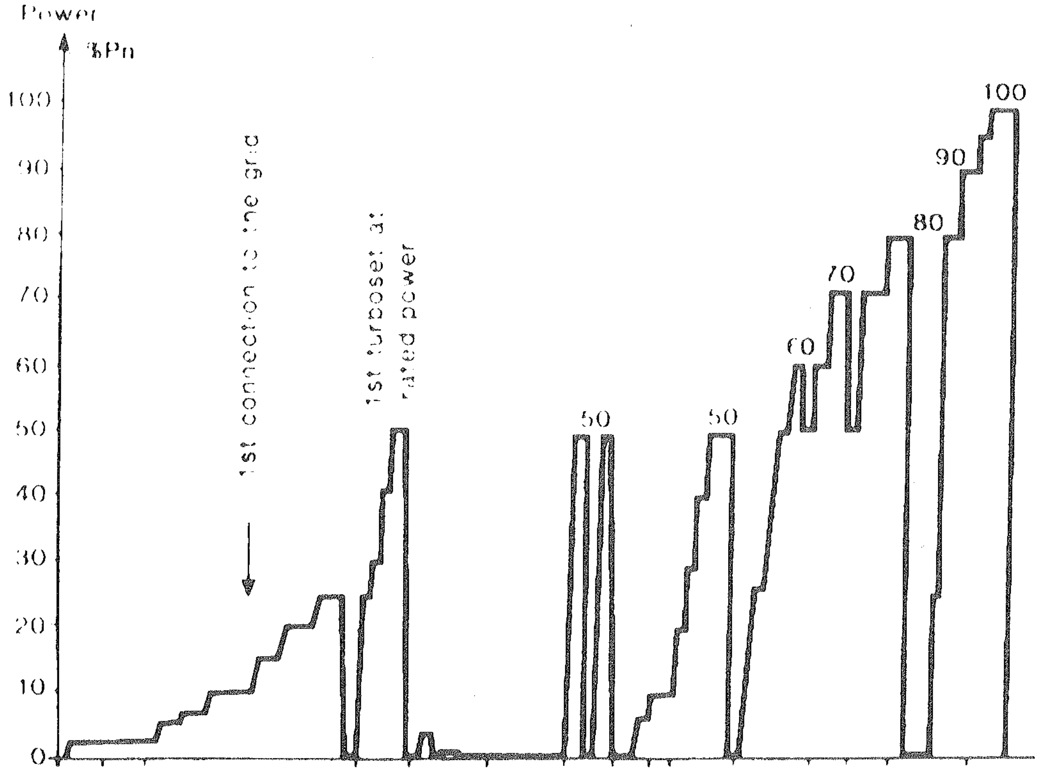
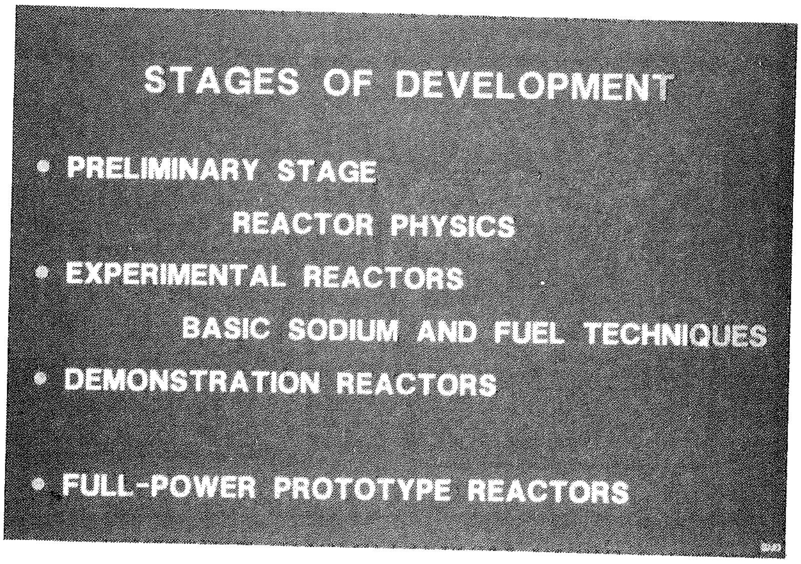
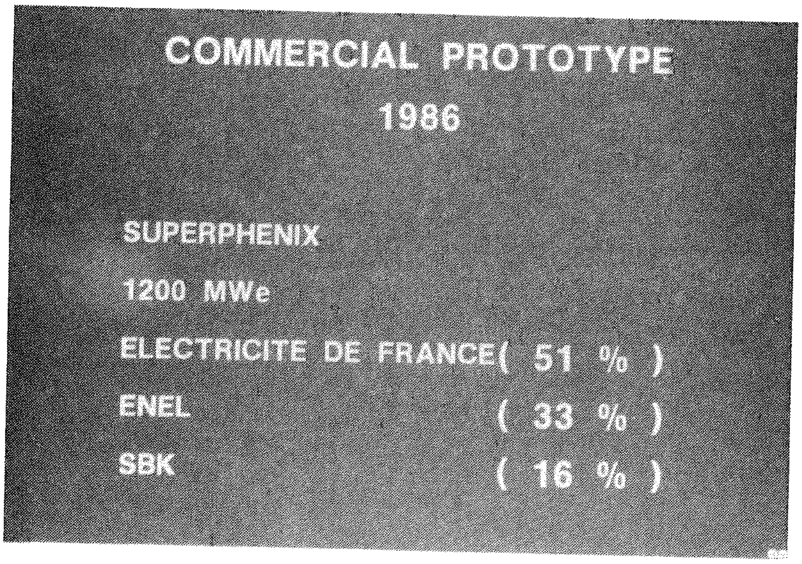


Fig. 3 - POWER BUILDUP



STAGES OF DEVELOPMENT

- PRELIMINARY STAGE
  REACTOR PHYSICS
- EXPERIMENTAL REACTORS
  BASIC SODIUM AND FUEL TECHNIQUES
- DEMONSTRATION REACTORS
- FULL-POWER PROTOTYPE REACTORS

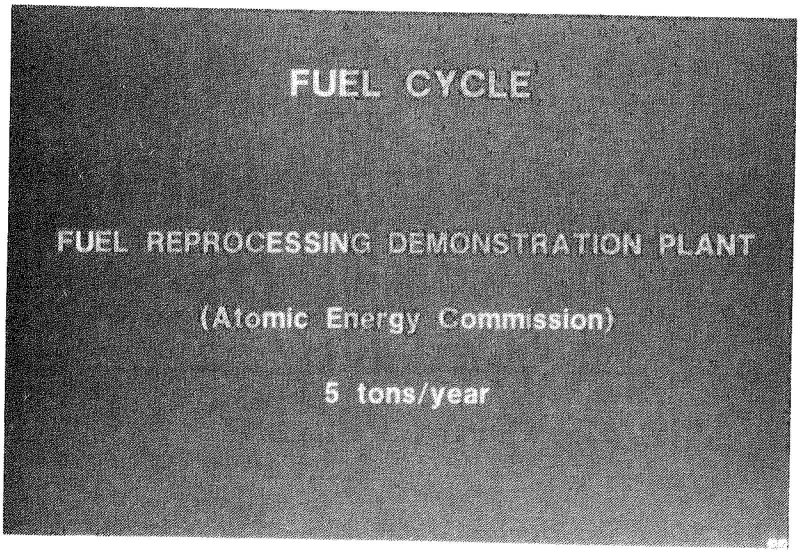


COMMERCIAL PROTOTYPE
1986

SUPERPHENIX

1200 MWe

ELECTRICITE DE FRANCE	(51 %)
ENEL	(33 %)
SBK	(16 %)

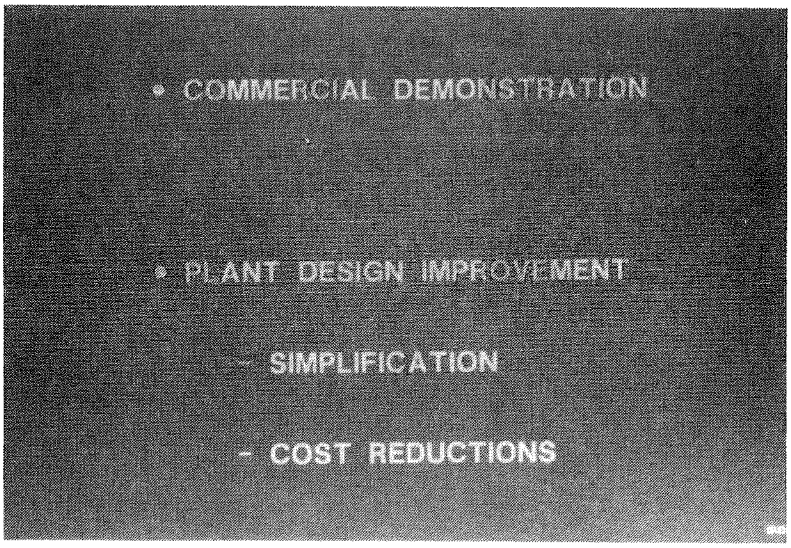


FUEL CYCLE

FUEL REPROCESSING DEMONSTRATION PLANT

(Atomic Energy Commission)

5 tons/year



- COMMERCIAL DEMONSTRATION
- PLANT DESIGN IMPROVEMENT
  - SIMPLIFICATION
  - COST REDUCTIONS

	SUPER-PHENIX 1	SUPER-PHENIX 2 (1,500 MWe)
REACTOR BLOCK	1	0.52
HANDLING - ASSEMBLIES	1	0.21
INTERMEDIARY CIRCUITS AUXILIARIES - WATER/STEAM	1	0.55
MECHANICAL SODIUM PUMPS	1	0.33
IHX AND STEAM GENERATORS	1	0.80
RESIDUAL HEAT REMOVAL	1	0.88

Japan Atomic Industrial Forum
Annual Conference 1986, Tokyo

How to use the full potential of nuclear energy

H. H. Haunschild, Vice-Minister,
Federal Ministry for Research and Technology, Bonn

After a period of relative calm on the oil market and the recent, unexpectedly sharp decline of the oil price, it seems to be difficult to attract attention to the long term problems of energy supplies. We know, of course, that - apart from an intermediate relaxation - little has changed basically since the 1970's, when "energy" was item number 1 in all international conferences. The problems are only delayed by a reduced growth in energy consumption and some progress made in energy conservation. But the basic problem of limited energy reserves remains. Only the emphasis may have shifted from the fear of a shortage to greater concern about the quality of fuel. The progressive depletion of reserves of high quality fossil fuel gradually leads to the use of fuel with lower quality with regard to economic as well as environmental standards. This is particularly true for the developing world with its vast potential - and its vast need - for economic growth.

Energy is only one of several important global problems, like wide-spread poverty in developing countries, population growth, food scarcity, environmental degradation etc.... But all of these problems have strong links to energy demand and supply.

Despite these problems we observe a decline in the funding of national energy r&d programmes practically in all OECD countries. But this is not only a response to the reduced oil price, it is also a consequence of the limited success of the comprehensive efforts in energy r&d during the past 12 years. We have found - in a thorough investigation of our energy r&d programme - that there were, of course, a great number of technical improvements, of new industrial activities, and - hopefully as a lasting effect - a better consciousness of the need for energy conservation and the technical means to achieve it. But there was no spectacular break-through of a new technology. Conservation was mostly achieved by improvement of traditional techniques. The search for new, in particular, renewable energy sources did not provide new solutions for industrialized countries, and the improvements in the use of fossil sources did not open up many new alternatives but were rather needed to harmonize their use with improved environmental standards. In general, the success of the nuclear r&d programmes i.e. the development of completely new energy technologies, could not be repeated. On the other hand, nuclear energy, while the search for alternatives was pursued, became one of the working horses of energy supply in most industrialized countries.

In Western Europe it is expected that in 1990 nucelar energy will provide 32 % of the total electricity production and 37 % in the year 2000. For the European Community a share of 40 % is expected in 1995. In the Federal Republic of Germany, nuclear energy contributes at present 35 % to the public electricity production and is expected to reach 40 % in 1990, which will be the maximum level on the basis of the present energy policy giving hard coal a guaranteed share of the market. Further growth can be expected later on, due to the economic and environmental advantages of nuclear energy as compered to electricity from fossil fuels.

Nuclear energy remains one of the cheapest sources of electricity. Neither the additional safety requirements nor the required financial provision for future decommissioning and the full inclusion of the costs of the fuel cycle and of waste management have affected its economic attractiveness.

Nuclear energy also has a good environmental record, whereas the global environmental problems, in particular acid rain, have led to the tightening of environmental standards for the burning of fossil fuels. Even only gradual solutions to these problems will bring about severe economic penalties, thereby further increasing the advantages of nuclear power.

Apart from its economic and environmental qualities, nuclear energy may also gain more importance by an expansion of its range of applications. While nuclear energy is today - with some minor exceptions - nearly exclusively used for electricity generation, there are trends towards using it for district heating or as process heat for industrial purposes.

Nuclear energy is also one of the pathfinder technologies with a great impact on the general standards of an industrial society. Even on the basis of its current progress in the full industrial implementation, it still has a promising potential of further technical and economic improvements. This is true for the light-water reactor and its fuel cycle and - even more so - for advanced reactor systems.

Efforts towards the full utilization of the potential of nuclear energy should therefore start with the LWR system. Let me address briefly the status of these technologies and the possibilities for further improvements.

The safety of LWR's was a subject of a most comprehensive German research programme during the past 15 years, a programme conducted in close international cooperation. After the termination of ongoing large scale experiments for the investigation of possible severe accidents we expect an end of this phase of LWR safety r&d.

Economic burdens imposed by a high safety standard were, to a large extent, compensated by improved availability factors resulting from safety-oriented design and better plant management.

The structure of the economics of nuclear power plants is characterized by a 2/3 dependance on capital cost. Therefore, availability obviously is a key factor for the determination of competitiveness. Consequently, major efforts to improve the LWR performance were undertaken in a number of countries. In the Federal Republic of Germany we are highly satisfied by the high availability factors achieved. For many years now, our power plants occupy leading ranks in world-wide statistics.

The high capital cost factor also calls for short and reliable time-schedules for planning, licensing, and construction. During the 1970's, most nuclear projects and programmes suffered from a slippage of time schedules. Some countries in Europe, as well as Japan, have meanwhile been able to re-establish short and reliable time frames. In the Federal Republic of Germany, we have, since 1980, demonstrated that nuclear power plants can be constructed in less than 70 months.

The current LWR technology has still some potential for further improvement with regard to the fuel economy, e.g. by slightly higher enrichment and by higher burn-up. In addition, a number of companies are also investigating advanced LWR concepts like converter reactors. In general, however, LWR's today represent a mature technology with only a limited potential for further technical improvement.

A more important area for the full potential of nuclear energy is the LWR fuel cycle.

The dominating enrichment technology still is gaseous diffusion, despite its clear disadvantage of an extremely high energy consumption. Reduced demand for enrichment services and the existing over-capacities have prevented a major switch to advanced enrichment technologies. The most advanced technology of today and - certainly - also of the 1990's is the centrifuge process as developed by the "Troika" countries: the United Kingdom, the Netherlands, and the Federal Republic of Germany, as well as by Japan. Recent developments have led to even better results than originally expected, allowing us in Germany to terminate public financial support of the technological development much earlier than planned. The technical advantage of the centrifuge process is also demonstrated by its competitiveness, even under the present world market conditions when major suppliers often do not apply full commercial pricing. There is certainly a potential for the improvement of market conditions for enrichment services by free competition and by diversification of suppliers. The German utilities e.g. have contracts with all major suppliers and thereby benefit from their competition.

In the future, laser technology may offer another interesting source of enrichment. In Germany we have some own development activities, and we follow closely the development pursued more vigorously by those countries operating diffusion plants. We limit our present efforts for two reasons: we are highly satisfied with centrifuges, and we are not interested in applications outside of the civil sector.

The closing of the fuel cycle lags behind in the industrial implementation in quite a number of countries. It is, however, of ultimate importance for the full establishment of the LWR system and, obviously, also for public confidence in nuclear energy.

In my country, we have considered the back end of the fuel cycle as a key element of the LWR system already for many years. In 1985, the Federal Government confirmed previous decisions to favour reprocessing as the main method of spent fuel management. The decision was based on a comprehensive assessment of possible safety advantages of direct disposal of spent fuel versus reprocessing. Based on the conclusion that direct disposal does not offer decisive safety advantages and is still far from technical feasibility, the German Government decided that direct disposal may become acceptable only for certain kinds of spent fuel and only after additional development and demonstration. Last year, construction of the first industrial reprocessing plant was started in Bavaria. The plant will have a capacity of 2 tons of heavy metal per day, leading to an annual capacity of 350 to 500 tons. The beginning of "hot operation" is planned for 1995. The plant design employs advanced reprocessing technology promising good standards in economy, in safety, and in safeguards.

Reprocessing has a dual purpose. One is the transformation of the spent fuel into different classes of radioactive waste which can then be treated according to its respective properties and be disposed of safely in geological repositories. The second purpose is the extension of the available uranium supplies by thermal recycling, and, ultimately, by fast breeder reactors.

We have followed the route of thermal recycling, like Japan, already for many years. With the delay of the breeder reactor commercialization recently also, other countries started thermal recycling of plutonium. This strategy is clearly favoured in countries with large nuclear power programmes but insufficient indigenous resources of uranium, like Europe and Japan.

The conditioning of the radioactive wastes prior to reprocessing is an important element in the nuclear fuel cycle which has reached full technical maturity only recently. An important milestone on the way to commercial application has been reached 1985 with the operation of the Pamela vitrification plant at Mol/Belgium.

Even if there may be no time pressure for an early final disposal of high level waste for technical reasons, we consider a timely closing of the fuel cycle a highly important task in a responsible approach to nuclear energy.

For the disposal of radioactive wastes, we have from the beginning chosen, for heat generating waste, the disposal in deep geological formations, in particular in salt formations. Today, we proceed on the basis of investigation conducted in the Asse salt mine from 1967 to 1978. The salt dome of Gorleben has been designated as the site in 1977, and in the meantime an extensive drilling programme has been completed. After the ongoing bringing down of two shafts the underground exploration will begin in

1990. If the suitability of the site is definitely confirmed, the repository will become operational before the year 2000. In addition, a former iron ore mine will become a repository for non-heat-generating waste by 1990.

Other disposal media like granite are subject to programmes of the European Community and, among others, Switzerland and Sweden.

We exclude some disposal methods like shallow land burial of low-level wastes, dilution of effluents with off-gas, or discharge into water, as well as sea-dumping, for environmental considerations, and because of the favourable conditions for geological disposal in our country. We have found that the inclusion of low level waste in a regime of geological disposal of medium and high level wastes can lead to satisfactory economic solutions. The total cost of final disposal will contribute by only one percent to the electricity generating cost.

The full industrial establishment of LWR technology including its fuel cycle, is still an important and demanding task. It also provides the basis for a continued development of advanced nuclear reactors for various purposes which can lead to a full exploitation of the potential of nuclear energy.

Both, Western Europe and Japan, have a high technical standard in nuclear energy, and a poor raw material basis. This leads to continued strong interest in the development of fast breeder reactors as the most important element for the full utilization of the nuclear potential. As in many countries, there will not, however, be a major economic role for breeder reactors before the year 2000.

Basically identical fuel cycles of breeders and LWR's will facilitate the incorporation of breeder reactors into the system. The greater the share of nuclear energy in power generation and the greater therefore the importance of an undisrupted supply of nuclear fuel, the more important will it be to improve the assurance of supply by the breeder reactor technology. The decision to commercialize the breeder reactor will, therefore, ultimately depend on how nuclear energy utilization will evolve in any one country and on a global level.

The progress which can be made with regard to the economic efficiency of large scale breeders and associated fuel cycle facilities will be one of the crucial factors influencing the commercialization. The cost of power generated in breeder reactor systems can still be reduced as a result of further developments and by jointly using existing capacities in international cooperation.

Cost saving international cooperation is of great importance even more today than at the beginning of the breeder development when industrial use was expected to take place at a clearly quicker pace. Although some problems are still to be solved, European breeder cooperation has reached an advanced stage, after confirmation and expansion by an intergovernmental agreement in 1984.

At present, negotiations are under way between the European partners. They are expected to lead soon to the first planning order for the SNR 2 project in Germany. This power station will be a 1500 MWe breeder reactor, the design of which will be based on the experience with the SNR 300, on the pooled European know-how as well as on German experience in LWR construction and operation.

A first review of the basic SNR 2 design by a group of licensing experts has led to a positive evaluation of the safety concept. The construction cost will be very close to the specific construction cost of a new German LWR power plant.

We have noted with great satisfaction that the European view on breeder reactors is shared in Japan. The 1985 decision, to start the construction of Monju clearly is an important milestone in the breeder reactor development in general. We hope, that the combination of interests from Europe and Japan will permit further progress in cooperative ventures. We also watch with great interest the ongoing process in the United States for the formulation of a new programme for advanced reactors, including various types of liquid metal cooled fast reactors.

With regard to the assessment of the importance of breeder reactor technology we also find ourselves in accordance with the USSR, which is planning a series of large breeder power stations, and with India sustaining an ambitious effort to develop an indigenous breeder technology.

If the world-wide efforts in breeder reactor development continue, nuclear energy will reach its full potential as a most powerful, most economic, and inexhaustible source of electric power.

The extension of nuclear energy application beyond electricity generation was always a special feature of the German nuclear energy programme. The High Temperature Reactor - HTR - was developed to provide a new source for the economic production of process heat for a variety of industrial applications.

A pilot plant of the HTR with a capacity of 15 MWe has been operated in the Jülich Nuclear Research Center for more than 18 years, with good availability and reliability also at gas temperatures of 950° C.

During the last decade the HTR development was focused on the 300 MWe reactor at Schmehausen, a demonstration plant still limited to power production. This reactor, the THTR-300, at present in the commissioning phase, has been connected to the grid for the first time in December 1985.

New industrial initiatives for HTR commcercialization cannot be expected before the THTR-300 has been successfully operated for a certain time. In any case, industry will have to bear the technical and economic risks of the commercialization of high-temperature reactors.

Today a number of future HTR-projects for the production of process heat and power are being investigated by two German industrial groups.

All HTR reactor concepts, in principle, aim at higher core outlet temperatures for nuclear process heat production. The specific heat transfer components for high-temperature applications have been developed in a comprehensive r&d programme and are presently being tested on a 5 to 10 MW scale, so that the technical basis for the future use of nuclear process heat is established.

HTR heat could be used for various purposes like processes in chemistry and petrochemistry, steam injection for oil recovery, processing of crude oil, sea water desalination, oil sands or oil shale extraction, and coal gasification.

Further future applications may also be found in combination with coal-fired stations or gas turbines which will increase the plant's efficiency.

The chance of international cooperation in HTR development is not as broad as in breeder technology. We continue the cooperation with Switzerland. New interest was shown by a number of American manufacturers and utilities in small and medium sized HTR's. This interest has led to design work for HTR power stations in the 200-300 MWe range designed for electricity or heat production using the US developed prismatic fuel elements. Recently, we heard about new plans for the design of very small HTR units of the 30 MWe range in Japan.

Also the LWR offers a special potential for application in small dimensions, in particular for district heating. A number of concepts are presently being pursued in Europe (Sweden, Switzerland, Federal Republic of Germany). The various designs have basically the same features: use of conventional nuclear components and standard fuel elements, low-temperature and low-pressure design, extensive use of inherent safety features leading to an extremely low demand for personnel in operation and maintenance, long lifetime. The designs vary for power ranges between some 10 to app. 100 MWth. All proposed designs are, at present, waiting for a first demonstration.

As in the case of medium and small HTR's, there is a potential for economic competitiveness with conventional power sources. For this purpose, nuclear technology would have to find new customers in addition to the large utilities. This process has up to now been hampered by the fact, that a possible competitiveness of small nuclear units does not provide a strong incentive for companies to become engaged in the nuclear field. In the case of large LWR's, a clear economic advantage over conventional plants paved the way for commercialization. As long as small nuclear plants, be it modular HTR's or small LWR's, do not offer decisive economic advantages, it will remain questionable whether the technical potential will ever be used on a broader scale.

Let me conclude by saying that there is no simple answer to the question, how to use the full potential of nuclear energy. The LWR system provides us with a very powerful tool in energy policy. On this basis, the clear economic and environmental advantages have made nuclear energy an indispensible part of the world's energy supply. The excellent record in safety and reliability increases our confidence that nuclear technology will have an ever-increasing, and lasting, impact on the economy.

In the short term, the LWR system has to be fully established by a timely closing of the fuel cycle on an industrial scale. In addition, a reasonable potential for further economic improvements can certainly be exploited.

In the medium term, new concepts for small reactors may open up new fields for the application of nuclear energy in district heating or for industrial production, but with uncertainty as long as technical feasibility and economic advantages have not been clearly demonstrated.

In the long run, the development and commercialization of the breeder reactor will permit a continuous employment of nuclear energy as the major working horse for the supply of electric energy, in particular for those countries, which have large nuclear power capacities but small, if any, domestic uranium production. It is encouraging to see that, internationally, the assessments of the potential of the breeder are, again, in wide agreement. Let us hope that we can turn this agreement into more and closer international cooperation.

NUCLEAR ENERGY POTENTIAL

BY
MILTON LEVENSON
VICE PRESIDENT
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Presented at
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This meeting to recognize the 30th anniversary of the JAIF, Japan's entry into the development of peaceful uses of atomic energy, must honor the size, maturity and high quality of the current Japanese nuclear power program and its 285 reactor years of experience. Perhaps even more importantly, it highlights the foresight of the people who 30 years ago undertook this effort.

Thirty years ago, in 1956, Calder Hall, the first British dual-purpose reactor was brought into service. The prototype of modern Light Water Reactors did not yet exist. Dresden 1, considered the first commercial Boiling Water Reactor, was completed in 1960; and Yankee, the first commercial Pressurized Water Reactor, was also completed in 1960. In fact, 30 years ago was a very short 5 years after the first production of electricity from a nuclear reactor. That milestone was achieved in December of 1951 by the Experimental Breeder Reactor number one (EBR-1). The visual evidence of that has become the classic four lightbulbs shown in Figure 1. The reason for the four lightbulbs is interesting and to some extent a prophecy for what has happened since that day. On that first day the reactor was generating power, the turbine was spinning; and the question became how to get visual evidence that electricity was actual being produced by nuclear power. The more conventional part of the plant, the electrical system required to take generator output and deliver it to other parts of the plant had not yet been completed. So four 120 v lightbulbs were connected in series and put directly across the 480 v terminals of the generator, the bulbs lit and the picture was taken for history. (The four bulbs did not represent the quantity of electricity that the generator was capable of producing as some have implied, but the voltage was right.) Today, in spite of all the public and media concerns about the advanced nature of nuclear power, quite often it has remained the conventional part of the plants that have slowed us down, run the costs up, or held us back. It should also be noted with interest (because I think it has a major bearing on the future of nuclear power) that this first power reactor was not a Water Reactor, it was a Liquid Metal Reactor. In the late 1940's it was perceived that a liquid metal reactor system was something that could be done within existing technology, and probably water reactors could not be. It remained for the very large expenditures of the U.S. Naval Reactor Program to develop the technology of pressure vessels and high pressure piping, which led to our current Light Water Reactors.

In order to make the reference to history complete, we must point out that it is only 44 years since the first man-made controlled nuclear reaction took place in the squash courts of the stadium of the University of Chicago. It is perhaps two billion years since the world's first nuclear reactor went critical and generated substantial amounts of energy – although it did not make electricity. Those natural reactors were in Gabon, Africa. The dark area on the left in figure 2 shows one of the reactors. I believe a total of six prehistoric nuclear reactors have been discovered so far. Because of the difference in half-lives of Uranium 235 and 238, two billion years ago all of the uranium in the earth's crust was between 3-1/2 and 4% enriched. Uranium leached from an ore deposit by a river and then deposited on a delta made of charcoal from forest fires could have produced such a natural reactor. A 3-1/2 ~ 4% enriched uranium matrix and a high enough concentration to go critical, could have produced enough power to boil the river dry. The "reactor" would sit there until the next rainy season when the river flooded, the reactor became critical again and operated at intermittently significant power levels for decades, perhaps even centuries. Exactly how these reactors came into being is theory, but there is no doubt that they did exist and did operate. The most relevant information to today's issues from these prehistoric nuclear reactors is that we have a billion years of experience of what happens to long-lived and stable fission products in the earth's crust, even after exposure to weathering and cycling (Fig. 3). Extensive analytical work shows that there has been no widespread dispersal of fission products or Plutonium. As engineers and scientists, we can take credit for harnessing atomic energy for supplying electricity to our society; but nature predates us by a very, very long time in the production of the first energy from a fission power reactor.

The current status of nuclear power as a source of electricity for our society hardly needs discussion for this audience. Suffice it to say that essentially every developed country in the world has recognized that nuclear power is the most environmentally benign and the most economically stable source of electricity. In the United States institutional problems have seriously distorted the economics. But that is not a function of the technology; it is only a function of the institutional problems. To understand why the U.S. view of nuclear power is different than that of Japan, and why the U.S. view is not very relevant to most countries, one needs to consider the energy reserve situation. Figure 4 shows the approximate ratio of energy reserves in Japan to those of the United States. The massive reserves of U.S. coal and the large reserves of oil and gas, mean that, while uranium may be a source of energy, it is not essential, not even for national security reasons. If the uranium square is expanded to include the energy available when breeders are in use, the resulting square more than fills the entire figure.

For a country that has massive reserves of gas and oil and coal, plus large reserves of lignite and shale oil, nuclear power, per se, is not necessary in order to have a diversified energy source. Nuclear power may be the most environmentally benign source of electricity and it may be the safest but at this time it does not have the same status for the U.S. as for most other countries of the world. In particular, since the U.S. – with the Light Water Reactor – already has four significant alternatives, one must discount the U.S. delayed decisions on the Breeder Reactor. Under these conditions, it is difficult to obtain a national consensus for a fifth source of energy in order to assure a reliable supply for the next few decades. On the other hand, for those countries of limited fuel reserves where nuclear power represents a major part of their electrical future, the Liquid Metal or Breeder Reactor should not be considered as a sequential follow-on to the Light Water Reactor. It should be considered in the light of a need to diversify the energy supply. The Liquid Metal Reactor technology is different than LWR technology; the fuel cycles are different; everything is different. For most countries of the world, the review of the role of the Liquid Metal Reactor should not be as an economic competitor for the Light Water Reactor, but rather as an economic competitor for oil or coal. If for Japan the Liquid Metal Reactor is cheaper than oil or coal, then Japan should proceed with the Liquid Metal Reactor as a way of diversifying its electricity supply in the most economic manner.

I will make no attempt to estimate the electricity needs of the future, nor the rate of growth of energy needs, nor the new applications that may require expanded supplies of electricity. Suffice it to say that electricity is the cleanest energy, the smartest energy, and the most flexible energy. Its percentage of our world energy will continue to grow. I assume that by the end of the century battery developments will have reached the point where a major fraction of the vehicles on most city streets will be electric cars and peak loads will be handled by some type of battery storage. It is important to recognize that much of conservation runs on electricity. When we substitute heat pumps for gas or oil furnaces, our total energy consumption declines; but our use of electricity increases. When we build smart buildings with rooms heated only when occupied, we are usually talking about electric heat. As we move workers from outside jobs and open factories to offices and service jobs, we add lighting, air conditioning, and electronic tools and electronic terminals — all require electricity. Regardless of the nature of our society, or the rate of growth of GNP, or the rate of population growth, it is very clear that the need for electricity 30 years from now will be significantly greater than the current need. It is also clear that new alternatives, such as solar and wind and wave, may play a minor part, but only a minor part. Fusion will probably not yet play any part. Concerns over the risks of fossil fuel use, such as acid rain and the greenhouse effect, will make the expanded use of fossil fuels questionable at best, and possibly prohibitively expensive.

Thirty years sounds like a long time but we should recognize that it is less than one lifetime of technology. Therefore, while 30 years from now we will be seeing the introduction of many new things (including things that today we might think are very unlikely, or very unique or not even thought of yet). We will also still be seeing a substantial part of what we see today. In 30 years we will not be deeply into a new era, we will be at the start of a new era. I would expect that 30 years from today, not only will a major part of the electricity of the world be coming from Light Water Reactors, but much of it will be coming from the very same Light Water Reactors that exist today. Today we are accumulating worldwide LWR experience at the rate of one reactor year per day — and it is continuing to accelerate. In 2016, less than 4% of the reactors now operating in Japan will be 45 years old. The program for life extension and plant improvements are an accepted philosophy that is being implemented today. Thirty years from now we will have gone one step further in the life extension of existing plants. I choose to call it — refurbishment. By the time a nuclear power plant has reached 40 or 50 years of age, even modest rates of inflation and escalation will mean that the non-deteriorated parts of the plant, such as the Containment Building, the Water Structures, the Auxiliary Buildings, the Structural Steel, Turbine Generators, etc., will have a replacement value that is so high that it would not be economically practical to junk them. It may be necessary to completely replace systems that have deteriorated. It may be that all of the electrical systems, all of the instrumentation, many of the small motors, many small components, and even the entire Primary System (Pressure Vessels, Steam Generators and Piping) would be replaced. But a major part of the investment of a nuclear plant has a potential for a 100-year lifetime and I believe that conservation of resources, limited sites, and good engineering will have introduced plant refurbishment to indefinitely postpone plant decommissioning.

It would have been better if the refurbishment concept had existed at the time current plants were being designed so that ease of replacement could have been planned for in the original design. I assume that will happen with our next generation of LWR's.

There certainly will be new Water Reactors built during the next 30 years, most of them in the next 15 years. Perhaps not very many new ones will be under construction 30 years from now because of the world fuel supply. Those that will be built in the interim will philosophically look more like those we built 10 years ago than they look like the ones we built last year. The unjustified complications that have been added in the panic that occurred after TMI will be replaced by a more rational assessment of what is technically sound, what is technically needed, what is real safety. The Light Water Reactors we will build in the next 30 years are not likely to be entirely new concepts, they are much more likely to be evolutionary models based on today's LWR's – just as today's automobiles have evolved from the automobiles of the 1930's, 40's and 50's.

Thirty years from now part of our electricity will be coming from Liquid Metal Reactors. I believe that the Liquid Metal Reactors will actually be introduced into our energy economy, not because of a rapidly rising price of uranium, but rather from recognition that any technology that offers the advantages of nuclear power – (environmentally benign, national security, economic stability, etc.) at a cost competitive with or cheaper than oil and coal cannot be ignored.

While Light Water Reactors have been receiving most of the attention world-wide (and making most of the nuclear electricity), Liquid Metal Reactor Technology has been making major progress. A paper in this Session covers the French program and the very successful design and construction of the Phenix Reactor. The Russians have been running the BN 600 Reactor for several years now. The Experimental Breeder Reactor (EBR-II) in Idaho has been rather consistently demonstrating the safety and reliability of Liquid Metal Systems. It is now almost 24 years since EBR-II was last cooled down to room temperature. Recent experiments conducted at that reactor included a full loss of flow experiment and a full loss of heat sink experiment. In both cases the reactor was taken to full power, the safety circuits were inactiviated so scram could not occur, and then all power to pumps were turned off. In both cases, the reactor passively shut itself down due to phenomena such as thermal expansion. Analyses indicate the same would occur for large size reactors of similar design. This should help to eliminate the hypothetical "what if" consequences that had been assumed for Liquid Metal Reactors.

While the Power Reactors in operation in 2016, whether they are Light Water Reactors, or Liquid Metal Reactors, will look very familiar to an engineer of today, there will be differences. Instrumentation and control, maintenance provisions, and fuel cycles will probably be significantly different. Instead of millions of feet of wire, thousands of conductors and hundreds of cable trays and conduits, each plant will probably contain a relatively few simple closed loop systems for handling all information functions – what today we call instrumentation and control. Such a loop would most likely be fiber optic, but it might also be an infra red or micro wave system. Dispersed Data Processing will be done by micro versions of expert systems. Input to the expert systems will come from an extensive network of monitors of all types – strain gauges, stress gauges, corrosion monitors, sonic monitors, temperature, pressure, flow, speed, vibration, etc. Analyses will be done routinely and automatically, with a local silicon chip making a decision and taking the action necessary to adjust operating conditions of the plant.

With the plant running smoothly in the hands of the Information System, the operators' role will be different than it is today. The Information System will have learning ability so that it will be aware of all abnormal events that have ever occurred and know what to do about them. The operator will be a supervisor monitoring what his robot staff is doing.

Perhaps the major difference in the physical design of the plants that will be built in the year 2000 and beyond is that they will be designed for remote maintenance (automatic maintenance, robot maintenance – whatever you care to call it). We will not be exposing people to even low levels of radiation in order to do ordinary and routine repairs and maintenance. Today there is a great deal of effort on the development of robots that can do anything – they can enter a contaminated building, they can explore the bottom of the sea or roam on a distant planet. They've been used in the clean up of TMI. This is a very interesting challenge for the designers of robots. But it is not the best way to plan for remote maintenance.

It is much better to actually design a plant for remote maintenance. It may be a challenge to design a robot that can reach up underneath a piece of machinery to remove a bolt. It is much better engineering to put the bolt in from the top of the piece of machinery so that the robot does not have to reach up underneath. While no reactor has yet been built that way, one class of nuclear facilities – reprocessing facilities – have been built that way. The original reprocessing plants at the Hanford Washington nuclear site in the United States had all of its reprocessing plant facilities designed for completely remote maintenance. The installation and removal of all piping and electrical lines, and all mechanical components was done remotely.

Perhaps the remote maintenance concept reached its highest level of sophistication in the Fuel Cycle Facility (FCF) of the EBR-II which operated for five years without anyone entering the cells of the facility. Spent fuel was received from the reactor after cooling times as short as two weeks; cladding was removed from the fuel; the metal fuel was melted down into ingots; the ingots were cast into new fuel pins which were cut to length, inspected for diameter, porosity and density. The acceptable fuel elements were then clad in stainless steel cladding with automatic remote welding, assembled into subassemblies and returned to the reactor. Not only were the processes of fuel dismantling, melting, casting, fuel fabrication and assembly all done remotely, but all equipment was maintained, repaired and modified remotely — even to the changing of lightbulbs inside the plant.

Figure 5 is a picture taken inside that facility. In the foreground is the automatic equipment for inspection and sizing of fuel elements. In the background (the large cylinder) is a casting furnace for the casting of fuel pins. The background radiation inside this facility approached 1 million roentgen per hour. I am sure everyone in this audience has seen the greenish glow of Cerenkov radiation (the glow of highly radioactive materials usually submerged in water). Figure 6 is a very unique radiation glow. You are looking at the inside of an empty used crucible that has been used for melting very radioactive fuel. The red glow you see is not a temperature glow, nor is the background dark. You are looking through 5 feet of lead glass. The ambient light level inside the cell is over 100-foot candles and the red color you see is the radiation glow above that background. This gives you some idea of the levels of radiation that remote operations have already coped with.

The next figures show some remote maintenance activities taking place. Figure 7 shows the replacement of a motor in a bridge drive. Manipulators and cranes were designed so that motors plugged in like old-fashioned radio tubes. When plugged in, motors and gear reducers were physically located, electrical contact was made and power drives or clutches were engaged. If the motor burned out, the repair "robot" gripped just the one handle and pulled. This unlocked and then unplugged all aspects of the motor — mechanical, electrical and drive. A new motor could be installed in just a few minutes. This same concept applied to everything in this entire facility.

Facilities designed for remote maintenance have been in operation for more than 40 years; it is time we introduced the concept to power reactors. This concept of design for remote maintenance, a concept of the late 50's, implemented in the early 60's, will return as a basis for reactor plant design of the 90's.

There will also be new thinking about fuel cycles. EBR-II driver fuel has been taken to burn-ups in excess 180,000 MW days per ton. FFTF has demonstrated extremely long life and low swelling for new cladding and fuel assembly structural alloys. It is probable that, long before 30 years have passed, Liquid Metal Reactor Fuel will exist that has a lifetime equal to the nominal lifetime of the power plant. The economic optimum may dictate refueling every 10 year, but technically it may be possible to refuel only once every 20 or 30 year.

On the political scene, it is very unlikely that oil prices will be free market prices. The current disarray of OPEC, partially due to the introduction of nuclear power and the small automobile, will be under control by the oil producers. However, the expansion of nuclear power and the use of electricity for transportation, via the electric car, will help put a cap – be it a high cap – on oil prices.

In summary, it is my opinion that 30 years from today essentially all of the nuclear power plants now operating in Japan will still be operating. However, they will be only a fraction of the total nuclear power of Japan. Nuclear power will be a much larger fraction of Japan's total electricity than it is today; and electricity will be a much larger fraction of the country's total energy than it is today. While today's plants will still be in operation – 40 years will turn out to be middle-aged for well-run, well-maintained nuclear power plants – most of the plants will be plants not yet under construction or not yet scheduled. These will not be new concepts – basically they will almost all be evolutionary, not revolutionary, versions of today's LWRs and LMRs. There will be differences, lots of differences, but they will be in special fields, in auxiliaries, in supports and not in the basic technology.

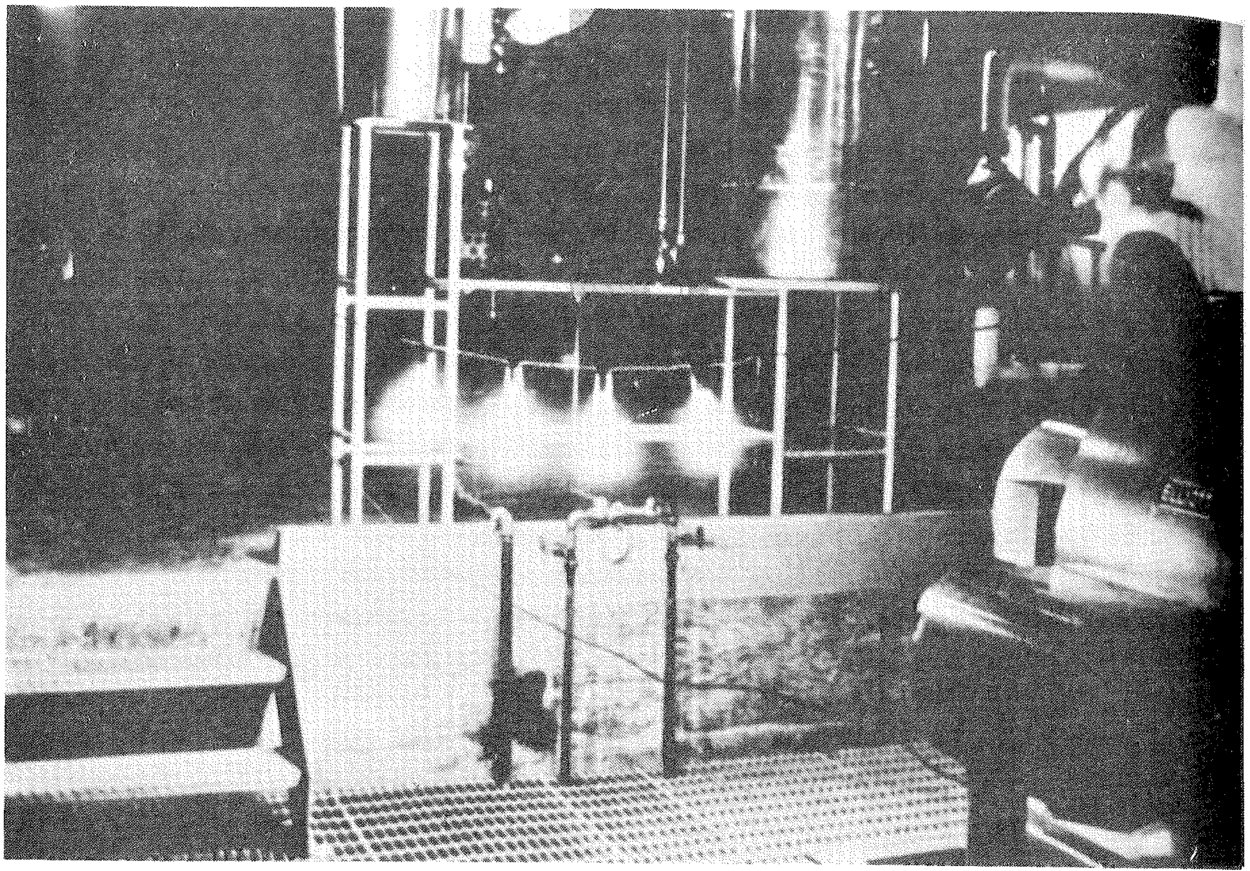


Figure 1

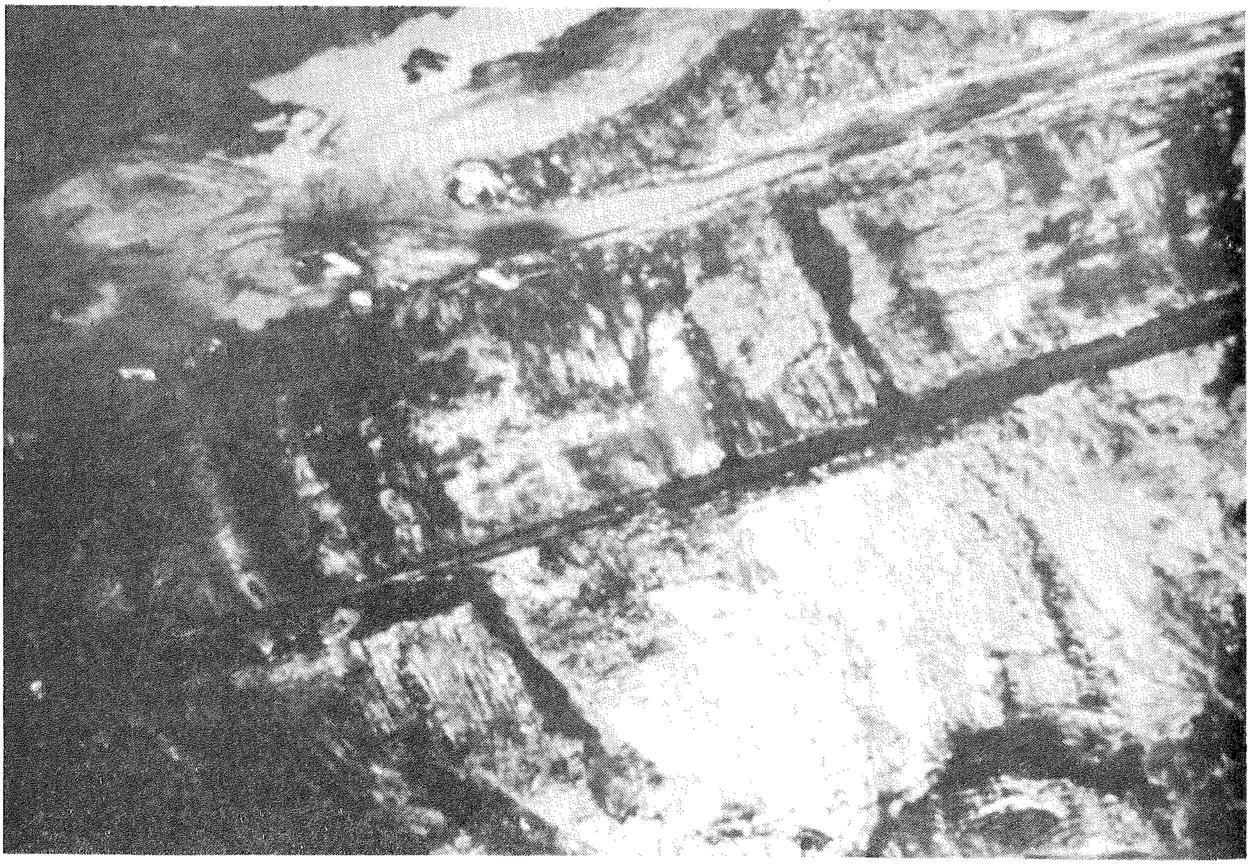


Figure 2

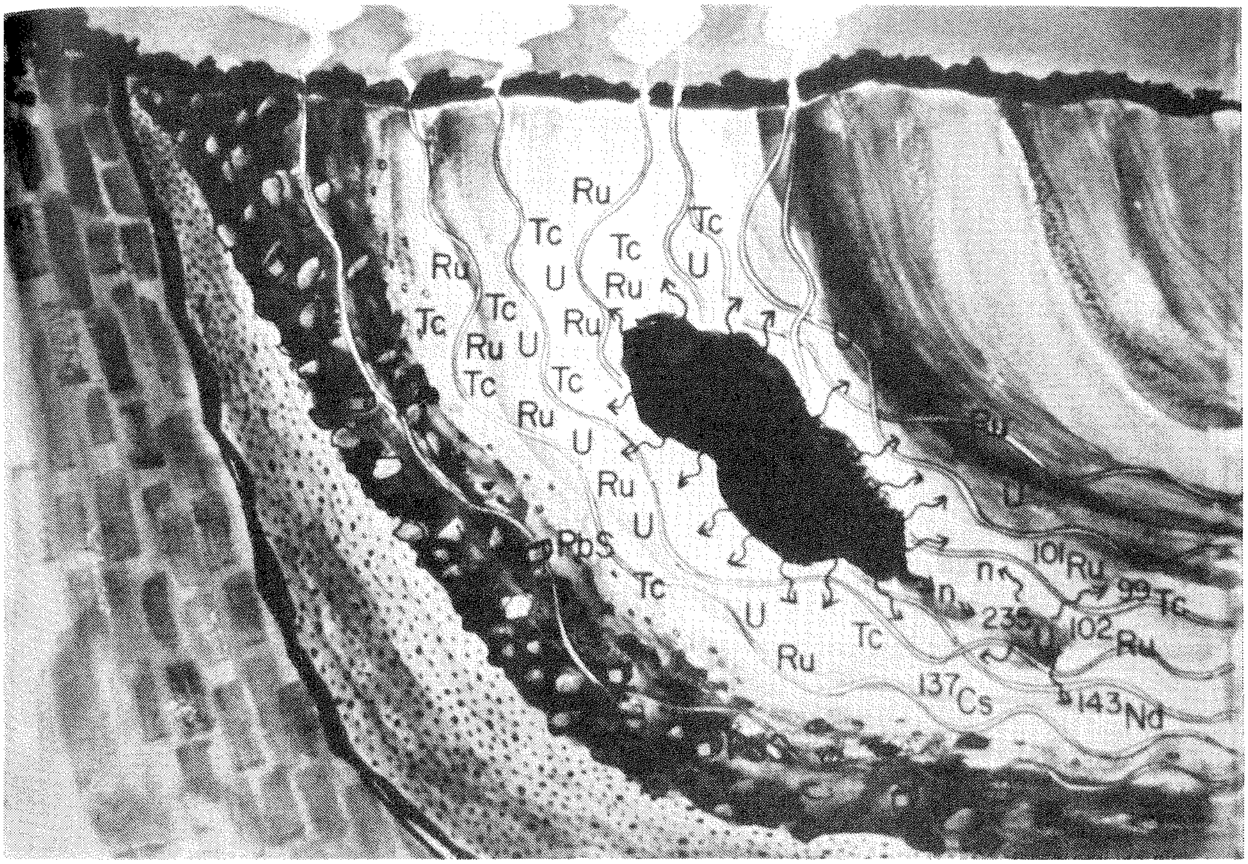


Figure 3

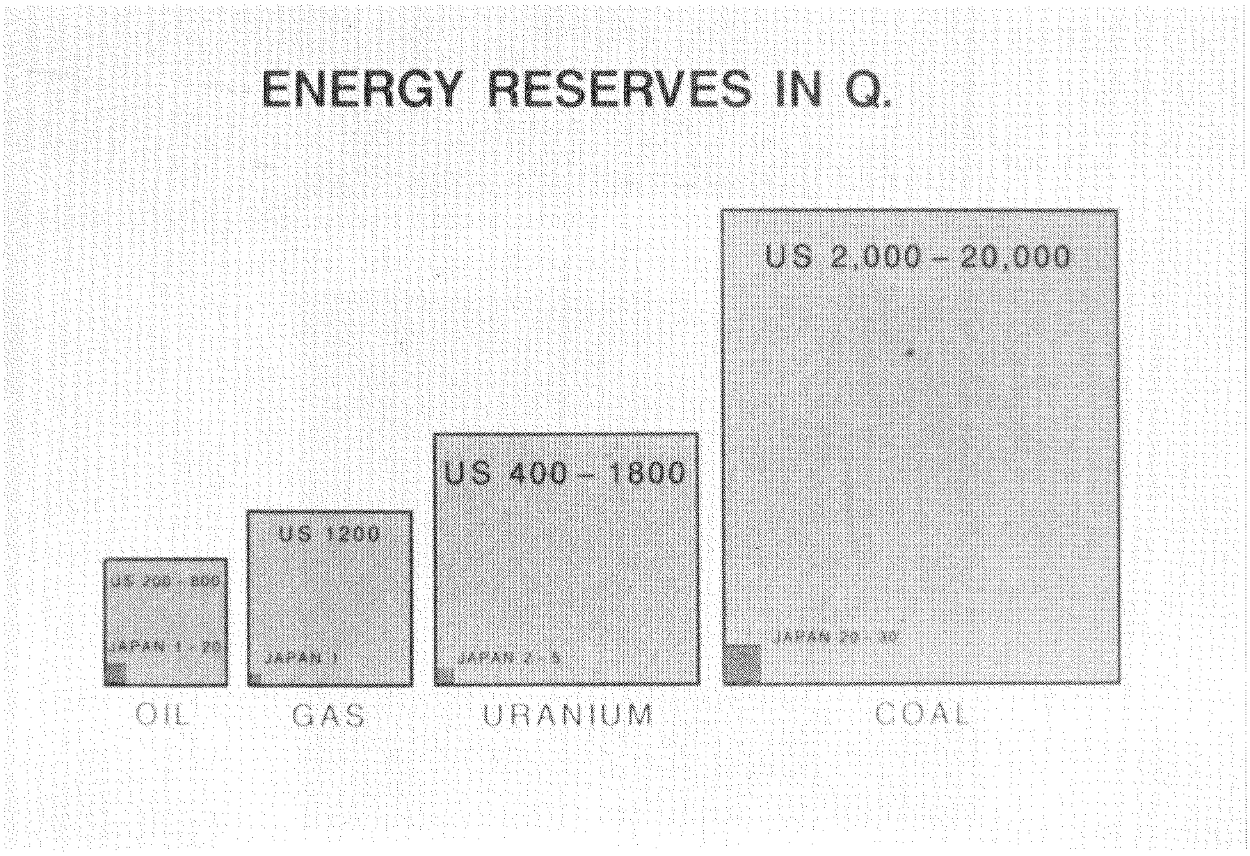


Figure 4

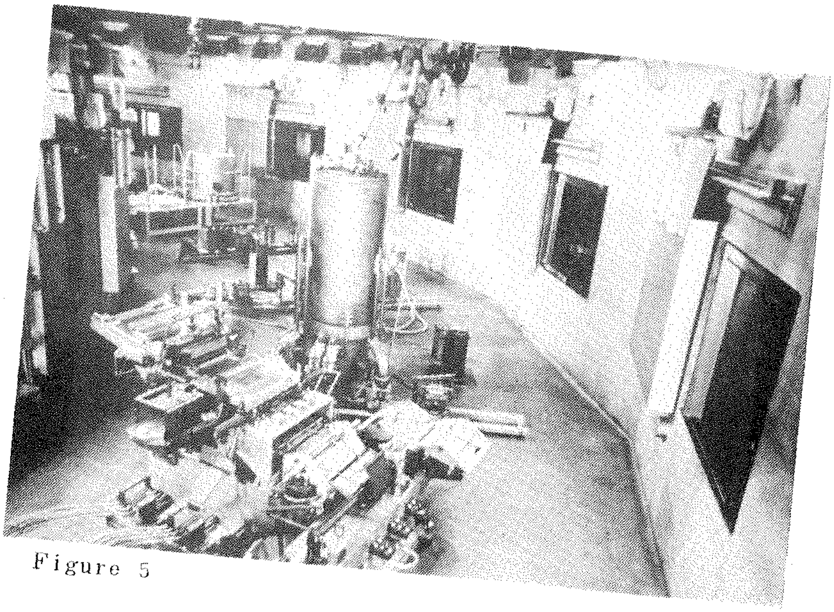


Figure 5

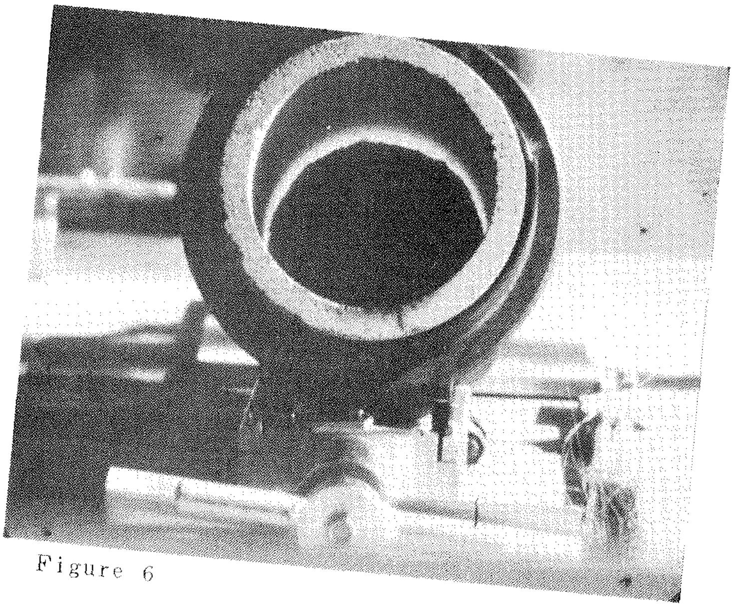


Figure 6

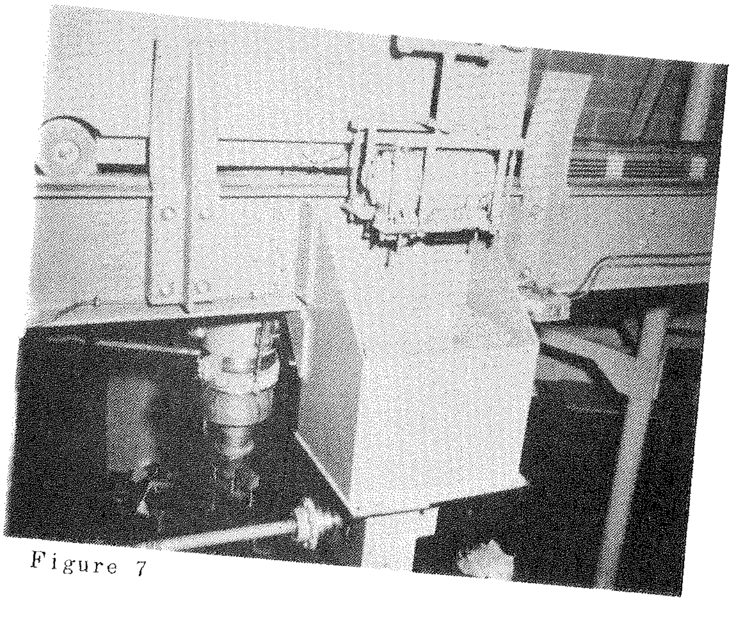


Figure 7

セッション２

原子力産業の活力ある発展をめざして

アメリカにおける原子力発電の将来

米国原子力産業会議（ＡＩＦ）理事長

Ｃ．ウォルスキー

原子力産業基盤強化への課題

関西電力㈱副社長

(社)日本原子力産業会議産業基盤強化小委員会委員長

飯田　孝三

総合電機産業と原子力

㈱日立製作所社長

三田　勝茂

SESSION 2
TOWARDS DEVELOPMENT OF A VIABLE NUCLEAR INDUSTRY

"Future of the Nuclear Power Option in the United States"
Carl Walske
President
Atomic Industrial Forum, Inc.
U. S. A.

"Ways to Strengthen the Nuclear Industry Foundation"
Kozo Iida
Chairman
Sub-Committee on Strengthening Industrial Foundation
Japan Atomic Industrial Forum, Inc.
Executive Vice President
The Kansai Electric Power Co., Inc.

"Nuclear Power and the Electric Machinery Industry"
Katsushige Mita
President
Hitachi, Ltd.

Future of the Nuclear Power Option in the United States

by Carl Walske
President
Atomic Industrial Forum, Inc.

It is a pleasure to be in Tokyo again and to be participating in the Japan Atomic Industrial Forum's annual conference.

Since this meeting takes place as JAIF celebrates its 30th anniversary, I can add that the pleasure is all the more keenly felt. Some of the early organizers of our own Atomic Industrial Forum worked very closely with the organizers of JAIF when it was founded after ours.

I am old enough to recall the sense of excitement that prevailed in the 1950s during the formative years in the development of nuclear energy.

Looking back, much has been accomplished in the space of three short decades. Our words today are not likely to rate more than passing mention outside of industry circles. But, the numbers speak for themselves, loudly. Preliminary estimates indicate that 26 countries last year generated on the order of one-and-a-quarter trillion kilowatt-hours of electricity from nuclear energy, or about 15 percent of the world's total. France now derives two thirds of its electric power requirements from nuclear plants. Belgium is nearly 60% nuclear electric; Sweden, 50%; Finland and Switzerland, 40%. West Germany gets a third of its electricity from the atom, and Japan more than one fifth.

In the U.S., we produced 384 billion kwh last year from nuclear plants, which was almost 16 percent of our total generation and second only to coal. In terms of market penetration, this isn't as high as in some countries, including those I just mentioned, because the U.S. is rich in resources and has chosen to develop its nuclear program more slowly. But nuclear's market share in the U.S. is deceiving, because our national grid is so large. In absolute terms, we now have 100 operable nuclear units, which is more than any other nation. Indeed, our reactors represent one-third of the world's total nuclear plant capacity.

Three decades ago, it was hoped that energy derived from splitting the atom would provide the world with another source of energy that would be cost-competitive with fossil fuels. That hope has been largely realized. Today, we are witnessing the benefits of the foresight and planning done 30 years ago, as we watch the world price of oil decline.

Not too long ago, OPEC analysts looked around in an effort to understand why markets for their oil had fallen so low. One of the reasons, they found, was nuclear energy, which they determined has permanently eliminated worldwide markets for some 6 million barrels of oil daily since 1973. The total is more than the current level of U.S. imports. By the end of the decade, the oil savings will grow by an additional two million barrels daily, the analysis showed. Nuclear plants have directly replaced oil-fired units. They have forestalled the development of new oil-fired capacity. In addition, electricity generated in nuclear plants has gone on to replace oil previously used in homes, businesses and factories.

As proud as we can be -- and should be -- of the market penetration nuclear energy has achieved, I have been asked today to use this occassion to look forward into my crystal ball. Specifically, where is the nuclear industry in the U.S. heading in the future? We are often asked that question because of the continuing lull in new reactor orders.

To begin with, it is important to point out that, in the short term, U.S. nuclear capacity will continue to expand at a record, or near-record, pace, despite the current ordering pause. Almost without notice, we have on average brought a new reactor on line every ten weeks since 1980. Some two dozen additional reactors are still under construction. By the time all of them are in commercial operation, uranium will fuel about one-fifth of total U.S. electrical generation.

But by the late 1980's, this rapid growth in the U.S. commercial nuclear energy program will come to a hiatus. Our utilities are not ordering virtually any central-station generating capacity. They are still working off a significant surplus of capacity that has accrued from slower-than-anticipated growth in demand. Currently, they have about 12 percent more capacity than they need in order to ensure reliable service.

This means it will be a few more years before they once again begin ordering large numbers of central station generating facilities. When the surplus is gone, however, significant amounts of new capacity will be needed to ensure reliable service in the 1990s.

The sheer size of the U.S. grid, which is approaching 700 gigawatts of generating capacity, shows how large the potential market is. No forecasters today believe the U.S. will see a repeat of the pre-oil embargo days when demand for electricity grew 7 percent annually. But even if demand grows at a moderate 3 percent per year -- which is a little less than it has averaged during the past three years -- the U.S. would need to add some 21 gigawatts of new capacity each year. This is equivalent to 21 large, 1,000 MWe generating stations, not counting the need for additional capacity to replace aged or uneconomic units.

For a variety of reasons, we believe nuclear plants ought to capture up to half of the expected new orders. Under the scenario I have outlined, there would be as many as 10 nuclear plant orders per year. This is by far the largest potential market in the world.

In a few minutes I'll come back to why I think this is the most sensible -- and therefore most likely -- scenario for the future. But for the moment, let's talk about what the U.S. will be doing in the interim. The impending hiatus in nuclear energy expansion in the U.S. does not mean in any way that civil nuclear technology will stagnate. On the contrary, both industry and government are committed to maintaining U.S. nuclear technology at the cutting edge.

Our utilities are currently engaged in a cooperative program, conducted through our Electric Power Research Institute, to advance the state of light water reactor technology for the next round of orders. Separately, our domestic manufacturers also are carrying out work independently.

Toward this goal, the U.S. can count as an asset its enormous industry infrastructure, which has more reactors, more scientists, and more engineers than any other nation.. I'd like to toss out a few numbers which indicate just how large this infrastructure is.

All told, the U.S. commitment for some 130 commercial reactors, including ones now operating and those still under construction, represents a capital investment approaching $200-billion. These plants require servicing, which by itself supports a multi-billion-dollar annual market.

During the next decade, U.S. industry also will be participating in the federal program to build an underground repository for nuclear waste by 1998, and in state programs to build a series of regional low-level waste disposal sites. Our high-level waste program, by the way, is being financed largely by a 1 mill per kilowatt-hour surcharge on nuclear-generated electricity. Spending for the high-level waste program in the fiscal year that begins October 1 is projected to be $769 million.

Beyond the commercial sector, the U.S. has related programs that support our industry infrastructure. In particular, this includes our large naval nuclear propulsion program, which represents another source of technical knowledge and a source of skilled personnel for our commercial program.. Today, the U.S. Navy operates 167 nuclear plants to provide power for 135 submarines and 13 surface ships. These nuclear-powered vessels and others now retired have operated with outstanding success for more than 2900 reactor/years.

In addition, the U.S. government supports sizeable R&D programs to enhance civil nuclear reactor technology. Last year, the U.S. government spent roughly half a billion dollars for this purpose, not counting our fusion program. This included research conducted for the Department of Energy and Nuclear Regulatory Commission. The work is conducted principally at several of the U.S. national laboratories, whose names are familiar: Oak Ridge, Argonne, Hanford, Idaho, Los Alamos and Livermore. This federal r&d effort will remain sizeable, even though it may not emerge unscathed from government-wide budget-cutting efforts aimed at reducing the U.S. deficit. The deficit-reduction effort is affecting virtually all domestic programs.

On the other hand, our civil nuclear technology may receive spin-off benefits from related r&d programs, such as for defense space and terrestial needs, which the Reagan Administration would like to increase.

This huge U.S. infrastructure, which I have briefly described, not only provides us with a foundation on which to build for the future. It also provides our manufacturers with an advantage in the international market. Indeed, I expect the U.S. nuclear industry to remain a leading player in the international market for years to come.

In closing, I promised you some additional thoughts on why I believe the nuclear option has an excellent future in the U.S.

One reason is the realization that, in the long term, sources of energy supply are limited, even for an energy-rich country like ours. Oil and natural gas are not viable options for future baseload electric capacity in the U.S., a fact reflected in a national law which prohibits their use for this purpose. It is an appropriate law, when we continue to burn more oil than we find every year, and when alternatives are readily available.

The U.S. conceivably could expand large-scale hydroelectric power a bit, but not by much since the best suitable sites have been used.

Other, non-conventional energy sources -- such as solar, wind, geothermal, and tidal power -- still have not proven their ability to provide reliable, economic energy: day or night, rain or shine. Today, they provide less than one-half of one percent of our electricity needs.

Nor is co-generation a viable option for providing the bulk of our electrical capacity requirements over the long term. Cogeneration currently is enjoying something of a spurt in the U.S., owing to a law requiring our utilities to purchase it. However, cogenerated power comes at a highly inflated price. In addition, most of our cogeneration comes from burning fossil fuels, which opens up questions about how reliably the public can count on it should the economic picture change. Indeed, cogeneration frequently represents a loophole in federal laws prohibiting utilities from building new gas-fired plants.

Over the long haul, this leaves coal and nuclear energy as the only viable domestic sources capable of providing the bulk of future U.S. electricity needs. We have sufficient coal reserves to last for centuries, which means the U.S. theoretically could forego a new round of nuclear energy expansion. But prudence dictates against such a course of action, if for no other reason than to give utilities a choice, and thus to maintain price competition between fuels.

Currently, the U.S. is bringing into service a generation of high-cost nuclear power stations. They have suffered from an unusual combination of economic and socio-political forces that have been well documented. In particular, this current generation of reactors has been subjected to post-Three Mile Island regulatory changes that stretched out construction schedules, making efficient management nearly impossible. The effect of this turbulence was further heightened because it occurred during a period of high inflation and high interest costs on borrowed funds.

However, with a return to more normal economic and regulatory conditions -- which is already showing signs of taking place -- the experience of the past few years will not be repeated. A study conducted by an AIF industry committee has shown that future nuclear plants will produce electricity for lower cost than coal-fired plants in all sections of the country -- if they are built under favorable conditions, such as are enjoyed here in Japan. By favorable conditions, I am talking, for example, about project lead times of eight years, with engineering completed before construction begins and with safety requirements as at present. Our study also assumes long-term utility borrowing at 11 percent and inflation on heavy construction at 7 percent per year.

Aside from the economic benefits nuclear plants can provide, there are also environmental reasons that dictate against the U.S. relying solely on its coal resources. One is the threat of acid rain from coal-fired electrical production. Our friends in Canada are very concerned about the acid rain fallout they receive from U.S. coal-fired plants -- so concerned that they want to sell us nuclear-generated electricity! Secondly, there is also the long-term concern about the greenhouse effect that is caused by the burning of fossil fuels. Some of our scientists are beginning to speak out on this issue.

All in all, when one looks at the total energy picture, one comes away assured that the nuclear power option in the U.S. has a long future.

原子力産業基盤強化への課題

原産会議産業基盤強化小委員会委員長
関西電力㈱　副社長
飯田孝三

議長さん、ありがとうございました。ご紹介頂いた関西電力の飯田であります。先程米国原産会議、理事長のウォルスキーさんから、米国の原子力産業の基盤強化あるいは活性化について、興味深いお話を頂いた。とくに、長年月に亘る原子炉発注低迷に悩んでいる米国原子力産業が次の発注にそなえて、ユーザーである電力会社がＥＰＲＩを通じて米国の経済的、社会的状況に適した軽水炉の改良に努力していること、さらにＤＯＥもＮＲＣもこの様な計画に協力していること、などはわが国にとっても示唆するところ大と考える。

さて、わが国の原子力産業は、原子力発電開発以来20年の歴史を経て、軽水炉発電の分野では、産業として自立化できるに至った。しかしながら、原子燃料サイクルの確立については、漸やく緒についたばかりであり、1990年代における事業化に向けて、今後事業化体制を早急に確立していく必要がある。また、高速増殖炉の開発及び増殖サイクルについても、今後研究開発を進めていかなければならない。現在は、軽水炉の定着化から、次のステップへ進む時期にさしかかっていると言えよう。

一方、国内における原子力立地の難しさや低成長下における電力需要の伸び悩み、等によって、原子力産業は今後大巾な発注増加を期待しがたい状況下にあり、この傾向は今後も長期に亘って続くものと予想される。加えて、昨今の為替レート、石油価格等の動向如何では、原子力の他のエネルギーに対する経済的優位性が一時的に揺らぐこともありうることと予想され、経済性の一層の向上が急務となっている。

これらを総合的に考えると、原子力産業は現在、１つの転機を迎えていると言っても過言ではなく、これをいかに乗切って産業の基盤を強化し、将来の発展につないでいくかが重要な課題となっている。

以上のような基本的な認識に立って、原子力産業の活性化問題を検討するため、原産会議では、一昨年10月に発電炉開発委員会の下に、産業基盤強化小委員会を設置し、私が委員長を勤めてきた。

小委員会においては、主としてユーザー・サイドの問題を検討する第１分科会（主査は中部電力山崎常務にお願いした）と、メーカー・サイドの問題を検討する第２分科会（主査は東芝青井副社長にお願いした）に分かれて、検討を行ってきた。そしてこれらを総括して、この３月末に産業基盤小委員会としての報告書を取纏めるに至ったので、本日はその概要について私自身の見解も加えて報告することとする。

（１．報告の概要）

（ａ． 原子力開発規模）

報告においては、原子力産業の長期的な見通しを得るために、2030年までのわが国経済社会の展望と原子力発電開発規模の予測を行った(スライド１)。

まず、わが国経済は1985～2000年は年間4.3%、2001～2010年は3.3%、2011～2030年は 1.8%の実質成長率を達成するものと予測した。この経済成長率に対する電力需要の伸び率の比、即ち弾性値は 0.7程度で推移するものと考えた。さらに、原子力発電は現在は発電量に対して kWで約14%、kWhで約23%を占めているが、2030年に向けて徐々にウェイトを増していき、2030年時点では、 kWで40%、 kWhで 60%程度に達するものと考えた。

この結果、2030年の原子力発電規模は14,000万kWとなり、年間平均の運開基数はリプレース分を含めて1985～90年 1.4基、1990～2000年 2.2基、2000～2010年 3.3基、2010～2030年3.6基と緩やかに増加していくものと考えた。なお、この場合、単基出力は2000年以前が110万kW、2001～2030年が130万kWとして計算している。

以上の予測は当産業界の活性化問題を浮きぼりにするため、やや控え目に策定したものであるが、これではどうも悲観的にならざるを得ない。もっと努力すればどれ位になるかということで更に検討を加えた。

すなわち上述の予測に対し、将来軽水炉発電の経済性が格段に向上し、他の電源に対する経済的優位性が十分確保されるならば、発電量に占めるウェイトは、kWで45%、kWhで70%程度に達することも可能であり、この結果、2030年の原子力発電規模は16,000万kWとなり、予測値に比し、２年に１基ずつ程度の増加が期待されることが分った。そこで、これを当面の目標値と考えることとした。

（ｂ． 原子力供給産業の現状と課題）

次に、原子力産業の現状であるが、これは電気事業と原子力供給産業に大別され、原子力供給産業はさらに原子力機器産業、原子力サービス産業、燃料サイクル産業の３つに区分される（スライド２）。ここでは原子力産業を狭義に解釈し、原子力供給

産業について、その現状と課題を検討した。

わが国の原子力供給産業は、高度な技術力と資金力を有する原子炉3メーカーを中核として、多層な構造の下に、約300社の企業が参加する体制を維持、発展させている。この原子炉３メーカーは合計で年間６基程度の供給能力をもっており、前述の原子力開発規模では、生産設備の稼働率は低いものとなる。

しかし、原子炉メーカー３社は巨大な総合メーカーであり、原子力の受注変動に対してはプロダクト・ミックス方式で対応する生産が行われているため、原子炉メーカー自身の経営努力によって、厳しい状況を乗越えることが期待される。しかし、長期に亘って低い水準の受注が続けば、技術力の維持が困難とされている。また、経営規模の比較的小さい原子力コンポーネント・メーカー約 150社は、今後の需要動向如何によっては、原子力部門の沈滞化により、高品質な製品を供給する能力の維持が困難になるものと憂慮されている。

（ｃ．原子力産業基盤強化の方策）

前述のような認識を踏まえ、私共の小委員会においては、原子力産業基盤強化のための方策として、以下の８つの提言を行っている。

① 第１は原子力開発規模の問題であるが、わが国の原子力発電所の安全性、信頼性は、国際的にも高く評価されている。今後ともこうした技術基盤を維持強化するため、軽水炉の経済性を一層向上させ、他電源に対する経済的有利性を高めることにより、国内での原子力発注量を増加させることである。これは先程述べたように経済の低成長がつづくなかで、これまで年間２基程度であった原子力発電の開発規模は、今後の約５年間はその水準をかなり下回ると見通される。それ以降２０００年頃までの開発規模は、年間２基程度の現状水準のまま推移するものと予測される。しかしながら、軽水炉発電の格段の経済性向上が図られ、他電源に比して相当の経済的優位性などが確保されるならば、１９９６年以降は２基程度の規模に加えて、さらに約２年毎に１基導入することも可能であり、この目標に向かって努力したいと思う。

② 第２に、この経済性向上のためには、電気事業者、原子力供給産業が協力してプラントシステムの合理化等による建設費の低減を図り、また、燃料サイクル費、運転維持費の低減のほか、利用率の向上等につとめることが肝要でこれにより、発電コスト面で大幅な経済性の向上を達成していくことが可能となる。また、このためには、国は軽水炉の安全な運転実績、研究開発の成果から得られた多くの知見を反

映して、実情に即した規制・基準の合理化を積極的に進めて頂きたいと思う。

③　第3項以降は技術研究開発にかかわることであるが、思うに原子力発電はまさに技術によってつくり出されたエネルギー資源であり、このため継続的に研究開発を行なうことが長期的にこの資源の優位性を確保する方策であると思われる。当小委員会もそうした意味で研究開発を重視して以下の提言を行なうものである。即ち、第3として、軽水炉段階の技術開発は引き続き電気事業者の主導のもとに原子力機器産業との連携によって進めるが、一方、燃料サイクルの確立、高速増殖炉開発等の実用化のための研究開発については主として民間が中心となって進め、国が強力かつ適切な支援を行うことが望まれる。そして、これに関連する国の研究開発予算については、とくに民間の意見を十分に反映して頂き、効率的に活用して頂きたいと思う。

④　第4に原子力機器産業の研究開発機能の維持と自立化をはかる必要があるということである。発注量の冷え込み等によって、原子力機器産業においては、再投資能力の増大が期待し得ないこともあり、その研究開発機能の維持と自立化を図るためには、発注者である国及び電力会社とメーカーとの間で研究開発の資金分担のあり方について再検討を行なうことが望ましい。

⑤　第5に原子力の基礎的研究は、これまで大学や国の研究開発機関に委ねられていたが、レーザー濃縮等の電気事業に直結する革新的技術の研究開発については、民間においても必要に応じて基礎的技術の範囲まで踏み込んで資金、人員を投入することを考えている。その際、国は税制改正等の措置を含めて投資環境の整備を進めて頂きたい。

⑥　第6に原子力コンポーネント・メーカーについてである。先程、原子力供給産業のあり方も含めて検討を行ったが、その結果、原子炉メーカーは自己の経営努力によって対応せざるをえないとしても、経営規模の比較的小さい原子力コンポーネント・メーカーは、今後の市場変動の影響によっては原子力部門の沈滞化による品質保証能力の低下が憂慮され、場合によっては脱落、撤退も懸念される。この原子力コンポーネント・メーカーが高品質の製品供給能力を保持するためには、適性な価格の維持をはかるとともに、品質管理、検査運用の適性化も必要である。またこれらメーカーと原子力メーカーあるいは電力会社との共同研究などの方策を拡充することが必要であろう。

⑦　第７に２０００年以降において、その実用化が期待される長期的プロジェクトや新素材を用いた革新的技術に取り組む研究開発に対しては、原子力機器産業は夫々の特色に応じて専門化、分業化し、研究開発の効率化を図ることが重要である。

⑧　第８として、国際協力は、原子力開発を円滑に進める上で極めて重要であり、先進国との研究協力や核不拡散問題に関しての国際協調を積極的に進めることとする。また開発途上国のニーズに応えるための機器輸出については、二国間協定の締結、燃料の供給保証等の環境整備をはかることが必要である。なお、原子力発電の定着に伴い、この分野での深い専門的知識と長年の経験をもつわが国の研究者、技術者は、この面においても重要な役割を果たすものと考えられる。

（２．補足および私見）

以上、産業基盤小委員会の報告の概要についてご説明を行ったが、報告を取纏める過程で、私なりに感じたことのうち主な点について補足的に述べてみたい。内容に若干の重複があるかもしれないがお許し頂きたい。ここでとくに述べたいことは、原子力産業の市場についての考え方と、経済性向上対策の２点である。

（ａ．原子力産業の市場についての考え方）

まず原子力産業のマーケットが今後大幅に増大することが期待できないという点に関して次のことを指摘したい。即ち、受注量についてはプラント建設受注のみを重視して考えるのではなく、この他に原燃サイクルの事業化、原燃サイクル／新型炉の研究開発、輸出を加えた４側面から、トータルとしてみるべきである、ということである。

現在、原子力供給産業の市場規模は約１兆円であり、関連する土木やＲＩを含むと約 1兆7,000億円、となっている。この原子力市場の中で、軽水炉については既にビジネスとして成り立っているが、原燃サイクルや新型炉の分野については、まだ事業化準備段階、研究開発段階にあり、今後、市場拡大が期待されるところである。

因みに、原燃サイクルについては、下北の濃縮工場、再処理工場、低レベル放射性廃棄物処分施設のみをとってみても、1兆円、55億ドル程度の発注量が期待され、さらに将来はこれに続く新工場の建設も予想されている。この他、高速増殖炉についても実用化までに 2～3基で1～1.5兆円、50～80億ドルの発注が見込まれている。さらに、これらに関連してサービス並びに研究開発に関する発注も年間相当規模が見込まれている。

ここにＭＩＴＩで試算されました原子力関連産業の市場規模の見通しというグラフがある。昨日コロンボさんの講演にも同じようなグラフが出てきて大いに共感を覚えたのであるが、このグラフによると、1985～2030年(45年間)の原子力産業関連市場は累積ベースで180兆円、約1兆ドルとしており、内訳は原子燃料サイクル 70兆円、発電所管理・補修 60兆円、発電所建設 50兆円となっている(スライド3)。このうち、原子炉メーカーその他には半分程度約 100兆円、5,000～6,000億ドルの発注が予想される。

従って、プラント建設については、発注の大幅増加は期待しがたいものの、原燃サイクルの事業化、原燃サイクル／新型炉の研究開発、さらに将来の輸出も考えると、原子力産業の将来の展望は決して暗くないと思われる。先程から発電所建設が少ないから大変だという危機感ばかり出ているが、発電所建設相当分の市場が関連産業面にもあるようであるので、どうか元気を出して活性化に励んで頂き、自らの経営努力を中軸として原子力産業の基盤強化に努めて頂きたい。以下、４つの側面のそれぞれについて、私の考え方を述べてみたい。

第１の国内における原子力プラント建設は当分年間２基程度であるが、長期に亘る安定的な需要であり、立地問題により若干の遅れはあるものの確実な需要であると言える。従って、わが国原子力産業にとって、国内の原子力プラント建設はコンスタントな需要として、経営のベースを保証するものと考えられる。

さらに、国内プラント市場を拡大していく努力を積極的に行うことにより、長期的な市場拡大を図ることも期待される。このための対策については多くのことが考えられるが、最大の要素は先程述べた通り経済性の向上である。原子力の経済性が他電源に比べて有利になるほど電源開発における原子力の比率が上昇することになる。また安い原子力発電が増加することにより、電力コストが平均的に低下すれば、エネルギー供給における電力の割合がふえることになる。この２つのシフト、即ち原子力シフトと電力シフトが相乗的に影響することにより、原子力プラント発注が増加することも可能であろう。

第２の原燃サイクル事業化については、わが国のセキュリティの確保、技術の確立等の観点から電力会社が中心となって推進することとしている。

既に日本原燃サービス、日本原燃産業の２社が設立され、1990年代における事業化に向けて着々と準備が進められているところである。これらによる市場は前述のように、今後大きな市場展開が期待される。これらの施設の建設、運転に当っては、原子力供給産業に大部分の発注が行われることになろう。

この意味で、国内原子力プラント建設を原子力産業の維持基盤とすれば、原燃サイ

クル事業化は原子力産業の発展要素と言えよう。

ただし、原燃サイクル事業化が円滑に発展するためには、コスト・ダウンを追求し、経済性においても、早期に国際価格水準を達成することを目標とすべきであります。

第３の原燃サイクル／新型炉の研究開発についても、電力業界がイニシアティブをとって積極的に推進することとしている。原子力の研究開発は長期に亘り、かつ大型プロジェクトが多いことから巨額の資金を要するものであるため、これらの研究開発の推進は、わが国原子力産業にとって、活性化のための最大のインセンティブとなるものと考える。

この場合、留意しておくべきことは、とくに新型炉について、数多くの種類の炉型の研究開発を行うことは、一時的な活性化にはなりえても、実用炉の建設に向けての長期的な発展性に欠けるということである。

従って、研究開発に当っては、長期的な炉型戦略及び原燃サイクル戦略を踏まえて、ターゲットを絞り、また、官民の役割分担を明確にして効率的な研究開発に心がける必要がある。さらに、新技術、たとえば、メカトロニクス、ロボット、新素材など他の分野における技術開発成果を原子力分野に導入することは、原子力技術の高度化に資するのみでなく、他の産業分野に対しての技術波及効果も大きく、それらの産業界の発展にとっても大きな刺激となろう。

第４の輸出については、国際市場の動向、核不拡散問題等に十分な配慮を行いながら、今後の展開を図ることが望ましい。。

輸出は、開発途上国等のニーズに沿って行うべきものであり、相手国の事情に適した軽水炉について、わが国原子力産業としても着実な研究開発を行うことも検討すべきである。また一国のみで原子炉の輸出と燃料の供給保証を行うという考え方だけではなく、他の原子力先進国との共同研究、共同受注といった水平的な国際分業体制も将来必要であろう。

（ｂ． 経済性向上対策）

私が強調したいことの第２番目は、経済性向上のための具体的な推進方策である。原子力産業が今後も順調に発展するためには、経済性の向上、とくに原子炉プラント建設費と再処理を中心とする原燃サイクル費の低減が不可欠であることは、既に述べた通りである。

問題は、どのようにして経済性の向上を図るか、という方法論が必要となっているということである。経済性の向上は、メーカーである原子力供給産業のみでできるも

のではない。メーカー、ユーザー、さらに規制当局が、夫々の役割に応じた努力を行い、それらが総合して経済性の向上につながる、といった進め方が必要である。

たとえば、規制当局においては、安全審査基準やそれを展開した指針を、これまでに得られた知見に基づいて最適化を行うことが望まれる。また、検査技術の向上、自主検査の活用等により、検査業務の一層の効率化を図ることも必要である。

ユーザーである電力業界においては、プラントの標準化を推進すると共に、プラントのシステムをより簡素化・最適化することによって安全性と経済性の向上を同時に達成することが可能となろう。

さらに原子力供給産業においては、メーカー・サイドからの標準化の具体的推進の他に、プラント・システム設計の簡素化・最適化、工場生産方式の拡大など工法の改善についての一層の努力が必要である。

前述のように原子力の経済性向上については、3者の総力を結集することが肝要であるが、この場合、経済性向上の目標水準を設定して、それに着実に向かっていくことが望ましい。とくに今後の原子力産業においては国際分業体制の展開が予想されるため、原子炉プラントおよび燃料サイクルの経済性の向上についても、常に国際的な価格水準に留意していく必要がある。

以上、産業基盤強化小委員会の報告をベースに、私の日頃考えていることの一端を述べたが、今後の原子力産業の発展にとって、何らかの参考ともなれば幸いである。ご静聴を感謝する。

スライド 1

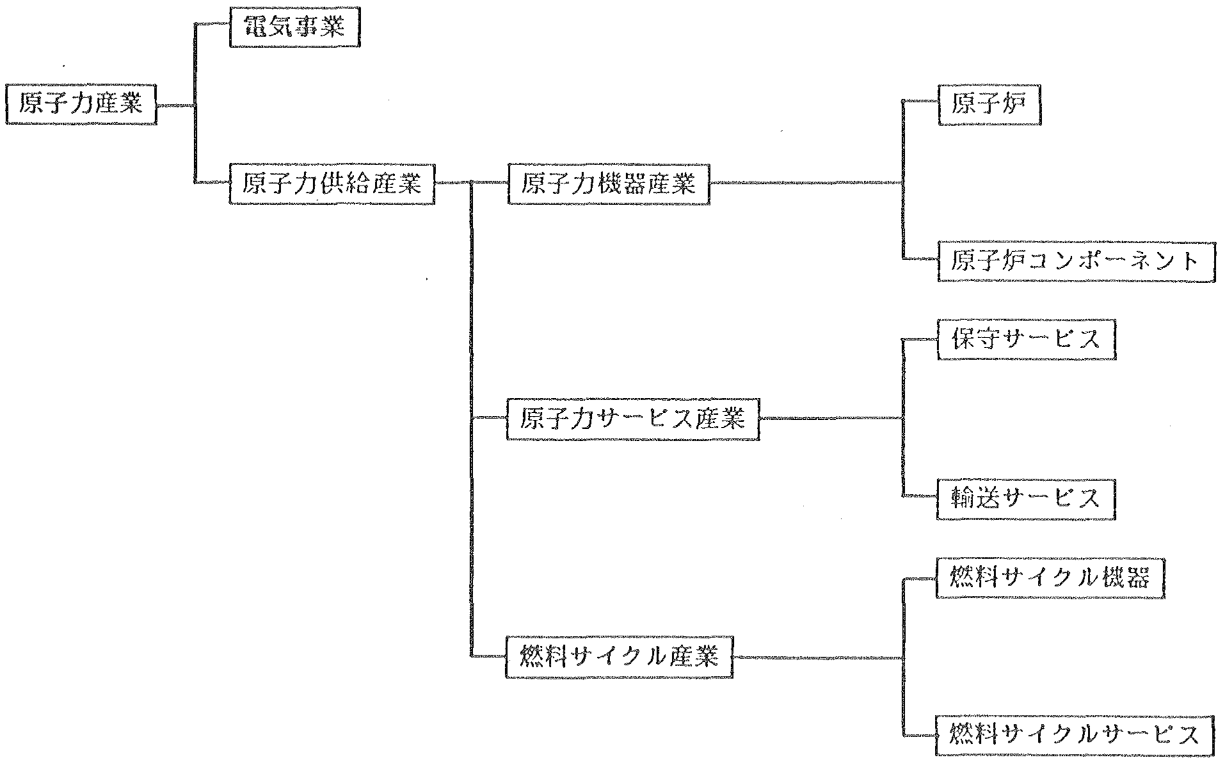
原子力発電開発予測

		1985	1990	2000	2010	2030
経済成長率（実質　%）			4.3		3.3	1.8
総電力需要(億kWh)		5,928		8,650	10,950	14,220
電気事業用発電設備(万kW)		15,425		23,000	28,600	35,300
第1次予測値	原子力発電設備（万kW)	2,452	3,150	5,300	8,100	14,000
	年間平均運開基数※		1.4	2.2 (0.2)	3.3 (1.2)	3.6 (1.3)
目標値	原子力発電設備（万kW)	2,452	3,150	6,200	9,500	16,000
	年間平均運開基数※		1.4	2.9 (0.2)	3.8 (1.2)	4.2 (1.7)

注）1. 発電設備は30年でリプレースされるものとした。
運開基数のうち（　）内はリプレース分対応（内数）である。
2. 単基出力は次のとおりとする。
1996～2000年運開分　　110万kW／基
2001～2030年運開分　　130万kW／基

スライド２

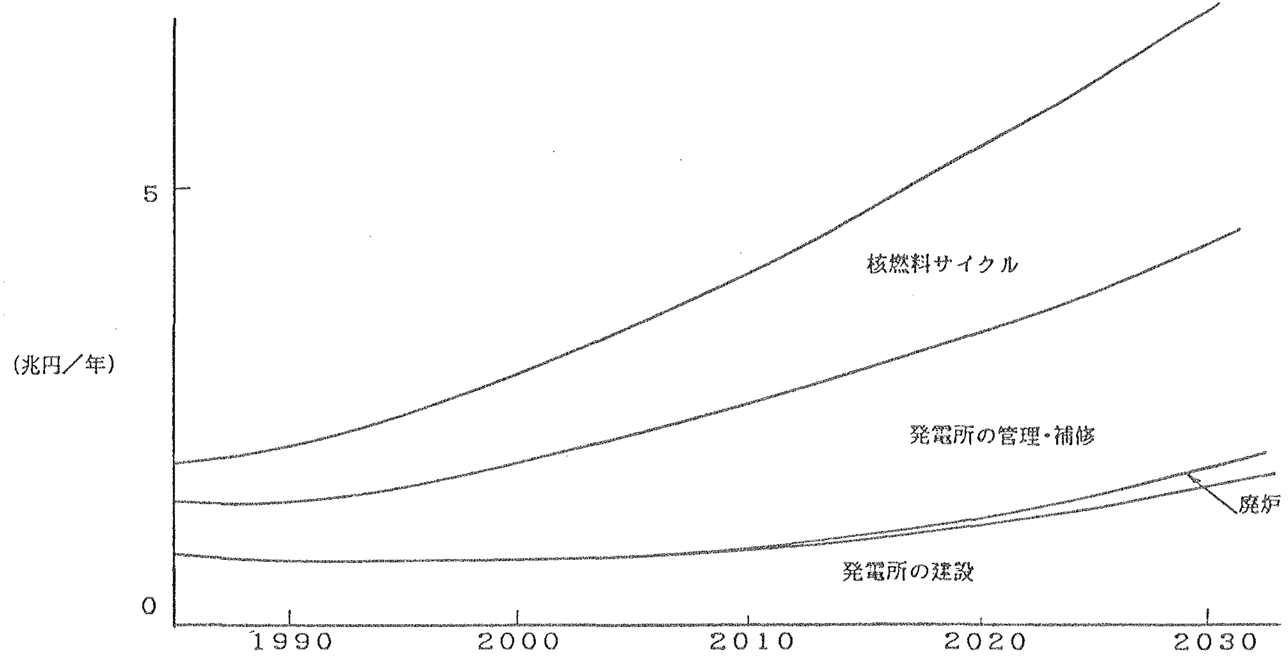
原子力産業の区分



- 原子力産業
  - 電気事業
  - 原子力供給産業
    - 原子力機器産業
      - 原子炉
      - 原子炉コンポーネント
    - 原子力サービス産業
      - 保守サービス
      - 輸送サービス
    - 燃料サイクル産業
      - 燃料サイクル機器
      - 燃料サイクルサービス

スライド３

原子力関連産業の市場規模の見通し



(通産省, ＭＩＴＩ)

１９８５～２０３０年(４５年間)の累積金額は１８０兆円と試算される。

Ways to Strengthen Nuclear Industry

Kozo Iida
Chairman, Subcommittee on
Nuclear Industry, JAIF
Executive Vice President,
Kansai Electric Power Co., Inc.

Thank you Mr. Chairman.

Mr. Walske, President, US Atomic Industrial Forum, Inc. has given a valuable presentation on the current condition of nuclear industry in the United States. Various efforts discussed in the presentation, for revitalizing the U.S. nuclear industry currently suffering from the prolonged slowdown of the nuclear reactor market, had much to teach those of us, who are involved in the nuclear industry in Japan. I was particularly impressed with American electric power utilities who are the users of nuclear power, putting much efforts via EPRI and through cooperation between NRC and the EPRI for modifying the light water reactors to suit the present U.S. economic as well as social conditions.

Nuclear industry of Japan has a history of twenty years in the development of Nuclear Power and has, in the sector of light water reactor, become self-reliant as an industry. However, the establishment of nuclear fuel cycle has just begun to take shape, with the urgent need of establishing its business scheme to be operational in 1990s. As for the development of FBR and the establishment of breeding cycle, R & D efforts must be exerted from now on. It may be said in this connection that the nuclear industry is presently in a transient period from the substantial establishment of LWR to the subsequent developmental step.

On the other hand, such actualities as an arduous task in domestic nuclear power plant siting and a lingering low-level power demand under the current low-rate economic growth has been darkening the nuclear industry's hope of expecting any substantial placement of orders, which will tell us that it would be long-ensuring trend extending over a long period of time. On top of that, it could be foreseeable in light of such economic trends as the current exchange rate and oil price level that the nuclear power's economic superiority over other energy sources might be upset temporarily; therefore, it is really an urgent task of the nuclear industry to further impose its economic viability.

It is not too much to say in the overall review of the foregoing that the nuclear industry is now at a critical juncture, and it is the nuclear industry imperatives how to weather through it foward the next stage of development.

Given such basic background, JAIF has established in October 1984 a Subcommittee on nuclear industry to strengthen its foundation, of which I am the Chairman. This Subcommittee was organized under the Committee on Power Reactor Development, and has the purpose to consider the long-term prospects of the nuclear industry in Japan.

The primary group within the Subcommittee headed by the managing director Mr. Yamazaki of the Chubu Electric Power Co., Inc. has focused on the issues on the user's side. On the other hand, the secondary group headed by Vice President Aoi of Toshiba, has considered the matters of the suppliers' side. Encompassing the findings of the both groups, a final report was completed by the Subcommittee this March.

Today, I will present the general content of this Subcommittee report along with my personal viewpoints on relevant matters.

1. Outline of the Report:

a. Forecast on Nuclear Power Development;

The report gave the prospects of Japan's national socio-economic condition up to the year 2030 along with the projected growth of the nuclear power development.(Slide 1) Such consideration of future expectations is vital for effective long-term planning for the nuclear industry in the years to come.

According to our findings, Japan's economy is expected to grow from the year 1985 to 2000 at 4.3% per annum growth rate in real terms, at 3.3% per annum between the years 2001 and 2010 and finally, at 1.8% per annum from 2011 to 2030. The electric power demand during those years then, can be expected to grow along with the growth in national economy with the coefficient of elasticity at around 0.7. Moreover, while the present share of nuclear power generation is approximately 14% in KW and 23% in KWh, the figures are expected to grow in the future, reaching to 40% in KW and 60% in KWh by the year 2030.

Consequently, nuclear power output in the year 2030 will be 140 million KW, with a steady increase in the annual average number of newly operating units from 1.4 units per annum in the years between 1985 and 1990, to 2.2 units per annum in 1990 to 2000, 3.3 units per annum in 2000 to 2010 and 3.6 units per annum in 2010 to 2030. These numbers include the expected replacements. And the unit electrical capacity was set to be 1.1 GW for the years from 1996 and to 2000 and 1.3 GW for the years from 2001 and to 2030.

If the cost efficiency of light water reactor can be largely improved in the future, giving it significant cost advantage over the other power sources, its share of output will reach 45% in KW and 70% in KWh. As a result, the capacity of nuclear power in 2030 is expected to be 160 million KW, indicating possible addition of new units to the projected figures I mentioned, at the rate of one additional unit every 2 years. We suppose these figures as the target of nuclear industry in Japan.

b. Nuclear supply industry——current condition and issues ;

Next, the so-called "nuclear industry" can be broadly divided into electric power utilities and nuclear supply industry. The latter is further subdivided into nuclear manufacturing, nuclear service and fuel cycle industries.(Slide 2) In today's presentation I would like to limit my discussion to the nuclear supply industry and consider their present conditions and relevant issues in some detail.

In Japan, the nuclear supply industry is comprised of approximately 300 companies of various sizes. And at the center of them there are 3 nuclear reactor manufacturers which have advanced technology and large investment funds.

The total production capability of nuclear reactor manufacturers amounts to around 6 units per year. Therefore, given the above-mentioned expected growth of nuclear power development, the manufacturers must produce at a rate significantly below their maximum operational capacity. Nevertheless, since these big manufacturers are capable of providing other products besides nuclear plants, they should be able to overcome the on-going economic condition with well-devised flexibility in their production strategy. However, the low level of plant orders for long years might make it difficult to maintain the present technology level for these manufacturers. In contrast, around 150 relatively small nuclear component manufacturers in Japan, will find it difficult to maintain high-quality supply capacity due to the stagnant orders in the nuclear field.

c. Measures for Strengthening Nuclear Industry Foundation;

With the conditions described above in mind, our Subcommittee has devised the following 8 measures for strengthening nuclear industry foundation.

(1) Until now, nuclear power development in Japan proceeded at a pace of about two units a year. With low economic growth continuing, it is believed that in the next five years or so the pace of development will be considerably below this level. After that and up to around the year 2000, it is

expected that the development pace will be around two units per year, as at present. If, however, the cost of light water reactor power generation can be lowered remarkably and made considerably more economical compared to other power sources, it might be possible to establish an additional unit every two years, over and above the figure given above.

(2) In order to make light water reactor power generation more economical, it is vital for electric power utilities and the nuclear supply industry to cooperate in rationalizing the plant system in order to lower the construction cost. The fuel recycling cost and plant operation cost, too, must be lowered, and efforts made to raise the plant utilization factor. Through such efforts, it will be possible to lower the generation cost. Also, the government should positively undertake the rationalization of the regulations and standards of light water reactors to reflect the data obtained from the record of safe operation and the results of R & D.

(3) R & D at the stage of the light water reactor itself will be conducted as hitherto on the initiative of electric power utilities in teamwork with nuclear manufacturing industry. On the other hand, R & D relating to the establishment of a fuel cycle and commercialization of the fast breeder reactor will mainly be carried out by the private sector, but it is hoped that the government will make strong and suitable support. In this connection, the views of the private sector should be reflected fully in the use of governmental budget for this R & D so as to ensure its efficient use.

(4) It is conceivable that the low level of plant orders and other reasons might make it impossible to expect the nuclear manufacturing industry to increase its investment in R & D. In order to sustain its R & D capability and independence, special consideration will be necessary both on the parts of the government and private sector in concluding future R & D contracts.

(5) From the standpoint of strengthening the industrial foundation,it will be necessary in future to bolster basic R & D. Therefore, expectations are placed on strengthening basic R & D by universities and research institutes. It is also conceivable that the private sector could step into the field of basic technology as part of its R & D efforts towards technological innovation and invest funds and personnel in basic R & D. For this,the government should improve the investment environment, including such measures as exemption of the tax incurred.

(6) Regarding the light water reactor market up to the year 2000, a study was conducted, including what is expected of the nuclear supply industry. As a result, although reactor manufacturers would have to cope with the situation through their own managerial efforts, it was feared that the ability of nuclear component manufacturers, whose business scale is relatively small, to guarantee a high quality level might decline as a consequence of stagnation of the nuclear power sector due to future market fluctuations. In certain cases, such small suppliers might be forced to drop out. Therefore, it is necessary to take measures to prevent the scattering of the excellent technologies of these companies and to ensure that they receive sufficient R & D funds to keep high level quality, thus maintaining their technological capabilities.

(7) With respect to long-range projects whose eventual commercialization is hoped for and to R & D for innovation in peripheral technology using new materials in the period after the year 2000, it is important for nuclear manufacturing industry to make efforts to increase efficiency through suitable cooperations and joint projects.

(8) In order to further nuclear power development smoothly, international cooperation is important. Therefore, positive international cooperation with other advanced countries must be promoted concerning R & D and nuclear non-proliferation matters. With respect to plant export, cooperations on technologies and human training, especially at the initial stage, are necessary. Furthermore, regarding matters which are beyond the efforts of a single company, such as the conclusion of bilateral agreements, guarantee of fuel supply, financing and insurance, it is necessary to create the right environment through ties-up between the government and the private sector, clearly defining the roles to be played by each party. It is believed that Japan's researchers and engineers who possess expertise and experience in nuclear power development will play an important role in the field of international cooperation.

2. Personal viewpoint on the relevant issues:

Such have been the general content of the report prepared by the Subcommittee. Now I would like to add some of my personal opinions and viewpoints under 2 general subtitles, namely, on the market of nuclear industry and measures for improving cost efficiency of nuclear power generation. I hope you will excuse some of the redundancy in the content with my previous presentation.

a. On the market of nuclear industry;

First, I would like to bring up the following point regarding the stagnant condition of the nuclear industry market expansion. In considering the prospective market size, the projection must not be limited to the number of expected nuclear plants construction. That is, we must also include commercial operation of neclear fuel cycle, R & D of both fuel cycle and advanced reactor, and export as variables contributing to the future market size. Comprehensive inclusion of all of these 4 areas would be necessary.

Presently, the market for nuclear supply industry is estimated to be 1 trillion yen. The market size, if relative construction and RI industries are included, is approximately 1.7 trillion yen. Given such a market, the area of light water reactors has been already established on a commercial basis. However, for fuel cycle and other advanced reactors, the market development is still at a very preparatory stage for hopeful market expansion in the future.

For fuel cycle industry, a total of 1 trillion yen or 5.5 billion dollar order placement is certain at this point for enrichment plant, reprocessing plant and Low-level radioactive waste disposal facility at Shimokita in Aomori Prefecture, with further expansion anticipated in the future. With respect to fast breeder reactor, the ordering of 2~3 units, amounting to a total of 1 to 1.5 trillion yen or 5 to 8 billion dollars, is anticipated only by the period of its commercialization.

Furthermore, MITI is estimating the nuclear industry-related market to be a total of 180 trillion yen or 1 trillion dollars for the years 1985 to 2030, of which 70 trillion yen for Nuclear fuel cycle, 60 trillion yen for maintenance of nuclear power plants and 50 trillion yen for plants construction (Slide 3). Around half of this total market or approximately 100 trillion yen or 500~600 billion dollars is expected as orders to nuclear reactor and component manufacturers.

Considering these projected figures then, while the industry will continue to suffer from low level orders of plants construction, the period must be regarded as the time for strengthening the overall industry because the industry overcomes these unfavorable years, the future prospects are indeed not so negative.

I would like to add further comments to 4 areas, above mentioned, namely nuclear power plants construction, business operation of fuel cycle, R & D for fuel cycle/advanced reactors, and export expected in the future.

(1) While domestic construction of nuclear power plants listed as point no. 1 above will remain for some time at around 2 units per year in Japan, and the number of constructions is not expected to grow for some time due to problems of siting condition, it is certain that the demand will maintain its long-term stability during the period. Therefore, domestic nuclear plants construction will remain relatively constant for some years to come, ensuring stable business base for the industry.

Moreover, longer-term market expansion is actually possible through diligent effors to develop domestic demands for plant construction. The key to such development is in greater economic efficiency. The share of nuclear power for electric power supply can be increased by improving economic efficiency of nuclear power generation, which in turn will promote utility of electricity through its general cost reduction. Such mutral interaction between demands for nuclear power and elctricity will then contribute to additional construction of nuclear plants.

(2) Business operation of fuel cycle listed as point number 2, will be promoted under the leadership of utilities, by focusing particularly on security assurance and establishment of necessary technology.

Japan Nuclear Fuel Service (JNFS) and Japan Nuclear Fuel Indurstry (JNFI) are 2 newly established companies, currently preparing to start up as commercial enterprises in 1990's. Their market, as I have mentioned earlier, is expected to expand largely in the future. It is believed that the orders of construction and operation of these plants and facilities will mostly go to nuclear supply industry.

In these ways, given the business basis of projected domestic nuclear plant construction, commercialization of fuel cycle will be an important factor for further progress of nuclear industry as a whole.

The condition for smoothly realizing the business operation of fuel cycle, is in further pursuit of cost reduction and greater economic efficiency towards the international cost standard.

(3) Regarding the third issue, R & D for nuclear fuel cycle and advanced reactors, electric utilities will take the initiative in it. As R & D of nuclear power often involve long-term large-scaled projects requiring enormous investments, promotion of nuclear power R & D is the most important factor for revitalizing the nuclear industry in Japan.

We must be aware of the fact that R & D efforts of various types of new reactors do not lead to long-lasting revitalization of the industry for further commercial plants construction. Rather, the researches must be performed by selecting the target on the basis of reactor/fuel cycle development strategy. Furthermore, respective roles played by the government and private sector need to be clearly defined for efficient execution of such R & D projects. Finally, introduction of new technology such as mechatronics and robots as well as of new materials to the nuclear industry will not only contribute to the additional improvement of nuclear power technology itself but also should stimulate the other industies as well.

(4) On the fourth point, the issue of exportation, I believe that we must put our effors for increasing exports by throughly considering the international market trend and non-proliferation matters.

Exportation from our country must suit the needs of the importing countries mostly currenthy under development. Japanese nuclear industry must engage in R & D of light water reactors appropriate for the requirements abroad. Moreover, Japan must cooperate with other advanced nations in research as well as in accepting orders from developing countries. Japan alone must not export the reactors and supply fuel to abroad. Rather, our country must internationally cooperate with other nations in providing nuclear power to the needed regions.

b. Measures for improving economic efficiency;

Next I would like to draw your attention to specific measures for improving economic efficiency of nuclear power. As I have mentioned earlier, improvement in economic efficiency, particularly in terms of reducing nuclear plant construction and nuclear fuel cycling expenses, is indispensable for future development of nuclear industry.

The problem then, is how to improve the economic efficiency in practical terms. As Mr.Walske of the US AIF has mentioned, the nuclear supply industry alone is not responsible for economic efficiency. Rather, our goal can be realized through various efforts on the part of manufacturers, users and regulatory bodies.

(1) For instance, regulatory authorities must specify appropriate safety standard and its guideline on the basis of their past findings. Furthermore, improvement in inspeciton methods, and introduction of voluntary inspection system will lead to greater efficiency.

(2) The electric utilities, the user of nuclear power can contribute through promoting standardization of plants as well as through simplifying and optimizing complex systems for both safety and economic efficiency at the same time.

(3) In addition, the nuclear supply industry must specifically promote standardization from the manufacturer's side, while simplifying and optimizing the plant system design and improving construction process by such as increasing the portion of in-factory-production.

As mentioned earlier, the cooperation and total efforts among the three parties are essential for improving economic efficiency of nuclear power. Furthermore, I think it is desirable to set the target standard in advance, to which we can proceed together.

Particularly with international division-of-effors in nuclear industry being expected, we must always be aware of international cost standards inpromoting higher economic efficiency.

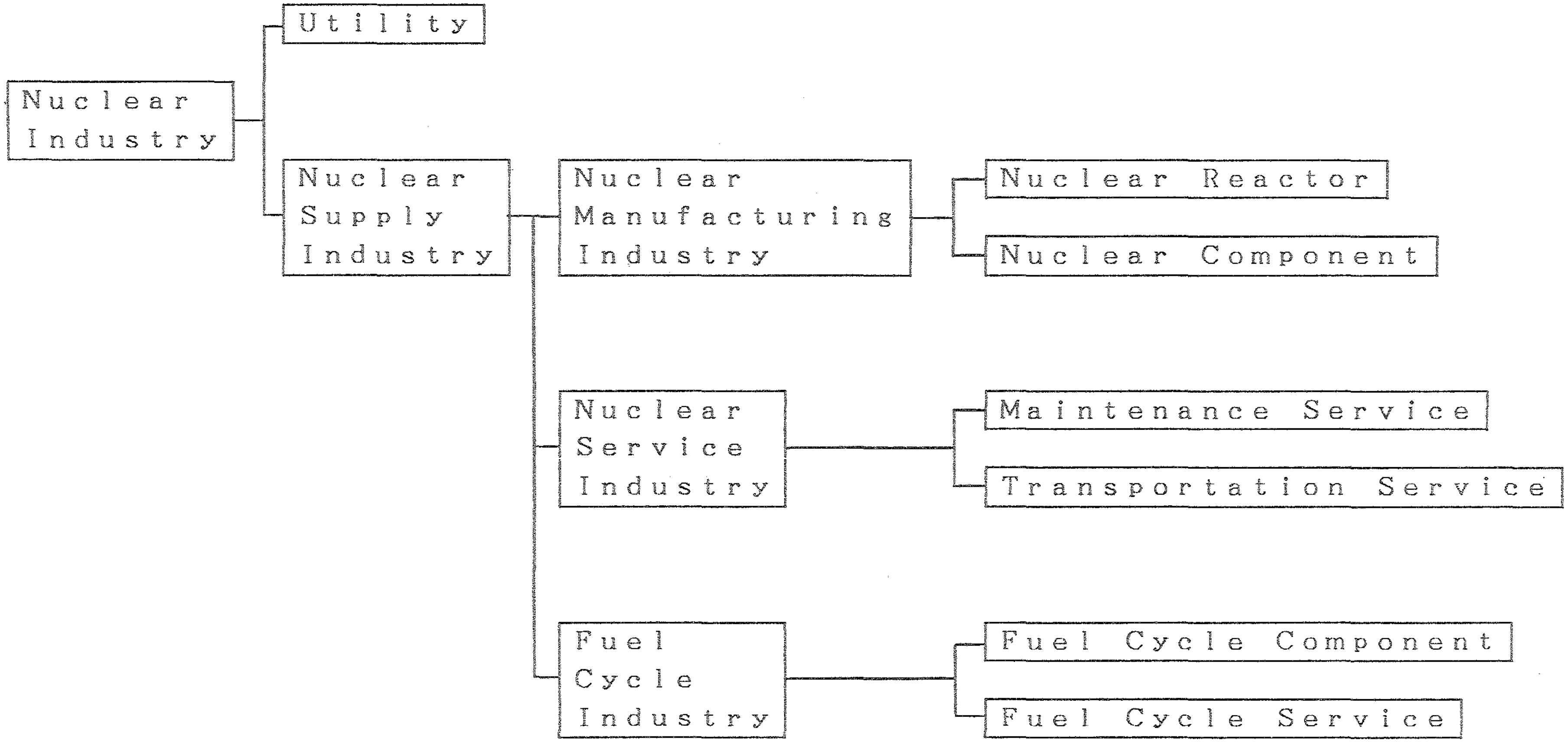
I have presented my opinions on the future of the nuclear industry on the basis of points covered in the report prepared by the Subcommittee. I hope that my discussion has sewed its purpose of providing you with some ideas for future progress of nuclear industry.

Thank you very much for your attention.

1. Nuclear Power Forecast

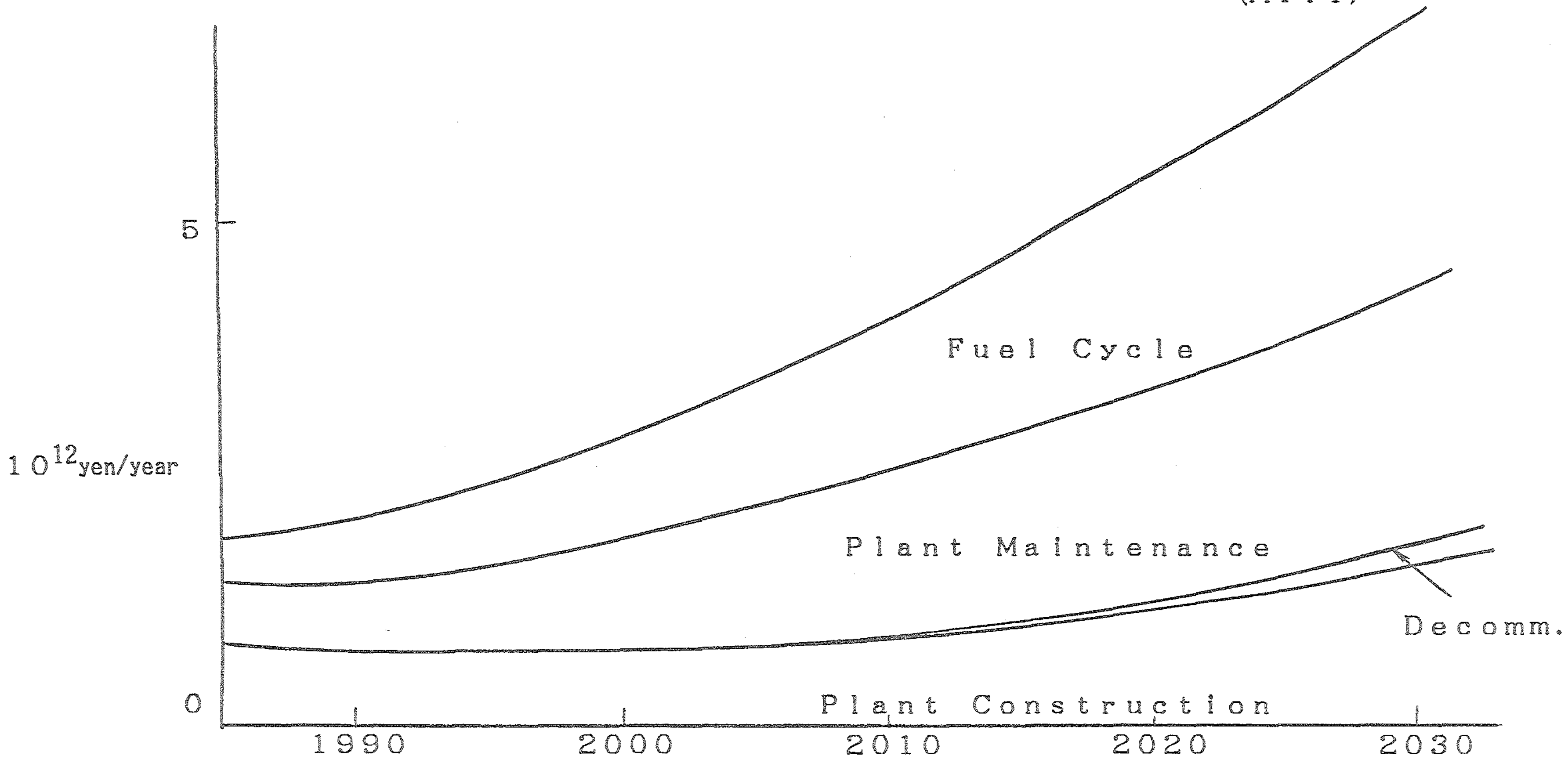
		1985	1990	2000	2010	2030
Economic Growth Rate (Net %)		4.3		3.3	1.8	
Total Electric Power Demand (10^8kWh)		5,928	―	8,650	10,950	14,220
Electric Generating Capacity (10^4kW)		15,425	―	23,000	28,600	35,300
Forecast	10^4kW	2,452	3,150	5,300	8,100	14,000
	New Units p.a.	1.4	2.2 (0.2)	3.3 (1.2)	3.6 (1.3)	
Target	10^4kW	2,452	3,150	6,200	9,500	16,000
	New Units p.a.	1.4	2.9 (0.2)	3.8 (1.2)	4.2 (1.7)	

2. Category of Nuclear Industry



3. Forecast on Market of Nuclear Industry

(MITI)



Cummulative Amount: 1.8x10^{14}yen

総合電機産業と原子力

㈱日立製作所　社長　三田勝茂

ただ今，関西電力の飯田副社長が，原子力産業基盤を強化するための課題と対策について，原子力産業会議の小委員会の検討結果をもとに，ユーザーならびにメーカーの問題点を含めて，貴重な御意見をお話になりましたので，私は少し観点を変えて，総合電機産業にたずさわる者として，エネルギービジネスの中で原子力の位置づけと特徴，他分野との関連などを考察し，続いて原子力産業の問題点と将来展望を述べさせて頂きます。

（電機産業における原子力機器）

総合電機産業は電力の発生からその応用にいたる広範囲な電機・電子製品を製造，供給する機器産業であり，これらの分野はわが国では現在年間生産高約３０兆円の規模に達しています。

発電プラントを中心とするエネルギー機器も，事業の中核的製品の一つであります。ただ最近産業構造の変化から，エレクトロニクス，情報産業などの分野が急成長しているため，エネルギー機器ビジネスの電機産業内における相対的ウェイトが低減しつつあることは否めません。しかしエネルギー機器の内では長期的に原子力のウェイトは漸増して，２１世紀に向けて主力になると期待されます。

（原子力発電の必要性）

エネルギー資源に恵まれぬわが国においては，エネルギー・セキュリティー確保のために，原子力発電は是非必要であります。

スライドはわが国の原子力発電の推移を水力，石炭・石油火力など，他の発電と比較して示したものであります。原子力は１９８４年度実績で既に設備容量（ｋｗベース）で１４％，年間発電電力量（ｋｗｈベース）で２３％に達しており、現在はそれぞれ１６％，２５％に増え，将来はさらに４０％，６０％程度へと増大し，主力電源の役割を果すことが期待されております。

エネルギー・セキュリティーの他に経済性について，スライドに電源別発電原価試算の一例を示しますが，原子力は石油，石炭火力に比べて有利であります。最近の石油の値下

りによって一時的に原子力の優位性が損われることがあっても，長期的には依然わが国においては優位性は変らないと思われます。

原子力発電の初期においてはわが国もいろいろのトラブルを経験しましたが，これまで関係各界の格段の努力により，スライドに示すわが国の実績は１９８３年以来連続して７０％を超える高い設備利用率を維持できるまでに安全性・信頼性を向上することができました。特に計画外運転停止の回数は１９８３年で年間平均１基当り０.８回と諸外国に比べて極めて少なく，安定な運転を続けています。従って原子力を主力電源として頼ることができます。

（高度な先端技術の活用）

原子力の特徴としては知識集約型の巨大システムであり，高度な技術及び生産・建設管理が要求されます。例えば，１１０万ｋｗ級軽水炉発電所の場合，部品点数１,０００万点以上，図面枚数１０万枚以上にも達します。原子力における先端技術活用の例をみましょう。

原子力は解析にコンピュータを大規模に利用し始めた最初の産業であります。３０年程前に，先づ原子炉炉心の核計算に使われ，続いて伝熱流動や遮蔽計算，安全解析にコンピュータが利用され，製品性能及び信頼性を高精度で予測すると共に，設計解析作業を効率化してきました。その後も，大型コンピューターの発達と共に，原子力計算コードの発展と応用は，各分野での先頭を切り，かつ広範囲に及んでいます。

最近における一例をあげれば，原子力発電所の最適配置計画への応用があります。従来は，スライドに示しますようなプラスチックモデルと図面とを用いて，これにより機械，土木，運転などの各種専門家が総合的に配置の妥当性を確認するモデルエンジニアリングを行っていました。これが最近になって知識工学，コンピュータグラフィックスなどの最新技術を取り入れた，総合設計・製造一貫システムとしての３次元プラントレイアウト計画ＣＡＤシステムに発展してきました。スライドに示しますように計画設計の段階で機器の配置，配管の３次元形状をいろいろな角度からグラフィックモデルシミュレーションでリアルに表現し，それらをＶＴＲに記録した後，大型スクリーンに撮影し，レイアウトの総合調整を行なうこともできます。さらにこれらは施工設計ＣＡＤシステムから配管

ＦＡ／ＣＡＭシステムにまで引き継がれ，このシステムを有効に活用しています。

自動化とかロボットなども，放射線被曝低減の努力を続けている原子力では，積極的に開発されています。スライドに示した移動形知能ロボットも，この目的で開発されました。これはテレビカメラの認識した画像情報を処理しながら，階段や障害物を乗越え，回避しながら自律的に移動するロボットであり，人工知能システムが利用されています。

次のスライドに示す設備は，東海再処理工場の高放射線部の溶解槽の検査・補修を実際に行なったもので，遠隔の位置から各種の検査用ならびに補修用ロボットを使用して修理しました。開発した装置は，ペリスコープ，空中・水中兼用テレビ，染色浸透試験装置，超音波探傷試験装置，研磨装置，溶接装置などであり、スライドはその内の遠隔自動溶接機を示します。これで補修された溶解槽はその後順調に運転されています。

またこのスライドは原子力発電プラントに異常や事故が発生した場合，その原因を診断し，プラントの状態を予測し，運転員に操作ガイドを出力する運転支援機能が組込まれた新形中央監視制御システムであります。マン・マシン・インターフェイスを重視した制御装置や，知識工学の応用が原子力では積極的に取入れられつつあります。

こうして高度な先端技術を早期に活用することにより，原子力プラントの信頼性，安全性を向上する努力を続けてきました。このように高度な技術を保有し，技術革新を継続できるのは，総合電機産業の強味であります。

（現地建設工法の合理化）

原子力発電所の現地建設工事においては工法の合理化，工期の短縮の努力が払われております。

例えば機器配管の溶接には，自動溶接機を大巾に採用しております。また機器・配管の大ブロック化・モジュール化を行ない，超大型クレーンを用いて据付・工期の短縮を図っております。このスライドは，７５０トンの大型クローラクレーンを用いて，格納容器を据付ているところであり，吊込回数を大巾に減らしております。

また建家工事との並行作業により工期短縮をはかっております。

（大型プロジェクト管理体制の発達）

原子力発電プラントは巨大なシステムであるため、火力や水力プラントに比べて取扱わ

れる物量が桁違いに多くなります。これらを高品質に保ちながら短かい期間で製作及び現地建設するためには，設計・製作のみでなく輸送・据付まで含めた一貫した物流管理体制が必要になります。

建設にたずさわる各工場と現地を大型コンピュータで結んだ大型プロジェクト管理体制も総合電機産業で発達しました。

（日本の原子力プラント・メーカーの特徴）

わが国の原子力プラント・メーカーは，原子力発電プラントのエンジニアリングを行なうのみでなく，自らハードウェアを製作し，土木・建築を除きターンキーに近い方式で納入していることに特徴があります。もちろんバルブなど個々の部品機器については，プラント・メーカーを支える１５０社程のコンポーネント・メーカーがありますが，原子炉など主要機器を自ら製作する原子力プラント・メーカーは，現在３社であります。

プラント・メーカーはハードウェアを自ら手がけているため，万全の一貫した品質保証体制と品質管理が要求される原子力機器では，従来の重電，産業機械及び電子機器などの検査・品質保証技術の豊富な蓄積の上に，さらに一貫した高度のＱＡ，ＱＣ手法を発達させました。

先端技術を活用したエンジニアリングと，多種多様な製品の製作技術を蓄積し，またプロジェクト一貫遂行体制に強味をもつ総合電機産業が，わが国の原子力プラント・メーカーになっており，原子炉のみでなく，原子燃料サイクル関連機器なども含めた原子力の全分野で機器供給産業の中核になっております。また納入したプラント・機器の定検・補修などアフター・サービスもわが国の原子力プラント・メーカーは一貫してやっております。

（原子力事業の問題点）

次に原子力事業の最近の問題点を考えてみます。原子力発電はわが国において軽水炉の技術導入から始まりましたが，国産実用化，各種の安全性・信頼性向上，機器改良開発やプラントの標準化を行なうことにより，今や軽水炉による発電はわが国経済社会の中に定着するようになってきています。しかしながら電力需要の伸びの鈍化に伴ない，原子力発電の長期市場予測は何度か下方修正を余儀なくされ，また最近の原油価格の急落や円高傾向という外部経済環境は，原子力の経済性向上の要求を急激に強め，従来から続く原子力

立地の困難と共に，将来の見通しを厳しいものにしています。

また原子力発電プラントは，計画開始から運開に至るまで１０年規模の長期間を要し，しかも計画段階から受注にいたるまでのソフト業務が極めて膨大であります。その上先に述べましたような高度の先端技術を開発するための研究投資も考えますと，投資回収に長期間を要し，これが他の電機製品に比べて著しい特徴であります。

従って総合電機産業としては，企業内で長期を要するものと短期のものとの製品バランスをとり，プロダクト・ミックスをはかりながら事業展開を計らなければなりません。

先に述べたように電機産業の内において大巾な伸びは期待されず，今後数年間は原子力機器生産量の端境期が到来すると予想されますが，わが国の原子力プラント・メーカーがこれに対応して行くことができると思うのは，総合電機産業として各種の製品を同時に手がけていることによります。原子力発電プラントについての適切かつ平準化された作業量があることが，この部門の設備や優秀な人材と技術を維持，発展させて行くために望ましいものであることは云うまでもありません。

（研究開発）

原子力は今後も多くの研究開発を必要としています。軽水炉による発電が定着化したとは云え，経済性向上の要求が強く，また電源構成における原子力のウェイトを高めて，電源のベストミックスに持って行くためには，日常の負荷変動に対応できるように運転性能を改良しなければなりません。

スライドは改良型軽水炉の例として，ＡＢＷＲのモデルを示します。従来の１１０万ｋｗ　ＢＷＲと同程度の建設費で１３０万ｋｗの改良型発電プラントを建設できるよう経済性を高め，出力変動巾１００％から５０％の日間負荷追従運転も可能とし，設備利用率も８６％以上を狙っています。

さらに２１世紀に向っては，高速増殖炉などの開発が必要であります。わが国では既にスライドに示しますように原型炉「もんじゅ」の建設が着工されていますが，将来の実証炉についても概念設計や，関連技術の研究開発を推進中であります。スライドはわが国のＦＢＲ実証炉の一つのモデルを示しますが，経済性向上のための格段の努力が求められています。

またＦＢＲへの中間段階でプルトニウム燃焼炉として有効な新型転換炉ＡＴＲは，原型炉「ふげん」で実績をあげていますが，次の実証炉も着工に向けての準備が進んでいます。スライドは格納容器内の構造をプラスティックモデルで示しています。

またこれらの発電プラントを支える濃縮，再処理，放射性廃棄物処理・処分，プルトニウム利用など原子燃料サイクルの確立が急務であります。ここにおいてもわが国では，信頼性ある原子力発電プラントを納入し，ユーザーの高い信頼を得た電機産業が機器供給の中核的役割を果すことになります。

より長期的には，熱供給など発電以外への原子力利用の開発や，人類にとって究極のエネルギー源とも云われる核融合炉の開発があります。スライドは昨年ファーストプラズマの点火に成功した臨界プラズマ試験装置ＪＴ－６０の本体及び全系制御設備を示します。

こうして産業界として今後も資金と人材を投入しなければならない研究開発は多方面にわたっています。

既に原子力産業全体では売上高に対する研究開発費の比率は５から６％台になっており，製造業全体の平均２から３％台に比べて高く，先行き低成長の見通しにおいて相当の負担になります。研究開発がほぼ完了し実証が進み，事業化が具体的工程に乗っているものについては，ユーザーの主導のもとに民間活力を生かした方向に進むのが当然でありますが，事業化までに大規模な資金と長期間を要する研究開発については，引続き国家資金による推進を期待するものであります。

メーカーとしては，協力開発による効率化も考えております。ウラン濃縮遠心分離機を開発・製造する「ウラン濃縮機器（株）」を原子力プラント・メーカー３社の合弁会社として設立したのは，その例であります。

（国際協力）

原子力は，他の電機製品に比べて輸出が困難な点も著しい特徴であります。すなわち先進国においては，一般に機器供給能力が需要を大巾に超過しておる一方，輸出市場が狭隘で，発展途上国においては，核不拡散などの政治的問題，巨額の投資負担など財政的問題，原子燃料サービス供給など体制的な問題があり，国の支援を得て外的制約要因の解決へ向かっての努力と共に，基盤づくりへの協力が望まれます。

また先に述べました研究開発の効率化のためには，先進国間の国際協力も当然考えねばなりません。

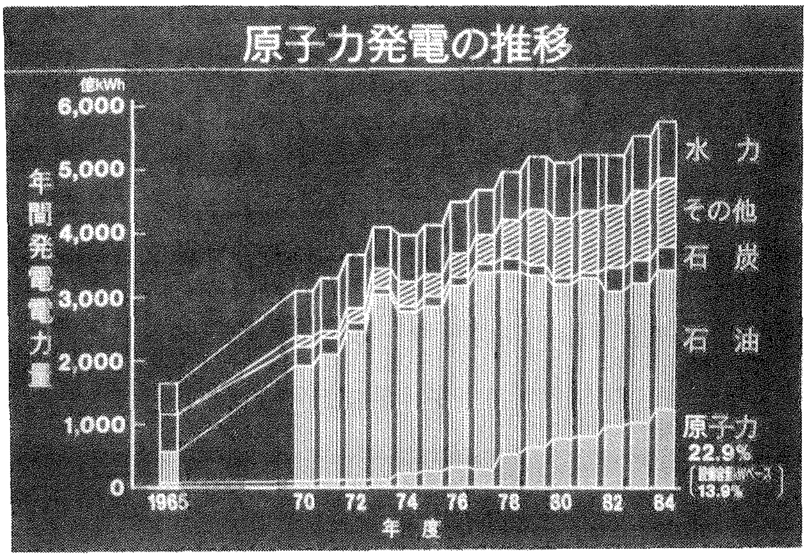
本会議でも午後，国際協力についてパネル討論されることになっていますが，将来に向っての実りある討論を期待しています。

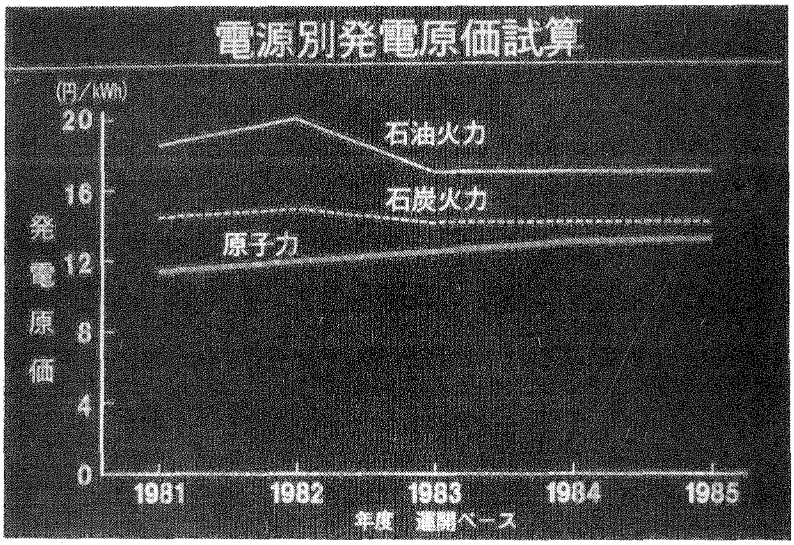
（ま　と　め）

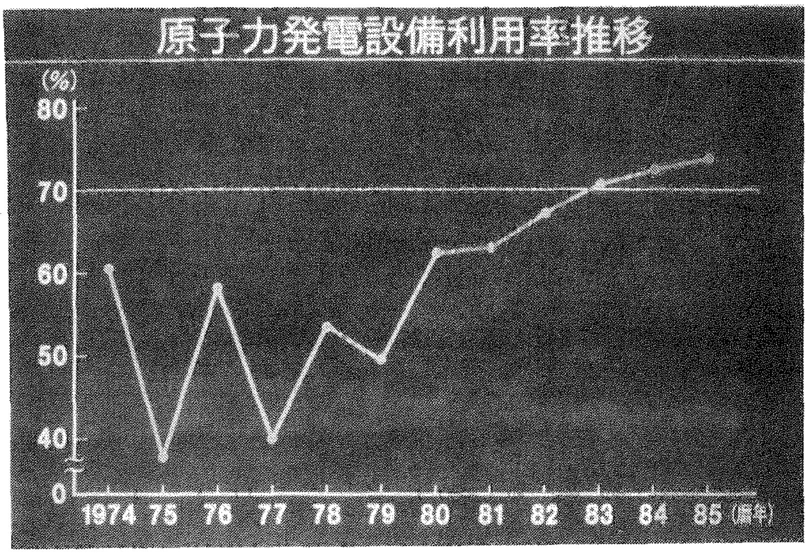
原子力を開発して３０年になりますが，現在２１世紀に向っての展望を行なうと，その環境は厳しいものとなっております。この内にあって軽水炉はようやく定着したとは云え，原子燃料サイクルの確立はこれから本格化しようとする時であります。また，高速増殖炉など将来のための研究開発を続けなければなりません。

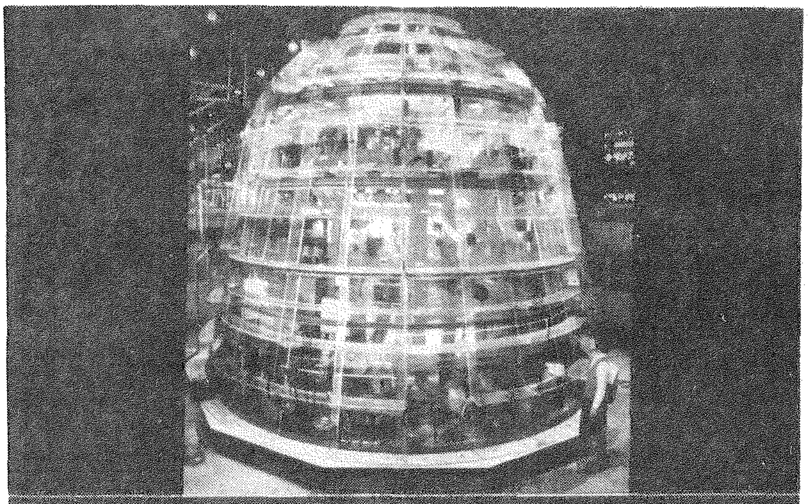
将来のエネルギー源の主力と期待される原子力については，引続き先端技術を積極的に採用し，研究開発の効率化を計り，長期的視野に立って事業展開を計らなければならないと考えています。

私ども総合電機産業はエネルギー機器供給産業の中核として，今後も安全性・信頼性の高い経済的な原子力機器を製作し，社会的責務を果す努力を続ける所存であります。今日この日本原子力産業会議に結集されました３０年の歴史を持つ原子力産業の基盤を維持し，発展させてゆくためにも，関係各界の一層のご理解とご支援をお願いして，私の講演を終らせていただきます。

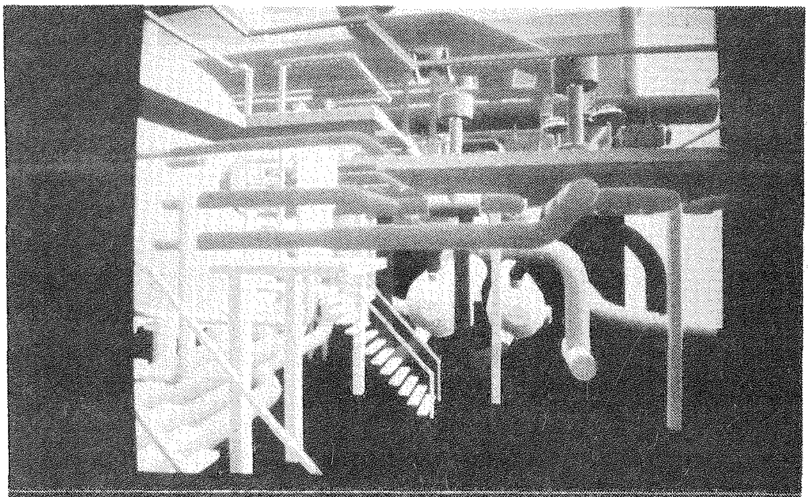

原子力発電の推移
億kWh
6,000
5,000
4,000
3,000
2,000
1,000
0
年間発電電力量
1965
70
72
74
76
78
80
82
84
年度
水力
その他
石炭
石油
原子力
22.9%
13.9%


電源別発電原価試算
(円/kWh)
20
16
12
8
4
0
発電原価
石油火力
石炭火力
原子力
1981
1982
1983
1984
1985
年度　運開ベース

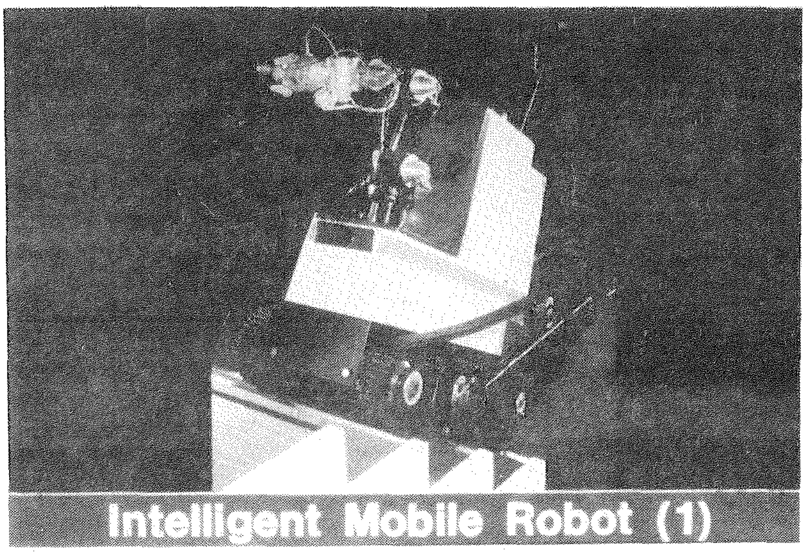

原子力発電設備利用率推移
(%)
80
70
60
50
40
0
1974
75
76
77
78
79
80
81
82
83
84
85
(暦年)



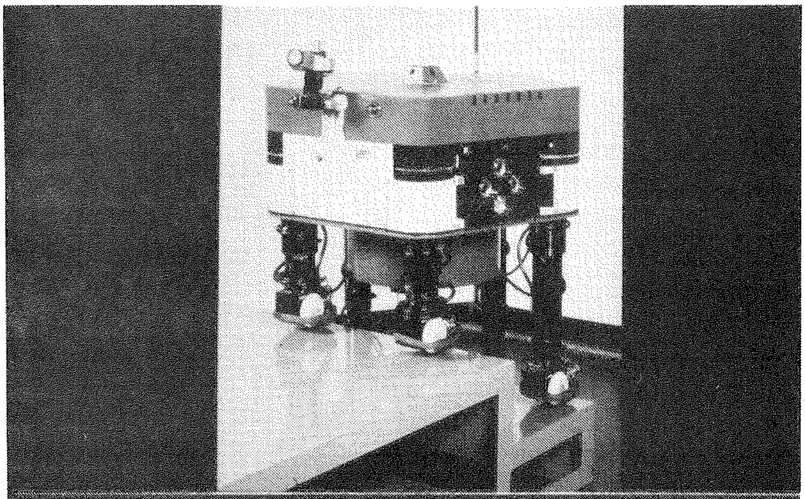
Model Engineering



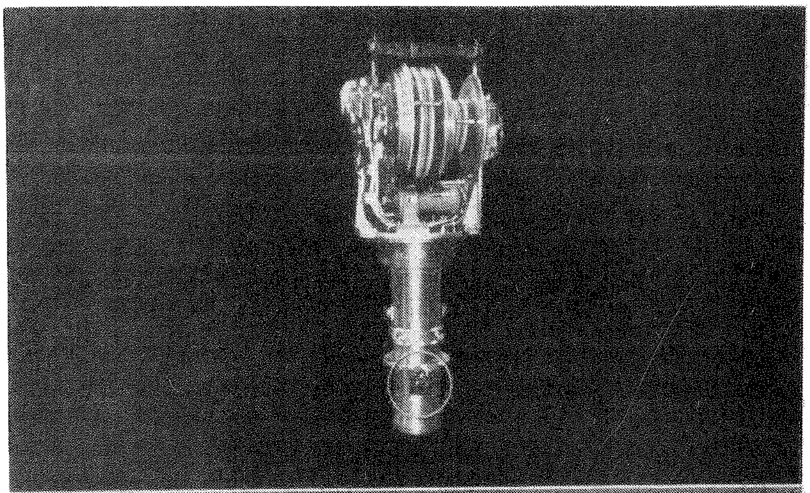
Computer Graphics



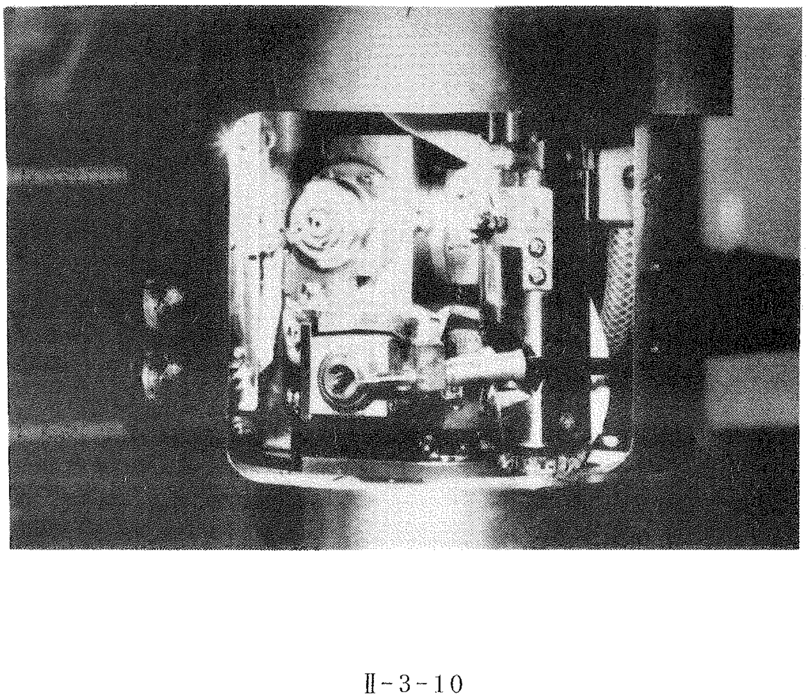
Intelligent Mobile Robot (1)

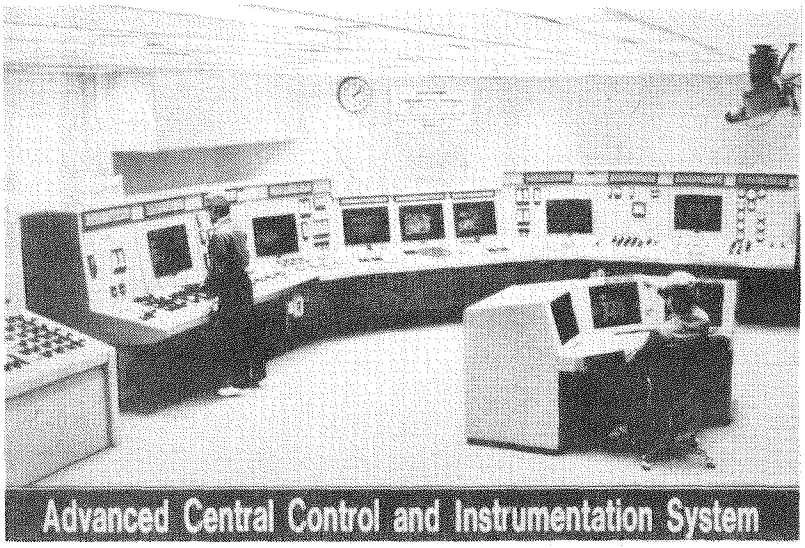


Intelligent Mobile Robot (2)

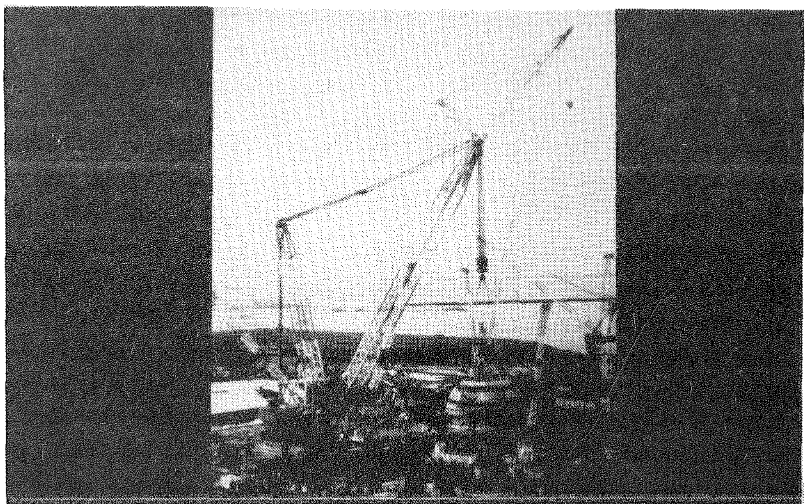


Remote Repair Robot

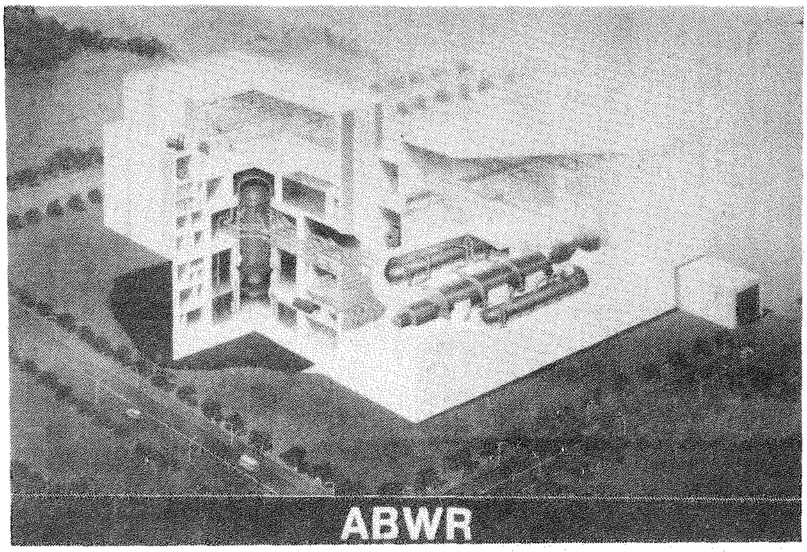




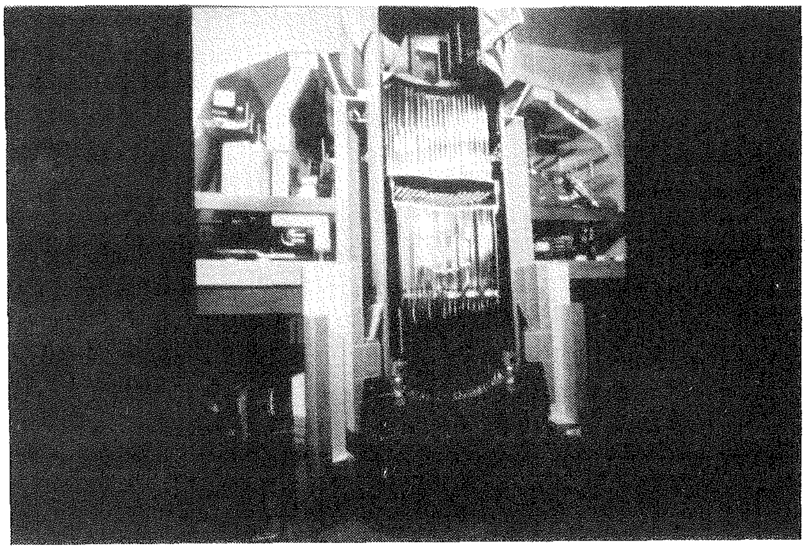
Advanced Central Control and Instrumentation System

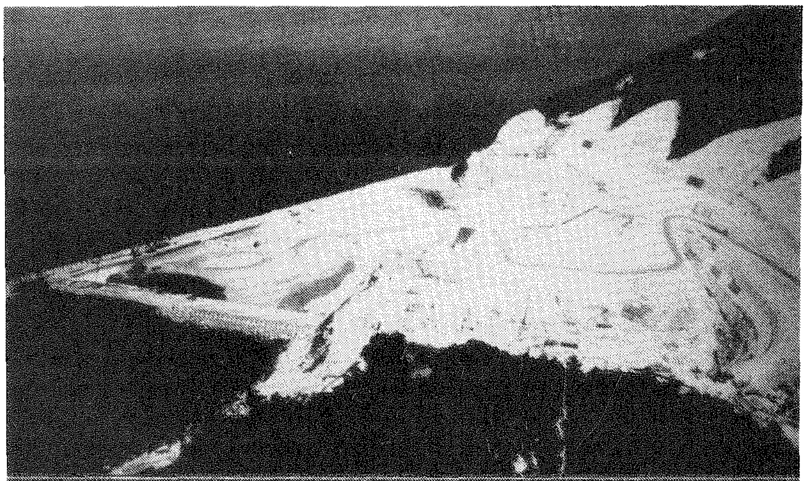


750t Crawler Crane

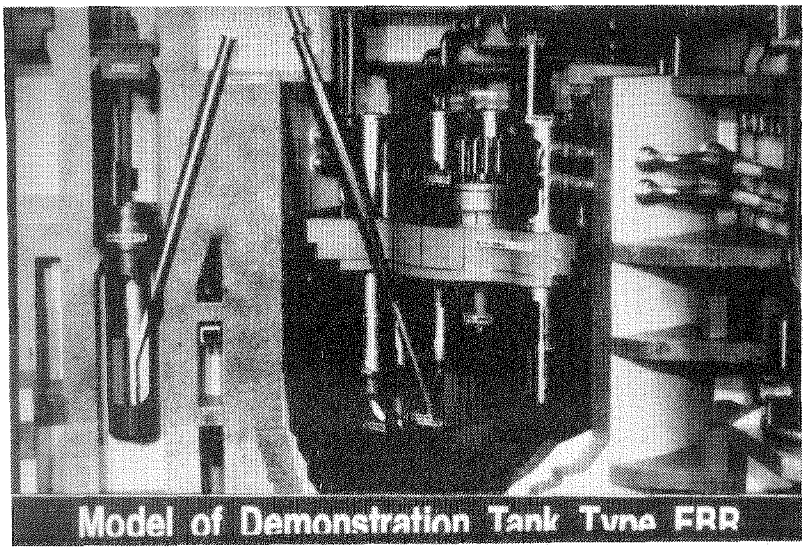


ABWR

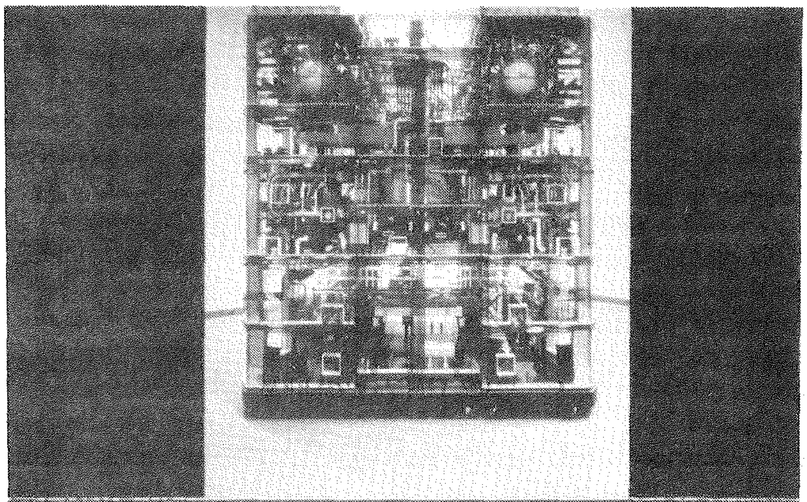




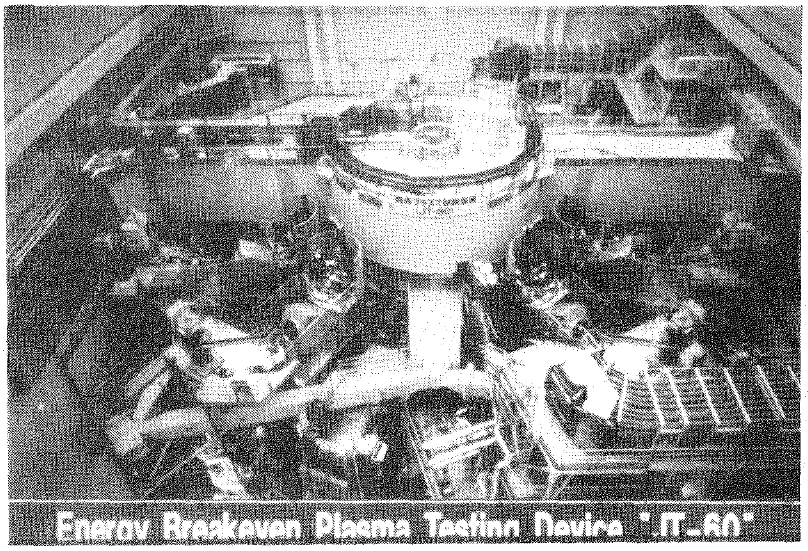
Site View of FBR "Monju"



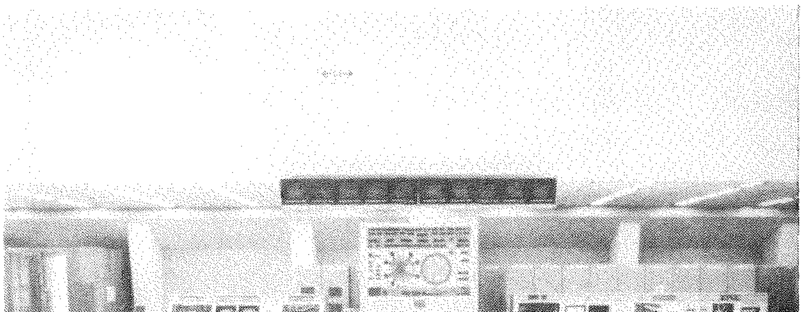
Model of Demonstration Tank Type FBR



Model of Demonstration Advanced Thermal Reactor



Energy Breakeven Plasma Testing Device "JT-60"



Central Control System of "JT-60"

C．ウォルスキー氏の講演に対するコメント

日本原子力発電（株）
副社長　田中好雄

それでは，ちょっとコメントをさせていただきたいと思います。先程から申しておりますように，すでにこの問題が始まって３０年経つわけでございますが，私も初めからこの原子力平和利用開発にずっと携わってまいった関係で，しかもアメリカにちょっとおりました関係で，コメントを求められております。多少時間をいただきたいと思います。

昨日ＭＩＴ名誉理事長のジョンソンさんからのお話は，長い目で見ると，今の原油価格は必ずそのうちに上がってきて，来世紀になると再度エネルギー危機が来るのではなかろうかと思う。したがって，現在はちょうど将来に備えるための猶予期間であると申されておりました。それからＩＥＡＬ会長のグレイさんからは，核燃料サイクルの問題につきまして，天然ウランの供給，転換，濃縮については，既設の発電所および今後２０年にわたって見通される発電所に対して，経済的なレベルで供給を続けることが可能であると考えるというお話がございました。また，ベクテルのレヴンソンさんは，最初に原子力による電気が点りましたのは液体金属冷却高速増殖炉によってで，今から３５年前の１９５１年であると申されておりました。今後３０年の将来を見渡しますと，多分全く変わった技術ではなくて，やはり原子力は現在の科学技術を基礎にしたものであろう。しかし，今から３０年後の２０１６年頃に建設される原子炉は，非常に合理的でかつ簡素化されているということでございます。そういうことで，結局のところ，ここしばらくの間は，大変苦しい状態が続くと考えなければいけませんが，将来は必ず再び原子力開発が槌音高く続けられるようになるだろうというふうに考えられるわけであります。

さて，ただ今のウォルスキーさんの御発言ですと，１９９０年までは大体１０週間に１基位の規模で原子力発電所が運転入りするということでございました。１年に換算して５基程度であります。１９９０年初めからは，先程のお話のように年３％の電力需要の伸びを考えてみても，ベースになります発電設備が７億ｋＷでございますから，リプレースを考えなくても１００万ｋＷの発電所で換算して２１基位，そのうち原子力が約半分の１０基位の割合で毎年建設せざるを得なくなるだろうということでございます。

のちほど関西電力副社長の飯田さんから発表がありますけれども，私共が非公式に手に

入れております見通しでは，これに比べまして，日本では１９９０年までは今のところ３年に２基位，１年に直しますと１．５基位のベースでございまして，現在メーカーの持っております能力から見ますとだいぶ低い数字になるわけでございます。それでは１９９０年以降はどうであろうか。昨日の朝，有澤先生が申されておりましたように，せいぜい２基程度ということでございます。

昨日のジョンソンさんの御発言で，この５，６年あるいは１０年近くをどういうふうに，原子力技術を温存していくかということは非常に重要な点でございます。先程議長からお話がありましたように，フランスのカールさんはこの間は燃料サイクルとか高速増殖炉とかで技術の温存を，またその開発を続けようというお話でございます。日本の場合も同様でございまして，やっとただ今下北半島に濃縮と再処理の工場をスタートさせ始めているところであります。高速増殖炉につきましては，「もんじゅ」の建設が１５～１６％のところまできておりますが，今後ともこれを続けて技術の温存とその向上を図っていきたいと思っております。この関係でぜひアメリカ側の皆様の御了解を得たいのは，なんとしても昨日レヴンソンさんが示されましたように，日本の持っております資源は，アメリカに比べまして，例えばウラン資源につきましても，まことに微々たるものであります。日本の国土はアメリカの２５分の１でございますし，資源にいたっては皆無に近い状態でございますので，どうしてもやはりその関係で，レヴンソンさんもおっしゃいましたように，プルトニウムの利用ということによって，できるだけその分をカバーしなければならないという立場にございます。プルトニウムの利用，特にＭＯＸ燃料の軽水炉への利用を，これも当社で今始めたばかりでございますが，なお引き続いて高速炉の問題，場合によりますと，ハイコンバーターのようなものにもっていきたいと思っているわけでございます。そういうことで，将来，プルトニウムの利用については，非常に重要な点でございますので，御理解を承りたいと思う次第でございます。

なお，最近は，コンピューター・エイデッド・デザインとかコンピューター・エイデッド・マシーンとかいったものがございますが，今後はこういうコンピュータナイズされた施設，あるいはメインテナンス，オペレーション，ロボットというようなものが出てきます。総合するとＣＡＴ，コンピューター・エイデッド・テクノロジーの進歩というものが付随的に必要かと思っておりますが，この辺は日本の産業界は大変力強い能力を持っておられると思います。相携えて原子力の開発がますます発展するようお祈りする次第であります。どうもありがとうございました。

飯田氏の講演に対するコメント

ｲﾝﾀｰﾅｼｮﾅﾙ・ｴﾅｼﾞｰ・ｱｿｼｴｰﾂ(IEAL)
会長　J．グレイ

まず，飯田さんの非常に包括的で示唆に富む御発表に対しまして，賞賛の念を表したいと思います。

昨日，「困難があってこそ明日が開かれる」というお話があったと思いますけれども，私が飯田さんのおっしゃった中で思い出しましたことは，過去数年間にわたってアメリカで出されたステートメントであります。すなわち，この時期というのは，産業全般にわたってさらに強化する時期としてとらえるべきである，ということであります。すなわち，このような低迷の時代を乗り越えることができれば，将来のR＆Dの展望というのは，それほど否定的なものでないということでありまして，これはウォルスキーさんが過去数年間にわたってアメリカでおっしゃっていることと全く同じだと思います。

それからまた，飯田さんのおっしゃいましたことで，いろいろと共通点が見られたと思います。すなわち原子力政策の意志決定に影響を与えるような点につきまして，日本，アメリカあるいはその他の先進国の間に共通点があるように思われたわけであります。特にこういった開発の鍵となりますのは，やはり経済性・効率と，電力需要と原子力発電の相互関係でありまして，これが原子力発電所の建設に影響を与えるということであります。

私が特に魅力的に感じましたことは，飯田さんが強調していましたように，電力会社がイニシアティブをとって，燃料サイクルの事業体制の指導をしているということであります。電力会社というのは，バイヤーであり，また原子力発電所の運転者であるわけですけれども，電力会社が実際に原子力活動の意志決定者であるということであります。特に燃料サイクル，新型炉のR＆Dにつきまして，電力会社がイニシアティブをとるべきであるということを強調しておられたわけであります。

飯田さんがおっしゃったことで，特に賛成いたしましたことは，R＆Dだけでは長期的な原子力産業界の活性化を図ることはできないということで，R＆Dというのは，いわゆる燃料サイクルと原子炉の戦略の展開を基盤としなければいけないということであります。R＆Dはこういった戦略にのっとって発展することができるということであります。さらに強調しておっしゃっていることは，いろいろな責任を政府と民間の両方が今から持つと

いうことでありまして，両者が分担することによりまして，Ｒ＆Ｄを効率よく遂行する必要性があるとおっしゃったわけです。また，輸出の話をされた時，飯田さんは国際市場動向と核不拡散上の考慮について特定され，途上国にふさわしい原子力発電供給の条件として，先進国で開発された実質的な能力を用いるという関心を呼び起こしそうな点に触れられました。これは明らかに，いくつかのレベルの国際協力が考えられるべき点です。飯田さんが主張されている，日本のみが，原子炉や燃料供給を海外に対し行うべきではないという点は，的を射たものと思います。原子力プラントは，先進工業国どこででも開発されているのですから。

最近終ったＮＰＴ再検討会議の結論を思い出しますが，そこでは，途上国が適切に原子力発電供給の入手可能性の展望を広げられるよう，先進国の関心と責務をあらたに強調したものでした。

また経済性の改善というのは普遍的な問題でありまして，燃料サイクルコストあるいは建設コストを低減するということは，将来原子力産業をさらに発展させるにあたって不可欠であると飯田さんは強調しておられました。また飯田さんは実際に即した経済性向上の方策をとるべきであるとおっしゃいました。さらに，メーカー側，電力会社および規制当局が，協力してこのような問題に取り組むことが重要であるとおっしゃいました。それからまた，普遍的，国際的に重要なことは，規制当局が経験に基づき適切な安全基準を組み立てていくということであります。規制側の検査方法をさらに改良し，また同時に，自発的な自己検査というのを電力会社内で行うということ，につきましても言及なさいました。飯田さんがおっしゃいましたことについて，日本とアメリカその他の諸国で非常に多くの共通点があると考えているわけであります。

また状況の安定化ということについての私の見解でございますが，昨日燃料サイクルのフロントエンドに関しまして，現在，供給が需要を上回っていると言ったわけであります。商業炉の建設を始めた頃に，余剰の能力が必要になるというような時にはそれが利用できるように，つまり需要に合わせて供給できるようにということを考えたわけです。ただし，それはその時には経済的に非常に魅力的だったわけで，それまでその能力を作り出すための努力がなされ，非常に良い仕事の成果が得られたと思います。しかし，原子力産業，電力産業は，それにもかかわらず普通の経済法則を完全に満たすことができなかったと思います。どうしても需給のバランスが欠けるというようなことが，すべてのプラント，機器，サービスに関して起こったわけであります。これはなにも原子力発電には限らず，資本集

約的，技術集約的活動であればどうしても起こってくることであります。ということは，最初の導入の時期には非常な成功を収めた，そして世界中でその能力が需要を上回るまでになったということは，驚くにあたらないわけであります。その派生効果として余剰能力が出たということは将来建設的に使われるべきでありますけれども，ただそのように余剰能力があるということに対して驚愕の念を示す必要はないと思います。

国際協力関係について特に強調したいわけですが，私といたしましては，これまでもそうでありましたけれども，できるだけ正確に協力のメカニズムを定義する必要があると思います。さらに，電力会社がそのスタートを切るという意味では，一番良い立場にあると思います。つまり原子力に関するすべての点について，協力の糸口を作るのは電力会社だと思います。お互いに国内においても，また国際的にも競争関係にないということがその理由であります。それと同時に，非常に長い建設の経験，また効率的な技術協力，経済協力の経験を持っているということも一つの理由になります。電力会社が国際協力を一層広げていくことにより，政府自身の国際協力能力がますます高まると思います。電力会社こそ効率の良い国際協力における最善のホープであります。

最も印象的な他国間の事業で過去20～30年を振り返ってみて何があったかと考えますと，スーパーフェニックスのプロジェクトではなかったかと思います。私以外にもこう考える方はいると思いますが，このようなことが可能であったのは，西ドイツ，フランス，イタリアの３つの電力会社が集まって，その英知をあわせ，リーダーシップをとったということで，むずかしいプロジェクトも実現したということであると思います。これだけの市場へ，いろいろな意味合いがあったにもかかわらず，必要なサポートを得られたがために成功したと思います。電力こそ第一のホープ，次いで政府に望みをかけることができると思います。電力のすぐ後に政府がつくという形になりましたならば，原子力産業界にも非常に強力な協力への望み，最善ではないにしても強力な望みが得られると思います。将来，産業界が一致協力することにより，相互に経済的な利益を享受する特別な展望を探る必要があります。電力会社がリーダーとなり，それを政府が支持すれば，それに筋肉を提供するのは原子力産業界ではないかと思います。

ここで申し上げても決して不適切ではないと思いますが，他国間の機関として，２つの国際機関があります。一つはＯＥＣＤが作りましたＮＥＡであります。シェーバーさんがその代表として今回御出席でありますが，このＮＥＡが非常にＯＥＣＤ諸国のためには音頭をとることができると思います。もう一つはＩＡＥＡで，その友人達がいらしてますが，

ＩＡＥＡ自体が将来大きな指導権を発揮し，また先鞭をつけて人々を鼓舞することができると思います。つまり「途上国に原子力を」ということを，過去よりも強いイニシアティブでもっていくことができると思います。これはＮＰＴ体制をより強化するという意味でも必要になると思います。

このようなコメントをさせていただいてありがとうございました。以上でコメントを終わらせていただきます。

三田氏の講演に対するコメント

米国原子力産業会議
理事長　C．ウォルスキー

アメリカ人として，日立の社長のご発表に対しコメントさせていただきすのは，非常に光栄でございます。アメリカでは，日立という名前は非常に尊敬を受けておりまして，学童でさえ，これはアメリカの会社ではないかというふうに思っているほど，有名でございます。

三田さんがおっしゃった点について，いくつか拾ってコメントさせていただきます。他の方もおっしゃったことでありますけれど，三田さんは特にコスト削減が重要であると強調されました。可能な限り最低限のコストで原子力による電気を供給することが必要であるとおっしゃいました。こういう考え方は，日本でも非常に強いと思いますし，また全世界でますます重要になってきていると思います。例えば，私が知っている国々でも，こういう話をしておりますし，もちろんアメリカ，スウェーデン，フィンランドでもそうですし，こうした国々が一番大きな重要な点として言わなくても，やはり重要な点の一つとして考えられております。

原子力をいろいろな側面からみますと，例えば将来の成功または不成功は，パブリックアクセプタンスがあるかどうか，供給産業の健全性がどうなっているか，さらに電気事業者の幹部が原子力をどう考えるかなどによって変わってくるわけであります。私はコストの面からたまたま見る立場をとっておりまして，というのは，私はこれは金言・格言だと思いますが，原子力を安全にし，一般の人たちにアクセプタブルな形にできると考えております。これは金言・格言と申し上げましたが，なぜかと申しますと，安全な運転が可能であり，すべての人にアクセプタブルであるような運転が可能であると思っているからです。しかし，こういうことが可能になったとしても，将来コスト的にやはり十分に下げなければ魅力が減ずると思いますので，コストは非常に重要だと思います。

三田さんがおっしゃったことに，私，賛成するわけですが，現在の石油の低価格に影響され，原子力の新規発注が近未来的には少なくなるかも知れません。長期的には石油の低価格状況も変わりますし，石油の生産量が下がれば，石油価格が上がり，石油からの直接の競合ということを考えましても，原子力の観点からはマネージできると思います。皮肉

なことに現在は石油価格の下落により，原子力の新規発注は下がっているかも知れません。しかし，原子力で電力が供給可能だということ自体が，石油の価格を下げるのに役立っているわけであります。

原子力発電のインパクト，また石油価格と原子力発電の相互関連について種々の議論のあることを理解することが肝要です。私は，原子炉について２つのカテゴリーからみたいと思います。一つは現存するもの，あるいは，ほとんど現存すると言っていいもの，つまりほとんど建設されたもの，もう一つは，もしこれを建設するという決定が将来なされることによってのみ建設されるであろうものです。

今現存するプラントに関しましては，わが国のように最近のプラントコストは，いろいろな理由があるにしても，どうも高すぎて，魅力がないというのも事実です。しかし，石油に関して覚えておくべき大事な点として，石油火力発電所はいったん建設されてしまえば，建設後支払いの残っている不運な人を除き建設コストはさほど重要でなくなるということです。運転コストは，任意なもので，基本的には燃料コストだけということになるわけです。昨日も指摘があったように，原子力発電所の場合には，１バーレル当り５ドル以下になるまで石油火力発電所よりも優位に運営できます。現在世界で運転中の 2億 5,000万ｋＷの原子力発電所によって１日当たり 600万バーレルの石油が節約されていることになり，この 600万バーレルは，国際石油市場にとって，実際上恒久的な石油の減産ということになります。そして，現在建設中の原子力発電所が完成すれば，さらに 200万バーレル／日の石油の減産につながってくるわけでありまます。１バーレルあたり15ドルという石油価格になれば，カリフォルニアの場合には，石炭が競合できなくなって，石炭火力発電所は一時的にシャットダウンせざるを得ない状況になってきております。

新設のプラントの場合には，運転・燃料費の増加コストでなく，資本費，運転費，補修費，それから燃料費という全体のコストになるわけです。この点ではやはり他のものと競合するだけの十分な力を持たなければなりません。論理的な計算によりますと，ほとんどの国において，われわれが最善を尽くせば，他の代替電源全てに競合できるようになります。しかし，最善を尽くさなければ，つまり不必要な設計項目を除去するとか，不必要な規制要求を取り除くとか，効率のよいマネージメントをするとか，運転を効率的にするなど，こういうことを全部最善の形で実施することができなければ，コスト的に他と競合することは無理なわけです。

最後に三田さんがおっしゃいましたＲ＆Ｄですが，原子力のような先端技術を扱ってい

る分野においては，成功するためには，最善の科学者，エンジニアの興味がなければならないわけです。全部というわけにはいかないにしても，優れた科学者，技術者の何人かを我々の方に引き付けなければならないわけです。これからも継続的に原子力産業に優秀な頭脳が入って来ていただくことによって，我々の成功が確保されるわけであります。そのためには，若い技術者にとって原子力は成長産業であると認めてもらわねばなりません。この成長には２つの意味があります。１つは市場が拡大しつつあるということ，つまり原子力発電所がもっと建設され，活動がもっと活発になり，成長市場であるという意味の成長です。第２の成長は科学者，技術者にとって，技術が成長するかどうかということが心配なわけですから，技術の改善が行われるという意味の成長です。

もちろん技術の改善のためには，良い人材が必要でありまして，また，それをバックアップするようなＲ＆Ｄというものが必要になるわけです。高速増殖炉などは，長期的にみて原子力にとって絶対に必要なものであります。もちろん，世界中の原子力にとり，数十年から数千年位は必要になるわけです。その国の開発レベルによっても違います。つまり科学者，エンジニアにとりまして，まだまだ新しい技術分野というものがあるわけです。この分野は20～30年でもう終わりが来るということであれば，科学者，技術者で非常に良い人材はあまり引き付けられないと思いますが，我々はまだまだはるかな未来があります。

最後にＲ＆Ｄが重要なのは，それによってコスト削減に役立つからであります。またもとのところに一巡してきたというわけで，初めに私，コストが重要だと申し上げたところにもどってまいりました。日本の場合には，それを十分に御理解いただいているということは，すばらしいと思います。コスト低減が重要であるということの情報は，日本の原産の森さんが何年か前にこれをおっしゃったと思います。パイオニアとして森さんが，いかにコスト低減が重要であるかということを説かれました。日本の参加者の方が，今回の会議でも，コスト低減は非常にプライオリティーが高いということをおっしゃいました。しかも，アメリカでも，これは優先順位が高くなってきておりますし，我々の米原産といたしましても，これを促進しております。例えば標準化を進めるとか，運転・建設のマネージメントを効率的にするとか，もっと政府の規制を合理的にするなど，皆さんが御存知のことを通して，コストの低減を図ろうとしております。

どうもありがとうございました。

三田氏の講演に対するコメント

フランス電力庁（ＥＤＦ）
副総裁　Ｒ．カール

最初に申し上げたいのは，私，三田さんの御発表を，非常に興味深くお聞きいたしました。グレイさんが先程，電力会社の重要性を強調されました。電力会社の一員として，私は，この業界の重要性というものを強調したいと思います。電力会社は，業界の努力なしには何もできません。実際，一つ指摘させていただくとすれば，特別な原子力産業というのはないと思います。原子力産業というのは実際は古い産業であります。日立，三菱といった伝統のある経験のある業界であり，これは非常に重要な点だと思います。というのは，こうした事実によりまして，原子力技術も，古い昔の過去によって，従来の努力，業界の努力によって良い影響を受けることができるわけであります。

さて，原子力の分野ということになりますと，この業界は特別な努力をさらに払っていかなくてはなりません。品質とコストの問題があるわけです。この２つは実は相反している問題だと思います。

ですから業界としてはどうしても特殊な手段を使わなくてはなりません。三田さんがさっきおっしゃいましたように，確かに重要なこととしては，コンピューターを使うということがあると思います。確かにコンピューターによって品質の改善がはかられ，技術の継続性ができるわけです。決して奇跡的ということではないのですけれど，確実性ということでこの努力を行うと，私共が，必要とする昔の品質が，継続的に維持できるわけです。ＣＡＤというのは，確かに日本でも特に力を入れている分野でありますが，フランスでもそうであります。現在ＣＡＤ一連のセットがないわけでありますが，私共はこのＣＡＤを設計だけでなく，さらにエンジニアリング，プラント据付，加工，スペアーの部品の製造等にも広げていかなくてはなりません。もちろん，そうした努力もできるとすれば，一つのユニットということではなくて，プラントの全体のサービスというものを考えれば可能だと思います。

原子力産業のキーワードは，この標準化だと思います。これは非常に重要だと思います。日本もフランスも，標準化によって，独自の原子力技術を，国産技術というものを開発することができるわけです。フランスでは開発している原子炉のタイプは一つしかありませ

ん。それがベストだからというのではなくて，フランスは小さい国ですので同時にたくさんのものを平行して手掛けていくことはできないと思ったわけです。そこで一つのタイプを選択したわけです。

標準化というのは，やはり時間によって制限を受けているわけであります。技術者やエンジニアはいつも新しいアイデアというものをかかえていますので，とても標準化は危険なことであるわけです。ですから何とかして標準化を長くもたせたいとするわけです。そうすることによって完全主義を排し，より良いアイデアにより，このプラントの稼働率が下がってしまわないようにしなければいけないわけです。

標準化というのは全分野に影響を与えます。建設の分野においても，例えば建設工期の短縮ということにも影響を与えます。つまりデザインを良くしまたは検査手順を改善する程度で，あるコンポーネントについて，前のままのものが使えるということであれば，これは長い継続性があればやっていけます。

標準化は非常に運転上も有益だと思います。ちょっと例をあげてみたいと思います。非常に正確でしかも詳細に渡るシミュレーターを持ってらっしゃるわけですが，いくつかのプラントのオペレーターがこれを使おうとしても無理です。一つのプラントでしかこれは使えないと思います。

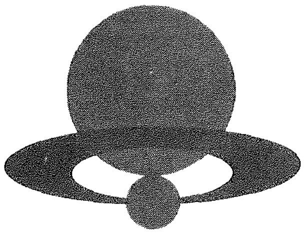
ただどうしてもエンジニアとしては，やりたくなってしまうことがあるわけです。プラントのサイズをもっと大きくしていきたいと思うわけですが，これはすべての国でそうでありますが，私の感じとしては，サイズという要素は，標準化に比べればそれ程重要で大事な要素ではないと思います。もし，大規模過ぎると人間のサイズのプラントではなくなります。重過ぎるコンポーネントですとか，距離があり過ぎるというものではなくて，人間に合わせた規模でなければならないわけです。あまりにも大きいと危険だと思います。ですから，この大きいものを作ることよりも標準化をすることの方が大切だと思います。

昨日，私は高速増殖炉開発について発表しましたが，シリーズという要素は高速増殖炉のコストに関して非常に重要だと思います。高速増殖炉は現在フランスではＰＷＲの２倍位のコストになっており，高速増殖炉のシリーズ化ということによってのみこの２倍というコストをもっと下げることができると思います。どの位まで下がるかは分かりませんが，かなり有意な違いというものが出てくると思います。

こうした品質，稼働率，コスト等の問題は全て，明確な問題であります。もちろん私達は品質を維持するためにそれの対価を払わなければなりません。

最後に私共の希望として世界的な市場において，これは確かに大きな市場ではありませんが，メーカー側，そしてバイヤー側どちらもこうした品質に要するコストというものを受け入れてほしいと思います。そしてあまりにも世界市場で競争が激しすぎるとやはり危険だと思います。異なった国々の業界はそれぞれ注意深くして，あまりにも値段を下げるというようなことはしてほしくないと思います。そのために品質が犠牲になってはいけないと思います。

午餐会



通商産業大臣所感

渡辺美智雄

特別講演　日本の心・言葉・文字

松下政経塾専門講師

石井　勲

LUNCHEON

Remarks
Michio Watanabe
Minister for International Trade and Industry

Special Lecture: "Soul, Words and Letters of Japan"
Isao Ishii
Lecturer
The Matsushita School of Government and Management

通商産業政務次官所感

通商産業政務次官　田原　隆

通商産業政務次官の田原隆でございます。本日は，第１９回原産年次大会にお招きにあずかり，誠にありがとうございます。

原子力の開発に長年携わってこられた皆様と親しくお話できる機会を得ましたことは，私の大きな喜びであります。また第１９回年次大会がこのように盛大に開かれることになりましたことにつき，心からお祝い申し上げるとともに，この大会を準備された有澤会長，圓城寺大会準備委員長をはじめ，関係の方々に敬意を表する次第です。

さて近年のエネルギー情勢をみますれば，原油価格の大幅な低下が生じております。この結果，電源間の経済性比較論議がなされているところですが，原子力の経済性については，石油火力に比べて依然優位性を維持するものと考えられております。特に，電源開発は，元来長期間にわたるコストやセキュリティを勘案して実施されるものであり，今後のエネルギー政策においても供給の安定性，経済性等の観点から，原子力を引き続き推進していくこととしております。

昭和６０年度には，原子力発電は二つの大きな記録を作りました。第一には設備利用率でありまして，７６％と史上最高を記録しました。第二は，原子力による発電量が初めて石油火力による発電量を上回ったことです。原子力発電量は全発電量の２６％に達しました。

このように順調な進展を見せております原子力発電も，初期段階では，多くのトラブルが発生したわけであり，これらを一つ一つ改善したわけであります。もちろんここに至るまでには電力やメーカーの方々の多くの努力があったことは申すまでもないことでありましょう。

このように，いまや，原子力発電は安定的な電力供給の担い手となったといえる訳ですが，今後も原子力発電を着実に推進していくためには，いくつかの課題があります。

まず第一には，自主的な核燃料サイクルの確立があげられます。

この点につきましては，昭和５９年７月に総合エネルギー調査会原子力部会においてその具体的方策の提言がなされました。これに沿って現在，電力業界により青森県六ケ所村むつ小川原工業開発地区にウラン濃縮，使用済燃料再処理，低レベル放射性廃棄物最終貯

蔵の三施設の建設計画が進められているところであります。

また高レベル放射性廃棄物対策については，官民の総力をあげて研究開発にとりくんでおり，総合エネルギー調査会においても，その具体的検討を行うべく，準備を行っているところであります。

また第二の課題としては，軽水炉技術の高度化およびプルトニウム利用の推進があげられます。

まず軽水炉が今後長期にわたり原子力発電の主流として貢献することが期待されており，主力電源にふさわしい経済性，信頼性を有するよう技術の高度化を進める必要があります。このため，先月，総合エネルギー調査会原子力部会において「２１世紀への軽水炉技術高度化戦略」についての報告書がまとめられたところであります。この報告書では，既存型軽水炉について一層の信頼性，経済性の向上を目指した技術開発を行い，それに継ぐものとして新型軽水炉を１９９０年代中頃の導入を目途に開発するとともに，更に２１世紀の軽水炉を目指した次世代型軽水炉を開発することとしております。

また，資源の乏しい我が国においては，ナショナルセキュリティおよび資源節約の観点から，使用済燃料を再処理して得られるプルトニウムを有効に利用することが必要であります。このため，軽水炉によるプルトニウム利用の推進，ならびに新型炉転換炉および高速増殖炉の開発を推進することが重要であります。軽水炉によるプルトニウム利用については，本格利用に向けて段階的に進める予定であり，現在総合エネルギー調査会原子力部会において具体的な計画を検討中であります。また，新型炉の開発についても，実用化に向けての必要な準備，技術開発等が鋭意進められているところであります。

国際協力も重要な課題であります。

我が国は御高承のとおり，平和利用に徹して原子力開発を行ってきており，この精神に沿って今後とも世界の原子力開発の推進のため，原子力先進国との協力を進めるとともに，これから新たに原子力利用を進めようとしている国々との協力についても，積極的に行っていく必要があります。これにつきましても，先月，総合エネルギー調査会原子力部会において「原子力発電分野における発展途上国協力のあり方について」と題する報告書がまとめられたところであります。今後は，相手国における開発の初期の段階から，我が国関係各機関が緊密な連携をとりつつ人材育成，技術指導等の協力を積極的に進めていくこととしております。

このように我が国の原子力開発利用は，電力供給における原子力発電の定着，核燃料サ

イクル事業化の具体的進展等，過去３０年の努力の結果，一つの節目を迎え，新たな段階に入りつつあるといってよいでしょう。

かかる観点から，現在，総合エネルギー調査会原子力部会において，２０３０年までの「原子力ビジョン」の検討を行っているところであります。これはエネルギー全体についての「２１世紀エネルギービジョン」と歩調を合わせて行われており，エネルギー需要低迷下において，原子力，石油，石炭，天然ガス等各種エネルギー間の競合の中で，総合的なエネルギー政策の観点から，原子力の役割と貢献の見通しを明らかにすることとしております。本検討は，安全性，平和利用を大前提に，原子力の本格利用段階に求められる経済性の確保，民間活力の導入，国際化の推進等の観点をふまえ，原子力発電と核燃料サイクルの整合性をとった長期的かつ総合的な展望のもとで，原子力の開発利用を着実に推進するという認識のもとに行われております。現在までの検討においては，２０３０年における我が国の原子力発電の規模は，１．１億ｋＷから１．４億ｋＷ，電力供給に占める割合は約6割にもなるとの試算も得られております。今後，残る部分の検討を経て，本年夏頃に結果がまとまるものと予定されております。

以上，我が国の原子力開発の現状，政策および課題を簡単に申し上げた訳ですが，これらの課題を着実に克服していくことが，原子力の円滑な発展のための鍵であります。このような幾多の課題を解決していくためには，国際的な理解と協力の下に，関係する者全員の英知の結集が不可欠であります。このため，本日御列席の皆様および海外の関係者の方々の御協力をお願いする次第であります。

来年の年次大会においては，また新たな成果を皆様に御披露できるよう，皆様の御協力の下，着実に原子力開発を進めてまいりたいと存じます。

最後に，この年次大会をこのように盛大に開催されました日本原子力産業会議の労をねぎらうとともに，皆様の御発展を心からお祈り申し上げまして，私の挨拶とさせていただきます。

日本の心・言葉・文字

松下政経塾専門講師　石井　勲

私は，約半世紀に亘り，日本の言葉や文字に就て研究して参った者でございます。それでその立場から，日本人の物の観方や考え方をお話申上げようと存じます。

日本語に“有情”という言葉があります。この言葉は，情，つまり“心有る物”という意味の言葉ですが，これは人間だけでなく，鳥や虫，更には梅や桜のような植物までを含めた呼び名であります。

数年前，イギリスのNatureという科学誌に角田(つのだ)忠信(ただのぶ)氏の“日本人の脳”という論文が掲載され，世界の話題になりました。今までは鳥の声，虫の音(ね)は，凡(すべ)て人間の右の脳で処理される，と考えられていました。所が，日本人に限って，これを左の脳で処理している，というのです。

然し，これは，日本人の脳が生れつきそうなっているのではなくて，日本語を日常語として使っている日本人に限られる，というのです。つまり，全く純粋の日本人でも，外国で生れ育ち，その国の言葉を日常語として使っている日本人の脳は，その国の人の脳と同じ様に，鳥の声，虫の音を右の脳で聴いている，というのです。

従って，この脳の仕組の違いは，生れつきの物ではなくて，後天的に作られた物であり，それは日本語の性質，角田教授の言に依りますと，「母韻が他国語に比べて著しく多い」という性質に因る，という事であります。

然し，私は，それよりも，この日本という穏やかな風土の中で暮しているうちに，自然と養われた心情に原因がある，と思っています。例えば，日本人なら誰でも，鈴虫や松虫，蟋蟀(こおろぎ)，螽斯(きりぎりす)など，その虫の名は元より，その鳴き音もよく知っていますが，外国の方々はこの様な物に関心が無く，従って，虫の名前も学術語としてあるだけで，生活用語としては無い，と伺って居ります。

所が，日本人は，これらの虫の名前や鳴き音を知っているばかりではなく，これらの虫の音を，私たちに語り掛ける，意味をもった言葉として受取っているのであります。それも恋人の語り掛ける言葉の様に，これをいとおしんで，うっとりと聴きほれるのであります。

私は子供の頃，晩秋の夜更けに鳴く虫の音を「つづれ刺せ，つづれ刺せ」と人間に語り掛けているのだ，と母親から聞かされました。それで，今でもその様な言葉としてこれを聴いて居ります。また，鶏の鳴き声は「夜が明けた」という言葉として聴いていますし，鶯の鳴き声は「法，法華経」という有難いお経の名前を表した言葉としてこれを聴いて居ります。ですから，この様な鳥の声や虫の音を，人間の言葉と同じ様に左の脳で聴くという事は，私は当然の事と思う訳であります。

然しながら，日本人は，鳥や虫だけを自分の仲間と考えているのではありません。梅や桜の木のような植物も，自分の仲間と見ているのです。花が咲くの“咲”という字は，中国で作られた字で，中国では，「人が口を開けて笑う」という意味の字です。所が，日本人はこの字を「花が咲く」という意味に用いているのです。これは明らかに「花が我々に笑い掛けている」と見，花を友達と考えているからだと思います。

ですから，日本人は，桜の花の咲く頃ともなりますと，その日を今や遅しと待ちかねて，酒や食べ物を携えて桜の木の下に訪れ，花と共に春のひと時を楽しむのです。

日本の田舎には，たいてい村の真中に，鬱蒼（うっそう）と茂る森に囲まれて，鎮守の神様を祭る社（やしろ）があります。田舎で育った私は，誰もがそうであった様に，その中で遊び回って成長致しました。その為，田舎に帰りますと，何よりもこの社の森が懐かしく，ここを訪れずにはいられません。彼らは，昔と全く同じ姿で私を迎えてくれます。それは，今は亡き父母や祖父母の様に暖かく感じられ，且又，非常に偉大な人物の様に厳かにも思われるのです。

さて，木は生き物ですが，私たちは生命の無い物を友達と見，語り掛ける事を致します。十三世紀の初め，明恵（みょうえ）という坊さんの歌に「雲を出でて我に伴う冬の月，風や身に滲む，雪や冷たき」という歌があります。冬の夜道を歩いて行きますと，雲間から月が現れ私のあとをついて来ます。お蔭で足元は明るいし，淋しさも紛れます。お月様，有難う。それにしてもお月様，この冬の夜風が身に滲みませんか。又，この雪が冷たくはありませんか。お月様，風邪を引かないで下さい…と，こういう意味の歌です。そして，これが典型的な日本人の心なのです。生命の無い物に対しても，親しみの心をもって語り掛ける，これが伝統的な日本の心なのです。

この様な日本の心は，この恵まれた自然の中から生れ，育ったものだと思います。その

事は欧米の皆様がよく口にされる「自然を克服する」という言葉と，私どもが口にする「自然の懐に抱かれる」という言葉とを比較してみれば，よくお解り頂けると思います。

日本人にとっては，自然は私たちを暖かく抱擁してくれる親の様な存在であります。事実，日本のある偉大な思想家は「自然こそ，我々の真の親である。我々は両親の肉体を借りて生れたのであって，ほんとは自然の力が両親に働いて，それで我という一つの生命が母親の胎内に宿り，この世に誕生したのである。我を作ってくれた真の親は自然であって，それは人間の出来る業ではない。我々は自然のお蔭でこの世を生き，仕事を果す事ができて，やがて元の自然に帰って行くのである」と説いて居ります。

ですから，人間も他の動物や植物と全く同じ様に，自然から生れ，自然に帰って行く存在であって，言わば人間も動物も植物も皆兄弟である，というのが伝統的な日本の心なのであります。

日本の言葉は，この様な自然の中から生れ，そして発達して参りました。欧米の皆様には凡て同じ様に見える虫を，鈴虫や松虫，蟋蟀，螽斯などと区別して見る事も，日本という優しい自然なればこそと思います。そして，鈴虫や松虫などの言葉が，虫の音に耳を傾ける優しい日本の心を養い育て，それが虫の音を左の脳で聴く日本人の脳を作るのだと思います。

私たちは，物事を考える場合は勿論，物を観る場合でも，実は言葉に拠って観ているのであります。言葉を通して観て，初めてそれが意識され，大脳に記憶されるものであります。ですから，同じ牛や鶏を観ても，言葉の異なる日本人と欧米人とでは，その観方が自然と異ならざるを得ません。

日本人は，“牛・鶏”という性の無い言葉でこれらを観ますから，全く雌か雄かを意識しないで観ますが，欧米人はcow かbullか ox,か，hen か roosterか，という様に，性を伴った言葉でこれを観ますから，いやでも雌か雄かを意識せざるを得ません。

この様に，言葉は物の観方や考え方を規定しますので，角田教授が発見しました様に，言葉が人間の脳の構造に変化を及ぼす程の力をもっているのだと思います。

そういう訳で，言葉が豊かですと，心も自然に豊かになり，言葉が貧しいと心も貧しくなります。ですから，私たちは，美しく優しい心を養い育てる為，美しく優しい言葉を豊かに使う努力をする必要がある訳です。

所で，日本語の主要な語彙は，この会の名称“原子力産業会議”という言葉がそうでありますように，漢字を土台にして組立てられています。

この漢字は，世界で最も内容の豊かな素晴しい文字でありまして，漢字を組合せますとどんなに複雑な思想や内容でも，実に適確に表現できる利点を備えています。唯，字形が複雑で，且字数が多いという事で，学習が困難であるとされ，低い評価を受けています。

所が，字形の複雑さや字数の多い事は決して学習困難の原因でないこと，又，漢字を最も容易に習得する時期は就学前の幼児期にあって，この時期に学習させない事が漢字学習を困難にさせている事を私は発見致しました。

わが国の学校教育では，アルファベットに当るカナ文字を初めに学習させ，その後，漢字の学習に移るのですが，これが大変な間違いなのであります。

試みに，全く文字を知らない二，三歳の幼児に“鳩，鳥，九，く”という四つの文字を教えてみて下さい。最も容易に，最も早く覚える文字は，最も難しいとされている“鳩”です。誰もが最も易しいと思う“く”は，実は最も覚え難く，“鳩”を覚える十倍もの時間を費しても覚えられないのが普通です。

二，三歳の幼児でカナが覚えられる子は極めて稀ですが，“鳩”が覚えられない子はまずいません。それも，驚く程簡単に覚えてしまいます。これは，私が数百園の幼稚園の数十万人の幼児に実験してもらって突き止めた事実です。

そもそも記憶を成立させる第一の要件は，“関心”です。もう一つは“反復”ですが，それは“関心”があっての上の事です。全く，関心の無い事をどんなに反復しても，記憶は出来ません。幼児がカナを覚えないのは，それが幼児には全く魅力が無いからです。

又，“鳩”や“蟻（あり）”などの複雑な字形の漢字を幼児が容易に覚える訳は，それが幼児の関心を惹く内容をもっているからですが，もう一つ，複雑な文字の方が記憶の手掛りが多いので覚え易く，覚えたら忘れ難いのです。

それは人の顔を覚えるのと同じ事です。複雑な顔をした人ほど覚え易いでしょう。然も，そういう顔の人は決して忘れないで，いつどこであっても直に思い出す事が出来ます。それに引き替え，単純な顔ほど覚え難く，覚えても忘れ易いものです。

この事は，欧米におけるアルファベットの学習に就ても言える事です。アルファベットをまず学習させ，それからwordの学習に移っていますが，これは間違いと言わなければなりません。

“m”は覚えられなくても“mammy ”や“mouth ”の覚えられない子はいません。だか

ら，mammyやmouthをまず学習させる事が先決です。mammyやmouthが読めるようになれば自然と“m”を教えれば，今度は容易に覚えられます。

実は，この教育法は“How to teach your baby to read”の著者Glenn Doman博士が，二十年も前から主張しているものです。然し，実践してみれば直に判るこの教育法が，世の常識になじまない為に実験されず，相変らずアルファベットから学習する方法が続けられています。

文字の学習は，カナやアルファベットから始める為に，難しいのであって，漢字やwordから始めれば，零歳児でも覚えられるものです。この事は，私もDoman博士も，二十年も前に実証しています。皆さんに信じて頂けないと思いますが，「文字は，本質的には，言葉よりも覚え易い」ものです。

もし，生後八か月から十か月の，まだ言葉の覚えられない赤ちゃんに，“目，口，鼻，耳，手”などの漢字を，言葉と一緒にその“物”と対照させて教えますと，言葉よりも先に文字を覚えて，物と対照させる事が出来るようになります。

例えば“目”という漢字カードを赤ちゃんに見せますと，赤ちゃんはそれを見て自分の目を指さします。“耳”という漢字カードを見せれば，自分の耳を指さします。

漢字が言葉よりも覚え易い事を証明する事実は他にもあります。言葉の覚えられない重度の精薄児に，零歳児と同じ方法で漢字カードと物とを対照させて教えますと，言葉は覚えられませんが，漢字は覚えてカードと物とを正しく結び付けます。そして，こういう学習を続けていますと，言葉が言えるようになります。

今，この様な実験を，多くの方々に協力して頂いてやっていますが，面白い事に，零歳の赤ちゃんでも漢字カードを観る事を楽しんでいる，と誰もが認めています。機嫌の悪い時，泣いている時でも，漢字カードを見せて読んでやりますと途端に泣き止み，機嫌が良くなる，という事です。ですから，人間は文字を読む事が楽しいように，遺伝子にプログラムされているのではないか，と私は思っています。

さて，私の発見した教育方法と，Doman博士が発見した教育法とは，原理が同じなので，これを“石井・Doman教育法”と呼ぶ事を博士に提案し，お互いにこの教育法の普及に努力する事を約束しました。然し，実験すれば直に判るこの教育法も，世の中の人は仲々実践してくれません。それは，頭で考えた所ではとても信じ難いものがあるからです。

凡そ，未経験の物事に対しては，人は皆，臆病なものです。経験者から見れば何でもな

い事でも，それを経験しない者にとっては，恐ろしい事で，敬遠するのが人情です。原子力の場合でも，未知なるが故に人々は恐れ，敬遠する訳です。

ただ，原子力は人間に不可欠のエネルギーに関わる重要な問題ですから，人々はいやでも関心を持たざるを得ません。ですから，私どもの教育問題よりも，きっと人々の理解が得られる事と思います。そういう日の一日も早からん事をお祈り致しまして，私の拙いお話を終りたいと思います。御清聴を感謝申し上げます。

原産創立３０周年への祝辞

アメリカ原子力産業会議
名誉理事（初代会長）W．シスラー

有澤会長，御出席の皆様，また古い友人の皆様。

私が最初に日本に参りましたのは３０年前でございます。１９５４年にアメリカの原子力産業会議を設立いたしまして，その後１９５６年に日本へやって参ったわけでございます。当時原子力発電所の模型，それはたまたま増殖炉でしたが，イエローケーキと石炭のかけらのはいった私のエネルギーボックスを携え，ヨーロッパから日本へ参りました。ヨーロッパ各国に駐在の大使に原子力の平和目的の利用について話をし，そして日本，韓国，台湾へ参りまして，同じように原子力の平和利用面の話をさせていただきました。

私自身は，エネルギーとそのマネージメントに携わって，すでに６４年になります。

３０年前日本に参った私は，当時の原子力委員長の正力大臣のところに連れていかれ，２時間ばかり原子力の平和利用についての話をさせていただいたわけでございます。正力さんは大手の新聞の発行もされていらっしゃいましたし，またテレビ局も実際に経営されていた方でいらっしゃいます。その折私は，原子力の平和利用について，正力さんとお話をすると同時に，講演会という形で日本の一般の方々にお話をさせていただきました。また日本全国の高校生に見せるため，持っていた原子力発電所の模型を置いて参りました。

アメリカにおきまして，初期の，国を動かしていくということがこれから非常にむずかしくなるという時期に，それにかかわり，続いて武器貸与計画に携わりました。その後陸軍に従事し，北アフリカに駐屯していたアイゼンハワー大将に報告し，彼とともにベルリンまで参りました。

私はコーネル大学を１９２２年に卒業しました。専攻は機械工学です。電力業界に終始携わって参りました。またオークリッジ，ハンフォード，ロスアラモス等の原子力施設の建設を助けて参りました。原子力産業に精通するようになりました。私自身，高速増殖炉（ＦＢＲ）開発を強力に支持・推進しているものであります。そしてデトロイトで，当時としては世界で最大規模のＦＢＲを建設，運転した経験もございます。

私は，原子力産業の将来にとって，プルトニウムの利用というものが決定的に重要であると考えております。私，今回の年次大会でいろいろな講演を傾聴しております。非常に

素晴しい発表が続いていると思います。特にフランスそして日本におけるＦＢＲ開発の現状に対しまして，私の賞賛の念をここで表しておきたいと思います。

こうして東京に参りまして，皆様と本席を共にできることを大変嬉しく思っております。また，この日本原子力産業会議が過去３０年間に原子力産業の大きな発展に対してなされたご努力を，非常に大きく称えたいと思います。また，私の親愛なる友人の一人であります橋本さん，もう一人の親愛なる友人の井上さん，あるいは私の非常な知己である松永さんに対しましても，非常にその業績を称えたい気持でございます。月曜日に松永さんのお墓参りをいたしました。沢山申し上げたいことがあるのですけれども，時間が限られております。

最後にまとめといたしまして，こうしてアメリカ人といたしまして日本へ参り，皆様方がこれまで成し遂げられました成果を，また世界中で原子力平和利用が達成されていることを，目の当りにするということは，非常に良いことであり，喜ばしいことであり，非常に嬉しいことであるということを申し上げたいと思います。このことに心の安らぎを感じます。と申しますのは，２つの世界大戦にかかわったとはいえ，私自身は「平和を愛する者」だからです。どうも御清聴ありがとうございました。

セッション３

原子力開発と国際協力 － ２１世紀への展望

原子力国際協力の意義 － 回顧と展望

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大島　恵一

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呂　得　賢

東京大学名誉教授
大島　恵一

SESSION 3

NUCLEAR ENERGY DEVELOPMENT AND INTERNATIONAL COOPERATION --PROSPECTS FOR THE 21ST CENTURY

Keynote Address:
"Significance of International Cooperation in Atomic Energy
--Retrospect and Prospect"
Keichi Oshima
Professor Emeritus
University of Tokyo

[PANEL DISCUSSION]

Maurizio Zifferero
Deputy Director General
International Atomic Energy Agency

John D. Negroponte
Assistant Secretary for Oceans and International Environmental and Scientific Affairs
U.S. Department of State

Harsono Wirysoumarto
Deputy Chairman for Technology Development
Agency for the Assessment and Application of Technology
Indonesia

Hans Frewer
Representative
European Nuclear Society

De-Xian Lu
President
Beijing Institute of Nuclear Engineering
Ministry of Nuclear Industry
China

Keichi Oshima
Professor Emeritus
University of Tokyo

原産年次大会　’86

原力国際協力の意義－回顧と展望

東京大学名誉教授
大　島　惠　一

わが国が原子力開発に着手してから３０年を迎えた今日、この第１９回原産年次大会の場で異なる立場の国々および国際機関の方々を迎えて２１世紀を展望した原子力国際協力のあるべき姿を論ずることは、現在原子力開発がいろいろな意味で世界的な転期にあることを考えると意義深いことと思う。

原子力平和利用の国際協力の歴史を振り返ってみると、いうまでもなく１９５３年１２月8日、アイゼンハワー米大統領が第8回国連総会で行った″Atoms for Peace″の演説がその契機である。これが１９５５年の第１回原子力平和利用ジュネーブ会議となったわけである。それまで軍事技術として秘密裡におかれていた原子力技術が、人類の繁栄のために公開されて原子力平和利用計画が初まったのである。しかし、この大統領の演説をもたらしたものは、当時、マンハッタン計画に参加した科学者、技術者を中心とする関係者の「原子力」というこの偉大な技術革新を人類の破滅ではなくて、繁栄のために役だたせようという理想を実現するための働きかけがあったのである。核兵器のこれ以上の拡散防止および核保有国の核軍縮と原子力の平和利用とは、盾の両面としてこの計画の基礎をなすものであった。

アイゼンハワー大統領に対する働きかけの中心的な役割を果したラビ教授が、昨年米国科学アカデミーで第１回国連原子力平和利用ジュネーブ会議の３０年を記念して講演を行ったのを聞く機会を得られた。その当時の事実を大変興味深く聞くとともに、最後に、核軍縮が当初の期待に比して決して満足なものではなく、我々はそのための努力を続けなければならないという結びの言葉に多大の感銘を受けた。

わが国は、米国からの呼び掛けを受けて、１９５４年に原子力平和利用計画が発足した。世界で最初の、しかも唯一の原子爆弾の被曝国として、激しい議論が各界で闘わされたが、原爆の惨状と同時にその威力を知るだけに、平和利用に徹してこの技術革新を人類の進歩と繁栄のために利用することの意義が強く認められて参加が決まったのである。

当時、我が国の原子力開発利用の最も基本となる方針を定めた「原子力基本法」第2条の「原子力の研究、開発および利用は、平和の目的に限り、安全の確保を旨として、民主的な運営の下に、自主的にこれを行うものとし、その成果を公開し、進んで国際協力に資するものとする」との内容は、この事実を反映するものである。

１９５６年には、日本原子力産業会議が発足し、次いで、１９５７年にははじめて大きな国際的な会議として東京で日米合同原子力産業会議が開催され、米国からの多数の原子力関係者が来日した。それまで文献等だけで名前を知っていた指導的な人々と初めて親しく接することができて、多大の感銘を受けたことを記憶している。

１９５８年の第2回ジュネーブ会議には、日本も初めて正式な代表団を送り、私もその一員として参加した。その時の議長は、インドのバーバー博士が務め、また、米ソ両大国をはじめ多くの発表が行われた。この会議では、軽水炉、重水炉などの現在すでに実用化されている原子炉技術のみではなく、高速増殖炉や熔融塩炉など、現在まだ実用化されていない未来の原子炉や濃縮、3処理の技術に対する発表もあった。核融合に関しても多くの発表があり、バーバー議長が核融合炉の実用化への期待を述べられたことが大きな話題であった。

原子力エネルギーの実用化が世界人類を飢餓と貧困から開放するものであるという発表がなされ、その期待は、原子力の将来をバラ色の夢で包んでいたといえる。この会議に日本から参加したわれわれが、ここに初めて世界の原子力のcommunityの一員に加わって、原子力の技術の真髄に接することができ、また平和利用の原子力開発の一旦を担うことになったという実感は、誠に感銘深いものであった。

この会議の帰途に私はＭＩＴの原子力工学科に滞在し、講義を聞くことになったが、当時の学科のChairmanのWhitman教授から親しく、1955年の第１回ジュネーブのSecretary Generalとして、その準備をされた時の話を聞く機会に恵まれた。その中で、「この会議の準備に当たって最初に行ったことは、ソ連のモスコーに飛んで、ソ連が平和利用のために原子力技術を公開発表するかどうかを交渉したことであった。ソ連との合意があって初めて原子力平和利用会議の成功が得られたのである」という話を伺った。軍事兵器での競争的立場にあった米ソ両大国の原子力関係者が、原子力技術を人類の繁栄のために開発するという偉大な理想に協力するということは、人類にとって極めて大きな意味をもつものであったと考える。

核不拡散と平和利用の両面において、世界の国々の協力の場として、１９５７年にＩＡＥＡが設立させたことは、この理想にむけての国際的な合意の結果であった。

原子力平和利用は、このように人類の夢と理想を託して出発したわけである。

原子力開発は、その後の１９６０年代の豊富な石油の供給によるエネルギー低廉の時代において、幾多の迂余曲折を経たが、１９７３年の石油危機の石油価格の高騰以降、原子力発電の経済性の優位と産業技術としての技術基盤が確立された。

原子力発電は現在、世界における電力供給の１５％を担い、わが国ではすでに総発電量の２６％を占めるに至っている。

わが国の原子力発電所はここ数年来、高稼動率を維持し、安定した運転を続け、かつ軽水炉技術の一層の高度化を目指して関係者のたゆまない努力が続けられている。３０年前に、我が国が原子力開発計画を発足した当時のことを考えると、国際協力を抜きにして、我が国の今日における原子力発電はありえなかったことが痛感される。

現在、原子力基本計画の検討が行われているが、我が国の原子力発電は、紀元２０００年において総発電量の４０％を占めるものと予測されている。また、我が国は、原子力エネルギー利用の究極的な姿である増殖炉や中間的な段階としてプルトニウム利用と核燃料サイクルの確立に

多大の努力を傾けているところである。

　わが国の経験は、エネルギー資源をもたない国でも、技術力とそれを支える産業基盤をもっていれば、安定的なエネルギー供給を原子力開発によって実現できるということを証明しているいえる。この原子力への期待は、今日も、そして将来も、大きく、不変のものであり、これを発展途上国を含めて世界人類が享受できるものとすべきである。

　特に、今後の人口増加と経済成長を考えると発展途上国の増加するエネルギー需要の充足は、２１世紀に向けての最大の課題となることは、すでに、多くの人々が指摘していることである。２１世紀を見通した、これからの原子力開発の国際協力を考えるにあたって、発展途上国のエネルギー供給源としての原子力の役割を強化しなくてはならない。

　これは、発展途上国のみではなく、全世界の関心である。これに関して、昨年に開催された第3回ＮＰＴReview会議が１９８０年の第2回の不成功とに対比的に成功裡に終わったことは、参加国の核不拡散へのコミットメントの強さと、発展途上国の原子力国際技術協力への期待の強さを現わしているものであり、この期待に応えることは原子力先進国の責任である。

　しかし、３０年をへた今日、果たして” Atoms for Peace″の理想が２１世紀に向けて順調に実現しつつあるのか、との問いかけに対しては、必ずしも全面的に「ＹＥＳ」ということはできない。

　現在の世界での最大の原子力発電設備量をもつアメリカの原子力産業は、パブリック・アクセプタンスや資金の面でここ数年来、発電計画の中止や新規発注の停止で低迷を続けている。また、他の先進国においても発電設備の市場の伸びと国際競争の点で原子力産業の将来の見通しは必ずしも容易な平坦な道であるとは考えられていない。発展途上国においては、多くの国で原子力に対する将来の期待がもたれているにもかかわらず、技術的・資金的な困難や、先進国の核不拡散政策上の制限から原子力発電の将来は、なかなか困難なものがある。

　さらに、最近の原油価格の下落は、将来のエネルギー需給の見通しを極めて予測の困難ものとしており、これは必然的に原子力の将来の発展にも大きな影響をもたらしつつある。

一言でいえば、３０年前の世界各国がいだいていた原子力のバラ色の夢は、現在、原子力発電が現実として、定着しはじめたという意味で、実現しつつあるともいえるが、原子力の将来にはいくつかの大きな灰色の影があるといえます。

このような時に、２１世紀への国際協力展望を考えるにあたっては、現在までの原子力平和利用の輝かしい成果が多くの国際協力によってもたらされてきたことを思い出すことが必要である。原子力ほど国際的な協力が進んでいる分野は他に類をみないといえる。今日の日本原産年次大会にかくも多くの海外の方々が参加され、このような発表やパネル討論が行われていること自体がこれを示している。

我が国の原子力における国際協力の現状を見ても極めて多岐にわたる活発な国際協力が行われている。

その詳細は省略するが、二国間、多国間、あるいは国際機関を通じて多くの協力が進んでいる。その中で特に指摘したいことは、発展途上国との原子力産業協力の進展である。

このような情勢にこたえ、わが国の原子力分野の発展途上国に関する方針については、総合エネルギー調査会原子力部会原子力発電国際協力小委員会において協力のあり方についての考え方が示され、国内での方針、協力体制も整備されてきており、今後発展途上国への協力活動が一層拡大していくことが期待させている。

このように個々の原子力国際協力は我が国のみならず、他の国々においても進められている。

それゆえ、われわれが今日、ここで考えるべきことは、これら世界各国の努力を"Atoms for Peace"の理想にむけて如何に再び結集するかということである。そのためには、先進国、発展途上国、それに国際機関がそれぞれの果たすべき将来の役割を十分に認識し、国際協力の目的を再確認することが必要である。

まず、重要なことは、３０年後の今日では、当時とは世界の情勢は大きな変化をみせていることである。世界の原子力のコミュニティは、技術的な活動においても、経済的な広がりにおいても、いまや当時の米ソ両大国のみを中心とするものではなく、世界の多くの国々がそれぞれの

重要な役割を果たしている。今後の国際協力の新たな推進は、これらの各国の集団的な合意と積極的な責任とリーダーシップのもとで行われなくてならない。

この新たな国際協力の構築に際しての具体的な課題として４つの点を指摘したい。

第１は、発展途上国の原子力発電計画への協力である。今日、多くの発展途上国が、平和利用目的の原子力開発に強い関心を示しているが、先進国に比較して原子力発電の定着化にはまだ多くの年月を必要とするといわざるをえない。しかし、原子力開発に積極的に取り組む意欲を持っている開発途上国に対し、先進国がその経験と技術をもって開発に協力していくことは重要は責務であると考える。

発展途上国が原子力発電を導入していくためには、確固たる経済、社会基盤の確立、すなわち、インフラストラクチャーの整備が必要である。

基本的には、原子力協力もより幅広い経済協力、産業協力の一環として位置づけられるものであり、先進国のこの面に対する総合的な援助体制の検討が望まれる。また、この際、原子力平和利用の基盤である運転保守を含む、安全性の確保の体系や核不拡散の担保に対する制度の確立が求められる。そのためには、単に一国だけではなくリージョナルな協力体制の整備も必要となる。

第２は、国際協力を進めていく上での先進国、発展途上国の十分な相互理解と協力である。これからの原子力開発を着実に進めていくためには、先進国、発展途上国のそれぞれの果たすべき分担と役割がある。当然のことながら、先進国と発展途上国とは原子力開発の段階が違うので、開発テーマによって、先進国間の協力が先行する必要性の大きいものがある。たとえば、新型炉として期待される高速増殖炉や将来の可能性としての核融合などは、その開発にあたって必要な資金、人材等の面で、先進国間の協力が必要である。しかし、その協力の成果は、全人類の将来を開くためのものであって発展途上国へも提供されるべきものである。これらの計画に何らかの形で発展途上国が参加する道を開くことが重要である。２１世紀へ向けての国際協力にあっては、こうした考え方と、これを実施するにあたっての先進国と発展途上国の相互理解が成功の鍵

となる。

第３点として、燃料サイクルの開発について触れたに。燃料サイクルの主要技術、とくに濃縮、再処理は、核保有国を中心とした先進各国でその開発が進められてきている。しかし、現在核原子力が核燃料としてウラン資源を完全に利用しうる究極的な形は核燃料サイクルの完結によるプルトニウムの利用によってである。わが国は、現在核燃料サイクルに積極的に取り組んでおり、平和利用を目的とした原子力開発における燃料サイクルの経済性の確立を目指している。

原子力基本法にうたわれている原子力平和利用に徹して、海外諸国がその成否を注視するなかで、この課題に挑戦しているのである。その意味で我が国は、燃料サイクルの確立は極めて高い重要性をもつものであると考えている。

２１世紀への国際協力において、核燃料サイクルの問題は、核不拡散上からの最も重要な課題である。この問題の合理的な解決のために、われわれは積極的な努力をする必要がある。

また、２１世紀を見通した原子力国際協力が円滑に進められるために、ＩＡＥＡの一層の積極的な活動とその果たすべき役割に期待したい。当然のことながら、核不拡散への努力は、その重要な役割であるが、同時に推進すべきことは、発展途上国のための技術開発である。たとえば、近年、話題となっている発展途上国のニーズに見合った中小型炉の開発等については、技術を保有する先進国との協力のもとにＩＡＥＡの場を通じて、その詳細な評価を行い、その実現に向けて努力することが期待される。

最後に、結論としていえば、３０年前の"Atoms for Peace"の計画は、今日の原子力エネルギーの実用化と、産業技術としての確立をもたらした。２１世紀のエネルギーとして原子力は現実のものとして大きな期待がもたれている。しかし、他方、その実現のためには、核不拡散レジームの確立、パブリック・アクセプタンスの向上、拡大しつつある先進国ー発展途上国間の格差の縮小、さらには運転保守の向上と安全性の確保など、多くの国際的なかかわりをもつ問題の解決が必要である。

いまや、新たな視点にたって、２１世紀への今後の協力のあり方をわれわれ一人一人が積極的に取り上げ、新たな国際協力の体制をつくる時である。人類の生んだ原子力という偉大な技術革新が世界の飢餓と貧困を解決するという大きな夢と理想の実現にむけてたゆまざる努力を続けることが、２１世紀への国際協力の姿である。

JAIF Annual Conference, Tokyo, 8-9 April 1986
Session 3, Panel on:

Nuclear Energy Development and International Cooperation - Prospects for the 21st Century

(Contribution by M. Zifferero, IAEA)

In 1984 we saw a record year with 34 new nuclear power plants starting operation around the world. 1985 was almost equally good with 32 plants bringing the total world nuclear capacity to 250 GW(e) and 1986 should bring about the same. This is, however, the result of orders placed in the mid and late 1970s and the fewer orders since then will mean a slower rate of increase in nuclear capacity in the beginning of the 1990s. Still nuclear plants are now generating 14-15% of the world's electric energy and we can with some degree of confidence say that this figure will increase to about 20% around 2000 when the total nuclear capacity will have doubled and reached 500 GW(e).

This is certainly a lower capacity than we would have projected 8 years ago at the time of the second oil price shock. It is, however, probably realistic and properly reflects the economic problems which we have been experiencing in both industrialized and developing countries. It is regrettable that the forecast is also that the major increase over the next 15 years still will be in the industrialized countries and that only some 50 GW(e) or 10% are likely to be in the developing world and in only some 20 countries out of more than 100.

Even to reach this fairly moderate projection some conditions will have to be met:

Firstly, the economic competitiveness of nuclear power will have to remain at least as good as it is now;

Secondly, we have to maintain the excellent safety record and make sure that public perception of it improves;

Thirdly, we have to provide assurance that the technical solutions to the waste problems, of which we are certain, really are demonstrably operable;

Fourthly, we have to provide continual assurance that nuclear power will not contribute to any spread of nuclear weapons.

As far as nuclear power plants are concerned this will, in the short term, mean a concentration on the presently proven light and heavy water reactor types, in particular on standardization of design, but also on contracting forms and project management to ensure that construction times are kept short. Japan has given the rest of the world an excellent example in this respect with the remarkably short construction times which are being achieved here. But it will also be of primary importance to continue to improve the performance of the operating plants.

The developing countries, of course, badly need much higher levels of energy supply. Nuclear is undoubtedly a difficult and complex technology for transfer into a developing society but we can learn some lessons from the successful nuclear power programmes in, for instance, Argentina, India and the Republic of Korea. The key undoubtedly is in the early recognition of the infrastructural requirements of nuclear power especially as regards the availability of qualified manpower at all levels, from project managers to code welders. The IAEA has set up a systematic programme to help to assess infrastructures (electric grid, manpower, industrial support) and to formulate development programmes for them. The manpower training courses have made a significant impact. Some 2000 trainees have participated in our interregional courses and we are now moving towards setting up national training in some 10 countries as part of nuclear infrastructure development programmes. We have been happy to see that this systematic and realistic approach is now meeting wide recognition in developing countries.

The availability of power plants in the small and medium power range for developing countries has always been of concern to the Agency. We have shown in a study published in 1985 that a major change has occurred in this situation as smaller power plants now would be available for export, several of them of proven types. Now it seems to be the developing countries which hesitate because of both a feeling that the economics of these plants still must be demonstrated and also because they recognize that the infrastructure requirements are essentially the same for a small or a big plant.

In the longer term i.e. for the late 1990s or early 2000s, there is a possibility that a new generation of small-medium size plants of safer and highly standardized design will emerge and be available for export.

In both cases I foresee a continuing role for the Agency as a go-between between suppliers and customer countries. It will be a continuing role as these plants always will address those countries which often are least prepared for the demanding nuclear technology.

In order to help better define the roles of the Agency in promotion of nuclear power in developing countries, including the relationship with financing questions, the Agency will call a senior expert group to discuss the matter and give advice on the Agency's role. We have hopes that this will be of great assistance in planning our future work.

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Early forecasts by energy planners were rather optimistic on the rapid growth of nuclear power, an increasing share of which was to be provided by fast breeder reactors (FBR). Yet as mentioned before the growth of nuclear power has not been as rapid as predicted in the 1970's. The large-scale deployment of FBRs has been delayed as a consequence and is expected to take place after the turn of the century perhaps 2010 to 2030 depending upon the country. Two recent events highlight the technical maturity and future role of these reactors: the large,commercial size, (1200 MWe) Superphenix I was connected to the French utility grid during January of this year and FBTR, the first LMFBR produced by a developing country, reached criticality in Kalpakkam, India last October.

Cost reduction is presently the most important objective and the main challenge for the FBR designer. Simplification of system components and structures, reduction in the quantity of piping, increased compactness of overall plant layout, and a more realistic and pragmatic approach to safety criteria will result in significant cost reductions. As an example, although Superphenix I costs more than twice as much as a standardized 1300 MWe French PWR, Superphenix 2 will achieve a 20-30% reduction in material masses while increasing output by 20%.

There is also a general trend towards an improvement in fuel cycle economics through a higher utilization of fuel. With reprocessing and recycling as indispensable components of a fast reactor system, increases in the target burnup of the fuel by almost a factor of two, from 100,000 to 200,000 MWD/T would also contribute significantly to decrease FBRs' generating costs.

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Improvements of present generation thermal reactors are currently being assessed in a number of countries. These relate to improved fuel utilization, especially for those reactors operating on a once-through fuel cycle, and making the reactors simpler, cheaper and easier to operate and maintain. Toward this latter end, simplification and standardization combined with a high degree of shop fabrication is being proposed. Various technical modifications are under consideration to increase uranium utilization. These include higher discharge burnup of the fuel, spatially varying enrichment, shifting the spectrum of the neutrons through moderation and making use of tight lattice concepts. In addition, for heavy water reactors, reduced power density and use of alternative fuel cycles are being investigated. While there is intrinsic merit in all these concepts, it is too early to settle on the ideal one until more development work is completed in the near future.

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For more than twenty-five years the high temperature gas reactor (HTGR) development programmes have been conducted in a number of Member States. In all countries the heat market is the primary long-range motivation for HTR programmes. Besides an economic generation of electricity, this technology can provide, with high safety margins and in environmentally acceptable conditions, a number of industrial applications. A primary consideration is the conservation, by substitution, of expensive energy raw materials, especially crude oil and natural gas. These heat applications include iron ore reduction, coal conversion technology, process engineering in the chemical industry, and, in the longer-term, hydrogen production. Another application, but for smaller reactors, lies in the centralized supply of district heating. The HTGR technology also makes possible combined sources of electrical power and process heat.

International cooperation has become an essential and useful means of reducing national funding for the development of these advanced reactor systems. Considerable savings can be effected by the pooling of knowledge, sharing of tasks, and utilization of infrastructural facilities. Such international cooperation is strongly evident in the fast breeder programmes in Western Europe and also amongst the CMEA countries. In other advanced nuclear technologies, cooperation is pursued, but to lesser degrees than with the FBR.

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It is a fact that the safe handling of spent fuel and the management of nuclear waste are the responsibility of national governments but it is also true that this area would benefit from increased international cooperation. The main objective of the International Atomic Energy Agency in the field of radioactive waste management is to assist its Member States in achieving safe and effective management of radioactive waste so as to provide adequate protection for man and his environment. This objective is achieved by exchange of the most up-to-date information on technical, scientific and regulatory aspects; the development of internationally acceptable guidelines, standards and recommendations; the development and exercising of responsibilities under international and regional conventions; the encouragement and sponsoring of research work; and the provision of training and technical assistance to Member States upon request.

The Agency's mechanisms for fulfilling these tasks are by means of organizing conferences, symposia, seminars, technical committee and advisory group meetings; by inviting recognized experts as consultants; by sponsoring and coordinating research programmes; by arranging training courses, study tours etc. The Agency awards fellowships, sponsors scientific visits and provides expert missions and field experts to assist Member States in implementing their national waste management programmes.

The IAEA waste management activity includes the areas of handling, treatment, conditioning, storage and disposal in land and at sea of various radioactive wastes, the assessment of environmental consequences of radionuclide releases as well as the decontamination and decommissioning of nuclear facilities.

Due to the increasing interests of Member States in safe and effective management of nuclear waste, the IAEA has enhanced its effort particularly in two areas: disseminating current technical information and assisting the developing countries in the planning and implementation of their national waste management programmes.

The demands for new and comprehensive technological information and inputs from developing countries have been substantially increased in the recent past. In endeavouring to satisfy these needs, however, the IAEA maintains a proper balance between the activities related to the interests of both developed and developing countries, although nearly 80% of our 112 Member States belong to the latter category.

As an illustration of the enhanced IAEA efforts in the exchange of information on waste management, more than half of the total (about 150) publications issued since 1960 were published within the last five years, therefore, they can be considered as rather up-to-date information.

The demands for technical assistance, in the waste management field, have been increasingly steadily. At the present time, 17 Technical Co-operation projects are in progress in the regions of Asia, Latin America and Africa. As a part of these projects the Agency provides field experts, fellowships, scientific visits, equipment and supplies. In the near future it is proposed to give the Technical Assistance activity in the waste management programme of the IAEA a higher priority and an integrated Waste Management Advisory Programme (WAMAP) is being planned to extend the scope of IAEA services for developing countries.

An important form of the IAEA programme is through the encouragement and support of research in the waste management area by conducting Co-ordinated Research Programmes (CRPs), or by sponsoring the research of individual scientific groups. During the last 10 years 10 co-ordinated research programmes have been successfully completed and their results published. In addition, five CRPs are in progress and two are in preparation. There has been broad participation by both developed and developing Member States.

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In the past few years the Agency's nuclear safety programme, following the worldwide trend, has gone through a twofold shift of emphasis firstly from siting and construction to operation of nuclear power plants and secondly from preparation of recommendation and standards to implementation of standards and discussion of important outstanding safety issues.

The emphasis on operational safety has been achieved through initiation of two relatively new activities of IAEA, Operational Safety Review Teams (OSART) and IAEA Incident Reporting System (IAEA-IRS).

The Agency's nuclear safety standards (NUSS) programme has resulted in development of 5 codes of practice and 55 safety guides. These documents represent a standard frame of reference for analysing nuclear power plant safety. In the next several years the Agency will continue assisting the Member States in the implementation of the NUSS programme documents and will collect feedback from the users of the documents.

To consider the outstanding important safety issues the Agency has recently established the International Nuclear Safety Advisory Group(INSAG) whose purpose is to exchange information and give advice on the issues to the Agency.

For the near future the Agency will endeavour to strengthen IAEA-IRS system to collect and disseminate information on incidents on the international level encompassing OECD, CMEA and developing countries. The objective here is to broaden the exchange of information to safety operating experience of all types.

In the long-term the Agency will continue to assist the Member States in the operational safety area through OSART missions. The comprehensive revision of the NUSS programme documents based on the feedback from the users, the development of new methodologies and practices in Member States which could result from the resolution of safety issues currently under discussion will be performed in due course. This revision could take into account the need for including other nuclear facilities, as appropriate into the scope of the programme.

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The road to commercial fusion power is a long and difficult one. The most optimistic estimates are that the journey will take us another 40 years or so. Progress in fusion research has nevertheless been steady and continuous. The development of this technology, however, has been one of the most demanding tasks undertaken by mankind, and its realization will not come overnight.

Where does fusion research stand today? When speaking of fusion at the international level one identifies 4 major groups or blocs. These are Japan, the European Economic Community, the USA and the USSR. These blocs account for virtually all the fusion research performed in the world; very little is performed elsewhere. The development of fusion science and technology to its present level has been characterized by a series of experiments each increasing in size beyond its predecessor. Of the various approaches to fusion, the most developed concept is the so-called tokamak, a toroidally shaped and magnetically confined plasma. The latest in this series of tokamak experiments are designed to reach the first major milestone in fusion - the demonstration of the scientific feasibility of fusion power. Three of the 4 blocs have already commissioned their machines, and the USSR plans to commission its own T15 in 1987. Scientific feasibility, that is the production of an amount of fusion power equal to the amount required to start and maintain the plasma, is expected to be demonstrated within the decade.

The next goal of fusion research is the demonstration of the Engineering feasibility of fusion, a formidable task. Present plans for the funding and construction of an experiment to accomplish this appear at present to be nebulous. None of the blocs have, to my knowledge, committed to such a step.

Since the declassification of magnetic fusion research in 1956 there has been international cooperation in this field. The level of cooperation has however been low, ranging from the exchange of personnel to the exchange of technology in specific areas such as neutron beam injection and radio-frequency heating systems. The one exception to this rule is the joint American-Japanese experiment known as Doublet III.

Fusion is, however, a subject very well suited to international cooperation on a much larger scale. The costs of future experiments are likely to be in the multi-billion dollar range. Commercial application of the technology is still in the future. The sharing of costs and the pooling of intellectual resources appears, therefore at least from the non-political point of view, an eminently reasonable thing to do.

In comparison to the worldwide fusion effort the role of the IAEA is small. It is nevertheless important. A fine example of what the Agency can do to foster international collaboration is the INTOR Workshop. INTOR was established in 1979, and as originally envisioned, called for the design and construction of a next generation experiment beyond those currently in operation. This work was to be performed by the 4 fusion blocs as partners. To date INTOR has resulted in a conceptual design for this machine and an examination and definition of the critical,physical and technological issues facing its construction. What is most important is that these results represent the consensus of the world's fusion community. Although the Workshop convenes in Vienna 2 or 3 times a year only, the work done in home laboratories in support of INTOR amounted to hundreds of man years of effort. The Agency's contribution to the project has been in providing the administrative support and structure under which it operated. Beyond this, INTOR functioned autonomously, with no technical input or direction from the Agency.

As we are all aware, an initiative to greatly expand international collaboration in fusion is presently under discussion at the political level in the 4 fusion blocs. There is in fact a possibility that a joint experiment, perhaps even as large as INTOR, will be constructed on an international basis.

It is difficult to identify the role that the IAEA would play in the eventuality that an international machine will be built, since this is entirely dependent on the Governments involved. It seems obvious that the management of a project of this size is outside the scope of the Agency's abilities and would require an "ad hoc" structure. On the other hand, administrative arrangements could be conceived in the Agency,under which even a project of this size could operate with the required level of autonomy.

If requested, the Agency is prepared to sponsor the activity that will permit the partners to define these arrangements.

In the near term, the Agency will continue to sponsor the INTOR Workshop until the end of its present phase, in December 1987. This important activity will focus on laying the groundwork for the proposed future activity.

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Concern for the environment and for the harmful effects of radiation are normally the main factors giving rise to antinuclear feelings in the general public. The passage of time and the improved education of the public will undoubtedly increase the present level of confidence in nuclear energy and help in removing what are largely emotional issues.

The possibility of a link between peaceful nuclear energy technology and the proliferation of nuclear weapons is, however, a steady source of concern to most Governments as well as to the educated sector of the public. This explains why international cooperation in nuclear technology and trade has been linked with safeguards from the beginning.

The Treaty on the Non-Proliferation of Nuclear Weapons, which entered into force in March 1970, and its counterpart for Latin America, the Tlatelolco Treaty, remain by far the most important and significant steps taken by States to prevent proliferation. Among other provisions, these treaties require non-nuclear-weapon States party to it to conclude Safeguards agreements with the Agency covering all nuclear materials in all their peaceful nuclear activities for the exclusive purpose of verifying that such material is not diverted to the production of nuclear weapons or other nuclear explosive devices.

At the end of 1985, 131 States were party to these treaties, including three nuclear weapon States.

Over the years the IAEA has developed and applied, in connection with the NPT requirements, a complex safeguards system based primarily on nuclear material accountancy, and which involves such important complementary measures as periodic visits to the installations concerned and continuing camera surveillance where required to ensure that the material involved is where it is supposed to be.

The establishment of the Agency's safeguards system has not been, and is still not, without problems, but looking at the future, there are many gratifying aspects in our experience on safeguards.

The acceptance of safeguards through either the NPT or the Tlatelolco Treaty, or other bilateral agreements, is now general, although full-scope safeguards -- covering all material in all installations -- are still unacceptable to some States. Almost 900 nuclear facilities, including research and power reactors, fuel fabrication and reprocessing plants, and fuel element storage facilities representing 98% of all nuclear installations in non-nuclear-weapon States are now under safeguards. Throughout its existence the system has been able to verify with a high level of confidence that no diversion has occurred of the safeguarded material. The system has also proven to be acceptable to plant operators and able to cope with the requirements of new technologies. The potential for improvement nevertheless remains high, both at the technical level and in respect of cost-effectiveness.

As to the future, taking into account the slower pace of nuclear development in recent years, one can expect a period of consolidation of the system in the period immediately ahead of us. It can safely be assumed that, although the NPT is due to expire in 1995, this is not going to affect the existence and continuation of the safeguards system.

The goal of effective and credible full-scope safeguards, in order to bring within the system all nuclear activities in all non-nuclear-weapon States, will continue to be pursued at the political level. At the same time, efforts will continue to increase cost-effectiveness in order to keep safeguards costs a marginal component of power production costs, which can be largely justified by the benefits realized in nuclear trade and assurance of supply. It is also expected that more and more peaceful nuclear installations in nuclear-weapon States will be put under Agency safeguards, not only as an equity measure, but to provide a significant world precedent in an universally-accepted international verification system. Continuing rapid developments in satellite-based communication, computer science, information handling and automation are likely to have a large impact on the timeliness, accuracy and cost-effectiveness of the system.

NUCLEAR ENERGY DEVELOPMENT AND INTERNATIONAL COOPERATION

REMARKS BY
AMBASSADOR JOHN D. NEGROPONTE
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FOR OCEANS AND INTERNATIONAL ENVIRONMENTAL
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BEFORE THE
JAPAN ATOMIC INDUSTRIAL FORUM
19TH ANNUAL CONFERENCE
TOKYO
APRIL 9, 1986

MR. CHAIRMAN, LADIES AND GENTLEMEN:

I AM PLEASED AND HONORED TO JOIN THE DISTINGUISHED MEMBERS OF THIS PANEL FOR A DISCUSSION OF THE TOPIC, "NUCLEAR ENERGY DEVELOPMENT AND INTERNATIONAL COOPERATION--PROSPECTS FOR THE TWENTY-FIRST CENTURY." I WOULD LIKE TO EXPRESS MY APPRECIATION TO THE JAPAN ATOMIC INDUSTRIAL FORUM, AND IN PARTICULAR TO THE ORGANIZERS OF THIS NINETEENTH ANNUAL CONFERENCE, FOR THEIR KIND INVITATION TO TAKE PART IN THE PROCEEDINGS. I WOULD ALSO LIKE TO OFFER MY CONGRATULATIONS TO THE FORUM AND ITS MEMBERS ON THIS, THE THIRTIETH ANNIVERSARY OF THE FORUM'S ESTABLISHMENT.

IT SEEMS TO ME THAT THE VISION OF PROGRESS AND COOPERATION IN THE PEACEFUL USES OF NUCLEAR ENERGY REMAINS EVERY BIT AS COMPELLING TODAY AS IT DID IN PRESIDENT EISENHOWER'S TIME THIRTY YEARS AGO. NEVERTHELESS, IT HAS BECOME INCREASINGLY IMPORTANT, BECAUSE OF THE COST AND COMPLEXITY OF NUCLEAR PROGRAMS, TO ASSURE OUR ALLIES AND FRIENDS THAT WE RECOGNIZE FULLY THEIR NEEDS FOR RELIABLE AND PREDICTABLE COOPERATION.

WHEN HE TOOK OFFICE, PRESIDENT REAGAN SET FORTH AS AN OVERALL GOAL THE RE-ESTABLISHMENT OF THE UNITED STATES AS A PREDICTABLE AND RELIABLE PARTNER FOR PEACEFUL NUCLEAR COOPERATION UNDER A REGIME OF ADEQUATE SAFEGUARDS AND CONTROLS. TO HELP ACHIEVE THIS GOAL, HE SPECIFICALLY DIRECTED THAT THE ADMINISTRATION WOULD:

- Undertake immediate efforts to insure expeditious action on export requests and approval requests under U.S. agreements for peaceful nuclear cooperation where the necessary statutory requirements were met;

- Not inhibit or set back civil reprocessing and breeder reactor development abroad in nations with advanced nuclear power programs where these activities do not constitute a proliferation risk; and

- Support IAEA programs and other international cooperative efforts toward ensuring nuclear safety and environmentally sound nuclear waste management.

I believe that in implementing the policy goals set forth by President Reagan, the United States has become much more sensitive over the past five years to the overriding concern of our nuclear trading partners that our cooperation be firmly established on a predictable basis. We have implemented, for example, a more efficient export licensing process, and we have made provision for multiple reloads of reactors, and general licenses. As many of you know, we have discussed with Japan and EURATOM, in the context of new or amended agreements for peaceful nuclear

COOPERATION, THE POSSIBILITY OF ADVANCE, LONG-TERM CONSENT FOR THE REPROCESSING OF U.S.-ORIGIN NUCLEAR MATERIAL AND USE OF THE DERIVED PLUTONIUM. WE IN THE UNITED STATES ARE VERY PLEASED WITH THE PROGRESS THAT HAS BEEN MADE IN OUR DISCUSSIONS WITH JAPAN, AND WE LOOK FORWARD TO ARRIVING AT MUTUALLY ACCEPTABLE ARRANGEMENTS AT AN EARLY DATE. WE EXPECT THAT SUCH ARRANGEMENTS WILL PUT OUR PEACEFUL NUCLEAR COOPERATION WITH JAPAN ON A STABLE FOOTING FOR MANY YEARS TO COME.

THE UNITED STATES IS COMMITTED TO FACILITATING THE FULLEST POSSIBLE EXCHANGE OF EQUIPMENT, MATERIALS, AND SCIENTIFIC AND TECHNOLOGICAL INFORMATION FOR THE PEACEFUL USES OF NUCLEAR ENERGY, NOT JUST AMONG COUNTRIES WHOSE NUCLEAR PROGRAMS ARE ALREADY WELL ESTABLISHED, BUT ALSO FOR THE BENEFIT OF COUNTRIES JUST EMBARKING ON PEACEFUL NUCLEAR PROGRAMS OR PURSUING PROGRAMS IN AN EARLIER STAGE OF DEVELOPMENT. WE HAVE NOT IGNORED THE LEGITIMATE NEEDS OF COUNTRIES THAT WISH TO SHARE IN THE PEACEFUL BENEFITS OF THE ATOM. WE WILL CONTINUE TO ENSURE, BOTH BILATERALLY AND THROUGH THE IAEA, THAT SUCH BENEFITS ARE MADE AVAILABLE ON A RELIABLE BASIS TO ALL COUNTRIES THAT ARE FIRMLY COMMITTED TO THE INTERNATIONAL NON-PROLIFERATION REGIME.

THROUGH THE IAEA, THE U.S. HAS ADVISED GOVERNMENTS ON THEIR PEACEFUL NUCLEAR PROGRAMS AND ALSO ASSISTED IN THE

DEVELOPMENT OF PROGRAMS FOR PHYSICAL PROTECTION AND SAFEGUARDING OF NUCLEAR MATERIALS.

It should be noted that, while the U.S. does endorse and support the IAEA's technical assistance program to all members (contributing over 25 percent of the total technical assistance budget), a preference in the use of the U.S.'s discretionary funds for extra-budgetary projects is shown to NPT parties.

U.S.-PRC Nuclear Cooperation Agreement

Let me turn now to some specific cooperative efforts.

On December 30, 1985, the U.S. and the People's Republic of China brought into force a nuclear cooperation agreement establishing a legal framework for cooperation in a variety of peaceful applications of nuclear energy. It provides the basis for the export of nuclear reactors, fuel components, and exchanges of technology including cooperation in health, safety and the environmental implications of the peaceful uses of nuclear energy. It lays the groundwork for strengthening economic ties between the U.S. and China and creates new opportunities for U.S. companies to assist China in the expansion of its energy sector. Such peaceful nuclear cooperation will provide an opportunity for both countries to work together

TO PREVENT THE SPREAD OF NUCLEAR EXPLOSIVES. I WOULD SUGGEST THAT CHINA OCCUPIES AN ENVIABLE POSITION TODAY, BECAUSE IT CAN, IF IT CHOOSES, BE THE FIRST NATION TO ENTER THE TWENTY-FIRST CENTURY WITH A SUBSTANTIAL CIVIL NUCLEAR PROGRAM BASED PREDOMINANTLY ON "TWENTY-FIRST CENTURY" TECHNOLOGIES, INCLUDING THE LATEST MODEL LIGHT WATER REACTORS.

FAST BREEDER REACTORS

IN THINKING OF "TWENTY-FIRST CENTURY" NUCLEAR POWER TECHNOLOGIES, ANOTHER TYPE OF REACTOR THAT COMES IMMEDIATELY TO MIND IS THE FAST BREEDER REACTOR. IN THE CASE OF FBR'S, AS IN MANY GOVERNMENT-SUPPORTED DEVELOPMENTAL EFFORTS REQUIRING LARGE INVESTMENTS, INTERNATIONAL COOPERATION CAN PROMOTE EFFICIENCY AND ECONOMY BY SHARING COSTS AND SCIENTIFIC TALENT.

U.S. FBR DEVELOPMENT EFFORTS HAVE BENEFITED FROM NEARLY 20 YEARS OF COOPERATION WITH OUR INDUSRTRIAL ALLIES IN AREAS COVERING VIRTUALLY ALL TECHNOLOGIES OF THE FAST BREEDER REACTOR AND ITS ASSOCIATED FUEL CYCLE.

THE UNITED STATES IS CONTINUING A STRONG TECHNOLOGY DEVELOPMENT PROGRAM AND IN THOSE IMPORTANT AREAS DEALING WITH LARGE PLANT DESIGN, CONSTRUCTION, AND OPERATION, WE ARE SEEKING NEW COLLABORATIVE INITIATIVES. LAST YEAR WE

SENT A SENIOR LEVEL GROUP OF GOVERNMENT AND INDUSTRY PERSONS TO EUROPE AND JAPAN TO EXPLORE OPTIONS AVAILABLE FOR SUCH EXPANDED COLLABORATION. THE WORK OF THIS GROUP CONTINUES.

MORE RECENTLY THE U.S. REACTOR DEVELOPMENT PROGRAM HAS BEEN SIGNIFICANTLY REDIRECTED. WHILE PROGRAMS INVOLVING LARGE PLANT CONCEPTS HAVE BEEN DEEMPHASIZED, OUR LIQUID METAL REACTOR (LMR) PROGRAM CONTINUES. WE ARE, AND HOPE TO REMAIN, IN THE FOREFRONT OF DEVELOPING THE MODULAR, ECONOMICALLY COMPETITIVE, INHERENTLY SAFE LMR REACTOR (CONVERTER OR BREEDER) CONCEPT.

WE FIND THAT SOME OF OUR MOST IMPORTANT COOPERATIVE ARRANGEMENTS HAVE BEEN WITH JAPAN. WE HAVE EVERY INTENTION OF CONTINUING TO BUILD ON THESE, IN PARTICULAR WITH INDUSTRIAL LEVEL COLLABORATION.

INTERNATIONAL COOPERATION AND COLLABORATION HAS BEEN AN IMPORTANT ADJUNCT TO THE U.S. BREEDER PROGRAM FOR MANY YEARS. WE ARE MAKING A CONSCIOUS EFFORT TO EXPAND SUCH ENDEAVORS EVEN IN TODAY'S ENVIRONMENT OF FEDERAL BUDGET DEFICIT REDUCTION, AND WE BELIEVE THAT THESE ENDEAVORS WILL BE INCREASINGLY WELL-RECEIVED OVERSEAS, NOW THAT THE PACE OF INTERNATIONAL BREEDER COMMERCIALIZATION HAS LEVELLED OFF.

Magnetic Fusion Energy

Let me turn now to magnetic fusion energy, another "Twenty-first Century" technology. The magnetic fusion energy program worldwide has made significant advances toward the goal of making energy available through the peaceful civil use of the fusion process. International cooperation and collaboration, based on strong domestic programs, has been an important factor in continuing this progress based on the need to pool both technical and financial resources.

What began more than twenty-five years ago in the form of scientific exchanges has now evolved into a network of bilateral and multilateral cooperative agreements between the U.S., the EC and Japan as well as with the IAEA. There is also a long-standing, successful, scientific exchange with the Soviet Union.

International fusion cooperation first appeared as a summit-level topic at the 1982 Versailles Economic Summit. At that time the Technology, Growth and Employment Working Group chartered eighteen specialized working groups including one on controlled thermonuclear fusion. The Fusion Working Group (FWG) has developed a practical framework for international collaboration among the Western Summit Nations in fusion research.

A joint planning effort involving fusion experts from the Summit participants provides a basis for consensus-building on requirements for major new fusion facilties.

In addition, in October 1985, General-Secretary Gorbachev discussed fusion collaboration with President Mitterrand in Paris and later that month Soviet Foreign Minister Shevardnadze discussed it with Secretary of State Shultz in New York. In November 1985, it was addressed at the Geneva Summit and the following joint Statement was issued,

> "The two leaders emphasized the potential importance of the work aimed at utilizing controlled thermonuclear fusion for peaceful purposes and, in this connection, advocated the widest practicable development of international cooperation in obtaining this source of energy, which is essentially inexhaustible, for the benefit of all mankind."

Follow-up meetings with both the Soviets and our western fusion partners are planned to pursue the best ways to enhance international fusion collaboration.

Nuclear Energy Agency

At this point I would like to say a few words about the Nuclear Energy Agency (NEA) of the OECD. We in the

U.S. ATTACH GREAT IMPORTANCE TO ITS WORK IN SETTING A COMMON TECHNICAL POLICY FRAMEWORK FOR OUR COUNTRIES IN NUCLEAR POWER. THE US CHAIRS THE STEERING COMMITTEE AND CONTINUES TO STRESS THE SIGNIFICANCE OF THE PROGRAMS BY SENDING HIGH LEVEL REPRESENTATIVES TO TECHNICAL COMMITTEES AND WORKSHOPS. JAPANESE PARTICIPATION HAS ALSO BEEN EXTREMELY IMPORTANT TO THE ACHIEVEMENT OF THE AGENCY'S OBJECTIVES.

THE AGENCY HAS RECENTLY PUBLISHED HIGHLY INFORMATIVE AND TECHNICALLY SOUND STATEMENTS ON PUBLIC ACCEPTANCE OF NUCLEAR POWER, THE MANAGEMENT OF RADIOACTIVE WASTE, THE ECONOMICS OF THE NUCLEAR FUEL CYCLE, AND THE SAFE DISPOSAL OF LOW-LEVEL RADIOACTIVE WASTE INTO THE OCEAN. IT WILL SOON ISSUE STUDIES ON REACTOR DECOMMISSIONING AND ON THE COMPARATIVE ECONOMICS OF COAL AND NUCLEAR PATHS TO ELECTRICITY GENERATION.

WITHIN THE MONTH, THE AGENCY'S STEERING COMMITTEE WILL CONSIDER A NEW THREE YEAR PROGRAM OF COOPERATION GROWING OUT OF LAST NOVEMBER'S HIGH LEVEL WORKSHOP ON NUCLEAR ENERGY PROSPECTS TO THE YEAR 2000. WE HOPE THAT THIS PROGRAM WILL CONTINUE ITS TECHNICAL POLICY FOCUS ON SUCH TOPICS AS: NUCLEAR REACTOR SAFETY; COMMON FACTORS IN "GOOD PERFORMANCE" OF NUCLEAR PROJECTS; THE IMPACT OF NEW TECHNOLOGIES ON FUTURE RESOURCE NEEDS AND INDUSTRIAL INFRASTRUCTURE; AND THE ENERGY SECURITY IMPLICATIONS OF A SLOWDOWN IN NUCLEAR PROGRAMS IN THE WEST.

Throughout last November's Workshop it was widely recognized that public acceptance is a critical constraint to nuclear development in a number of countries. The NEA will use every reasonable opportunity to report on its work in a manner that communicates clearly the technical consensus on important issues. In this way we hope it can serve as an objective and internationally-respected source for guidance on our nuclear future.

Small and Medium Power Reactor Project

Another recent example of international cooperation in nuclear energy which has been extremely successful is the IAEA's Small and Medium Power Reactor Project (SMPR). Begun in 1983, the purpose of the project was to take a fresh look at the small and medium power reactor concept, particularly its potential applicability for developing countries. While economies of scale are generally thought to favor larger plants, the better match-up with small grids or lower load growth and reduced financing requirements are often mentioned as favoring SMPR's.

Phase I on the SMPR Project consisted of an intensive study of the potential for SMPR's from the standpoint of both potential suppliers and prospective buyers. The IAEA

REPORT OF THE STUDY'S RESULTS CONTAINS THE MOST COMPREHENSIVE, UP-TO-DATE INFORMATION AVAILABLE ON THE POTENTIAL FOR SUPPLY OF SMALL AND MEDIUM POWER REACTORS. FROM THE BUYER'S PERSPECTIVE, THE REPORT MAKES CLEAR THAT ACTUAL DEMAND FOR THESE REACTORS HAS NOT YET MATERIALIZED, ALTHOUGH THERE IS CONSIDERABLE INTEREST IN THE CONCEPT.

THE U.S. PARTICIPATION IN THE SMPR PROJECT HAS BEEN A MODEL OF GOVERNMENT AND INDUSTRY COOPERATION. REPRESENTATIVES FROM FIVE U.S. FIRMS ATTENDED MEETINGS, DRAFTED QUESTIONNAIRES, AND HELPED DRAFT MAJOR SECTIONS OF THE REPORT. THE DEPARTMENT OF ENERGY CONTRIBUTED FUNDING TO THE STUDY WHICH WAS OVER AND ABOVE THE NORMAL U.S. VOLUNTARY CONTRIBUTION TO THE IAEA.

CONCLUSION

I THINK IT SHOULD BE PLAIN FROM THE FEW EXAMPLES I CITED, THAT THERE EXISTS AN ALMOST UNLIMITED POTENTIAL FOR COOPERATIVE VENTURES IN NUCLEAR SCIENCE AND TECHNOLOGY IN THE YEARS AHEAD. SURELY THE DREAM OF ATOMS FOR PEACE CAN REACH NEW LEVELS OF FULFILLMENT IN THE TWENTY- FIRST CENTURY, ESPECIALLY IF WE CAN STRENGTHEN COLLABORATIVE EFFORTS.

I BELIEVE THAT MAINTENANCE OF A STRONG DOMESTIC PROGRAM IS VITAL TO THE CONDUCT OF INTERNATIONAL

COOPERATION. ONLY BY BUILDING UPON A WORLD CLASS PROGRAM AT HOME CAN WE HOPE TO BE ABLE TO PROVIDE THE INFRASTRUCTURE NECESSARY FOR EFFECTIVE AND FRUITFUL COOPERATION. WE HAVE WORKED VERY HARD TO GENERATE AN ATMOSPHERE IN WHICH THE U.S. CAN CONTINUE TO MAINTAIN A STRONG NUCLEAR ENERGY PROGRAM, PARTICULARLY IN THE INDUSTRIAL SECTOR.

I THINK WE HAVE SUCCEEDED IN THIS ENDEAVOR. WITHIN A FEW WEEKS THE UNITED STATES WILL HAVE 100 OPERABLE COMMERCIAL NUCLEAR PLANTS WITH A GENERATING CAPACITY OF MORE THAN 84,000 MEGAWATTS. THESE PLANTS PROVIDE ALMOST 16 PERCENT OF U.S. ELECTRICAL GENERATION AND REPRESENT A $60-70 BILLION CAPITAL INVESTMENT. BY THE EARLY 1990'S ABOUT 125 NUCLEAR PLANTS SHOULD BE OPERATING, AND THE NUCLEAR GENERATING CONTRIBUTION WILL GROW TO NEARLY 20 PERCENT, SECOND ONLY TO COAL IN ITS CONTRIBUTION TO ELECTRIC SUPPLY.

THE WORLD'S BEST PERFORMING REACTOR DURING THE 12 MONTHS ENDING IN JUNE, 1985 WAS FLORIDA POWER AND LIGHT'S ST. LUCIE 1 NUCLEAR PLANT WHICH REGISTERED AN AVERAGE LOAD FACTOR OF 98.3 PERCENT. IN 1985, THE SALEM 1 NUCLEAR PLANT SET A NEW U.S. RECORD FOR ELECTRICITY PRODUCTION FROM A SINGLE ELECTRICAL GENERATING PLANT IN A CALENDAR YEAR. AS OF JANUARY 1986, U.S. NUCLEAR POWER PLANTS HAD ACHIEVED MORE THAN 940 REACTOR-YEARS OF SAFE OPERATION. I THINK THIS RECORD OF INDUSTRIAL ACHIEVEMENT SPEAKS FOR ITSELF.

FROM THIS STRONG DOMESTIC BASE FLOWS A PARALLEL U.S. RECORD IN INTERNATIONAL COOPERATION. SINCE 1955, THE U.S. GOVERNMENT HAS ENTERED INTO SOME 115 INTERNATIONAL AGREEMENTS WITH 40 COUNTRIES ON ISSUES RELATED TO ATOMIC ENERGY. IN ADDITION, A LARGE NUMBER OF INDUSTRY-TO-INDUSTRY LICENSING AND TECHNOLOGY EXCHANGE AGREEMENTS HAVE BEEN CONCLUDED BETWEEN U.S. AND FOREIGN FIRMS. COUNTLESS FOREIGN SCIENTISTS AND ENGINEERS HAVE BEEN TRAINED OR HAVE PERFORMED RESEARCH IN U.S. INSTITUTIONS AND BETWEEN 1979 AND 1983, NEARLY ONE-THIRD OF ALL PH.D. DEGREES AWARDED IN THE U.S. IN ATOMIC AND MOLECULAR PHYSICS WERE AWARDED TO FOREIGN STUDENTS. ALL OF THIS, OF COURSE, IS IN ADDITION TO THE BROAD RANGE OF TRAINING ACTIVITIES SPONSORED BY THE IAEA UNDER ITS TECHNICAL ASSISTANCE PROGRAM, TO WHICH THE U.S. IS A MAJOR CONTRIBUTOR. I CAN THEREFORE ASSURE YOU TODAY THAT MY GOVERNMENT IS COMMITTED TO MAINTAIN THIS STRONG RECORD OF INTERNATIONAL NUCLEAR COOPERATION.

ACTIVITY IN THE FIELD OF NUCLEAR AND ITS RELATED RESEARCH IN INDONESIA

BY

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PRESENTED
IN
THE ANNUAL MEETING
OF
JAPAN ATOMIC INDUSTRIAL FORUM
TOKYO - 8-9 APRIL 1986

I. INTRODUCTION

Nuclear activity in Indonesia is very small compared to the activity in the same field of developed countries. At the moment we have three small research reactors which are utilized for research work and producing radioisotopes.

At present Indonesia is considering to build nuclear power plant, therefore we are now building a bigger nuclear research reactor in order to minimize the gap between the small reactor to the much bigger nuclear power plant. With this nuclear power plant in mine, there is some study activity for the preparation of the coming nuclear power plant.

With our nuclear research reactor and its supporting laboratories which is under construction, and the planning for the nuclear power plant, there will be "many" activities in the field of nuclear, which may attract international cooperation. This new research reactor is built in the National Center for research, science and technology, with the reason that if necessary, research activity in this field can make use of the other laboratory facilities which are also built in this center.

With this reason, therefore in this paper it will be expalined also other laboratories which are built or being built in this center.

Indonesia at present is trying very hard to transform its economic base from agriculture to industry, therefore it is directed that the research activities should be applied research, so that with in a relatively short time can be applied to support the industrial development.

As we know that industrial development is mostly accomplished by applying better technology, therefore in all international cooperation, either in research or industrial activities, it is expected that the Indonesian scientists, managers and engineers should take an active part, so that they can master the technology.

This paper explains the outline of most research activities, organization and coordination, which are under supervision of the Minister of State for Research and Technology. For this specific meeting, nuclear activity other than research is also informed.

II. RESEARCH ORGANIZATION AND COORDINATION

a. Research Institute

Research activities in Indonesia, mostly conducted by government agencies and institutions and also mostly funded through the government budget. This pattern is a general pattern that prevails in many developing countries, in which industries are still in their early development. Because of this pattern, then almost all of the government departments have their own research and development section. Beside these departmental research activities, research is also conducted in state universities, in which of course the funding is mostly provided also by government.

To enhance research activities the Indonesian government has established also several institutes which are not connected to any department and provides to some of them with research facilities. These non departmental institutes are :

(1) The Indonesian Institute of Science (LIPI)
(2) The National Agency for Surveying and Mapping (BAKOSURTANAL)
(3) The National Agency for Atomic Energy (BATAN)
(4) The National Institute of Space (LAPAN)
(5) The National Center for Statistics (BPS)
(6) The Agency for the Assèssment and Application of Technology (BPPT)

The activity of all of this nondepartmental institutes are coordinated and supervised by the Minister of State for Research and Technology.

b. The Agency for the Assesment and Application of Technology

A research Institute is usually lead by a chairman and a vice chairman, and its devisions are led by deputy chairman. Then it is still devided further into directorates which is led by directors. The devision of an institute depends on its mission, as an example, the Agency for the Assessment and Application of Technology which is established by Presidential decree in 1974 has the following missions and function :

Missions :

a. to formulate general policies for consideration by the President regarding programs for the assessment and application of technology requisite for national development;
b. to provide over-all and integrated coordination of the execution of programs for the assessment and application of technology;
c. to provide services to both government and private organizations in the assessment and application of technology for national development;
d. to conduct activities in technology assessment and application which support government policy on the application of technology for development.

Functions :

a. to control and evaluate the execution of programs for the assessment and application of technology; and to foster technology transfer;
b. to encourage cooperation between government and private organization at home and abroad in the assessment and application of technology;
c. to develop and foster basic and applied sciences relevant to the application of technology, and to coordinate programs for their successful application in technology and industry;
d. to access, apply and further develop technology for increasing the quality of : life and human settlement, industrial processes, energy conversion and conservation, electronics and informatics; and to develop laboratories and physical facilites;

e. to access and apply technology in industry; and in the utilization of natural resources for development;

f. to access, develop and apply operation-research, management, systems-analysis, and technology-regulation methods; as well as to develop simulations and models for national development;

g. to develop the capabilities and skill of scientific personnel; and to develop and manage facilities required for the functions of BPPT.

Because of these mission and function, then this government agency is devided into 6 divisions :

1) Basic and Applied Sciences
2) Technology Development
3) Industrial Analysis
4) Natural Resources
5) Systems Analysis
6) Administration

Because of these special missions, therefore this agency is led directly by the Minister of State for Research and Technology. For executing its mission, this agency is provided with laboratories which is called the technical operating unit.

The organization structure of this agency can be seen in the organigram on page 7.

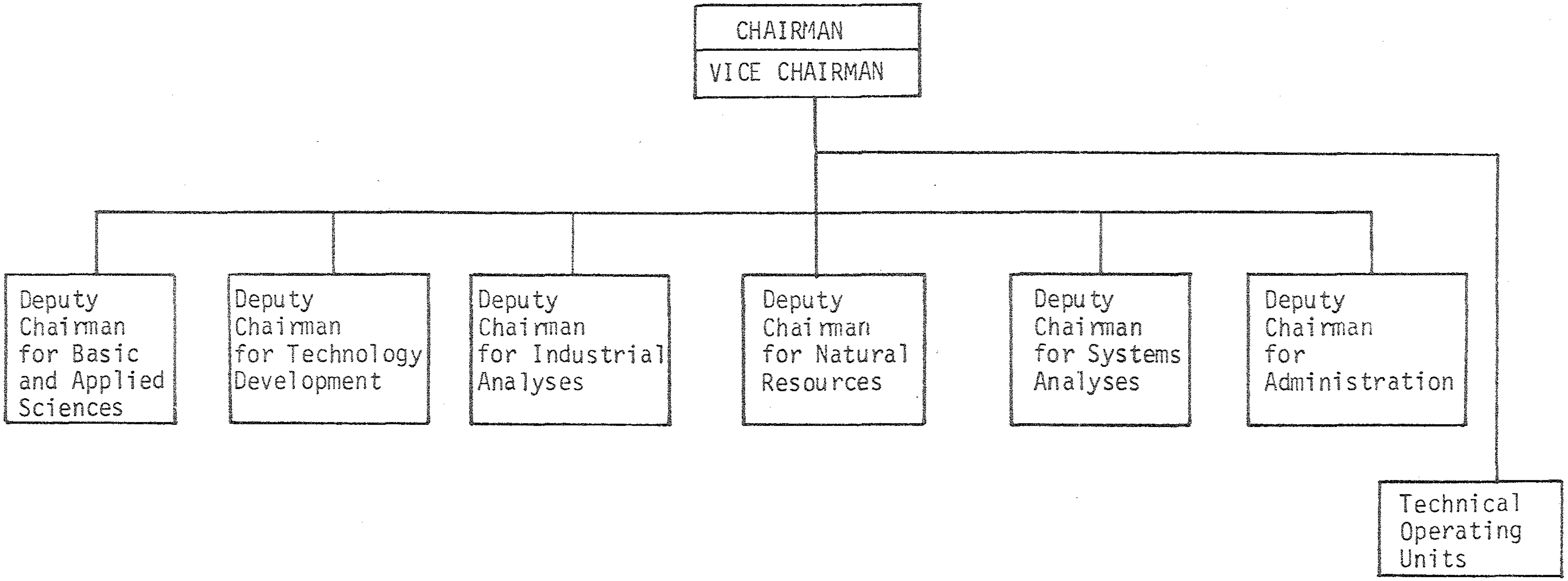
c. Research Coordination

As explained in the previous section, that most of the non departmental government agencies are provided with laboratories. This means that most of their main task are conducting research. In order to direct their research to suuport the national development, their research activity has to be coordinated and directed. This directive and coordination are trusted in the hand of Minister of State for Research and Technology.

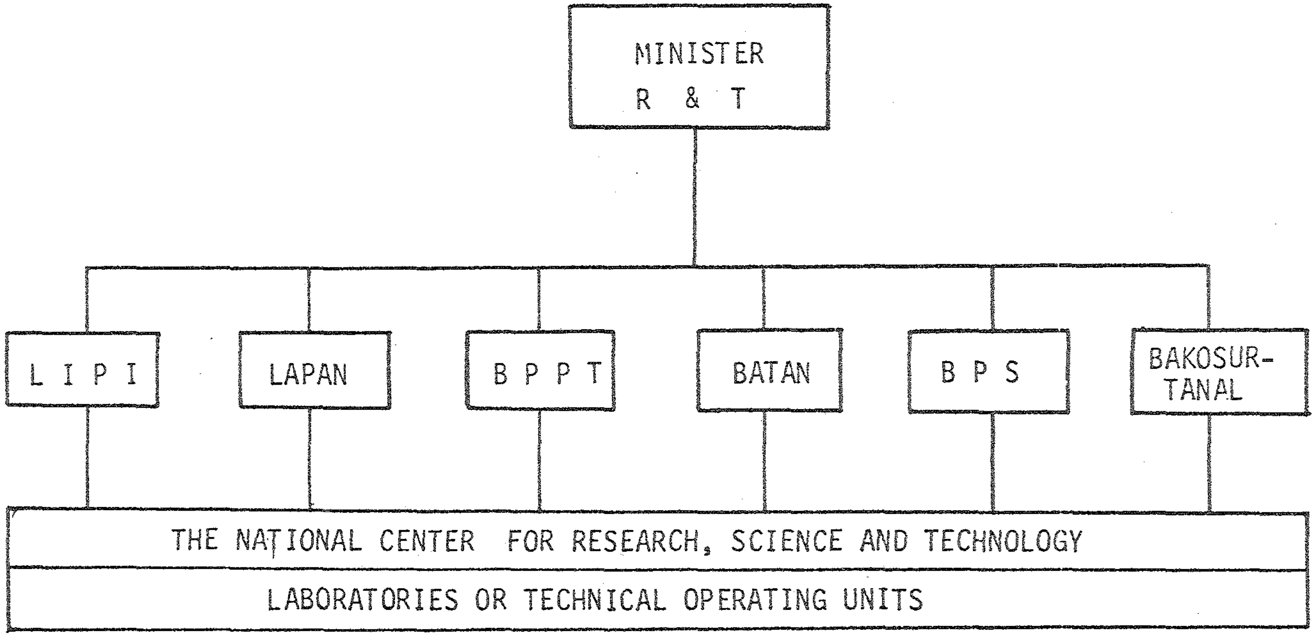
To maximize the results, to minimize the budget and to avoid as far as possible the duplication, the Minister of State for Research and Technology has provided a "campus" on which all of the laboratories of those non departmental agencies has to be built. This campus in The National Center for Research, Science and Technology (PUSPIPTEK), which is built in Serpong near Jakarta.

The diagram for the research coordination can be seen in organigram on page 8. The coordination in done in a National Coordination Meeting, which is held once a year. In this coordination meeting all research institutes, either non departmental or departmental institutes are requested to make presentation on their research results and research plan for the following year or the following 5 year development plan.

AGENCY FOR THE ASSESSMENT AND APPLICATION OF TECHNOLOGY



COORDINATION DIAGRAM



III. NATIONAL CENTER FOR RESEARCH, SCIENCE AND TECHNOLOGY

a. Laboratories

In the previous chapter it is explained that the National Center for Research, Science and Technology, or in Indonesian language "Pusat Penelitian Ilmu Pengetahuan dan Teknologi" which is abreviated as "PUSPIPTEK", is a Campus on which the Laboratories are built. The mission of PUSPIPTEK, beside to support the non departemental government agencies in fulfilling their missions, is also, in broader goal is to enhance and develop national capabilities in the field of research, science and technology to support the national economic development in the various sectors such as industry, transportation, energy etc. This center is built since 1976 and planned to be finished in 1986. But because of the economic crisis, it will not be completed untill 1988 or later.

In this short term planning this center will consist of the following laboratories :

a) Laboratories belong to BPPT :
   1. Laboratory for Strength of Materials, Components and Structures(LUK)
   2. Laboratory for Aerodynamics, Gasdynamics and Vibration (LAGG)
   3. Laboratory for Thermodynamics, Engines and Propulsion (LTMP)
   4. Laboratory for Energy and Energy Resources (LSDE)
   5. Laboratory for Technology Processes (LTP)

b) Laboratory belongs to BATAN :
   6. Multi Purpose Research Reactor and the Relevant Laboratories (RPSG)

c) Laboratories belong to LIPI :
   7. Laboratory for Calibration, Instrumentation and Metrology (KIM)
   8. Laboratory for Electrotechnique (LEN)
   9. Laboratory for Applied Physics (LFN)
   10. Laboratory for Applied Chemistry (LKN)
   11. Laboratory for Metallurgy (LMN)

b. Laboratory Development Status

Out of the 11 Laboratories, at the present time it is only two which are already in service, some are under construction or still in the planning. The status of these laboratories are as follow :

NO.	Laboratory Name	Status
1.	Laboratory for Strength of Materials, Components and Structures (LUK)	in operation
2.	Laboratory for Aerodynamics, Gasdynamics and Vibration (LAGG)	under construction
3.	Laboratory for Thermodynamics, Engines and Propultion (LTMP)	in planning
4.	Laboratory for Energy and Energy Resources (LSDE)	in planning
5.	Laboratory for Technology Processes	in planning
6.	Multi Purpose Research Reactor and the Relevant Laboratories (RPSG)	under construction
7.	Laboratory for Calibration, Instrumentation and Metrology (KIM)	in operation
8.	Laboratory for Electrotechnique (LEN)	under construction
9.	Laboratory for Applied Physics (LFN)	under construction
10.	Laboratory for Applied Chemistry (LKN)	in planning
11.	Laboratory for Metallurgy (LMN)	in planning

c. Other Facilities an Further Planning of PUSPIPTEK

This center (PUSPIPTEK) is provided with housing for scientist and staffs and also with a guesthouse that can accomodate 50 guest scientist. In the total plan, this center will cover a land of 1000 Ha, in which 500 Ha provided for the laboratories, 150 Ha for university and 350 Ha for high technology industries.

IV. ACTIVITY IN THE FIELD OF NUCLEAR

a. Multi Purpose Research Reactor

As can be seen in the previous section, the status of the Multi Purpose Research Reactor (RSG) is under construction. When this Laboratory is complete it will consist of :

(1) One multipurpose research reactor with capacity of 30 MW thermal, equiped with several irradiation facilities.

(2) Installation for radio isotopes production, which can be used in industries, hydrology, medical and others.

(3) Nuclear fuel element laboratory, which will conduct research on fuel element for nuclear power generator.

(4) Installation for production of fuel elements for research reactor.

(5) Nuclear waste laboratory.

(6) Radio metallurgy laboratories.

(7) Engineering and safety laboratory, for studying the reliability and safety of the reactor components and system.

(8) Nuclear Mechano-electronic laboratory.

The complition of this nuclear research reactor and its supporting laboratories, is planned to be in the year of 1988. The reactor itself will be in operation in December 1987, the radio isotope installation in October 1987, the installation for experimental fuel element in March 1988 and for the nuclear waste installation is also in March 1988.

b. Nuclear Power Plant.

(1) Energy Demand

Many studies have been done, and some are still being done. Therefore there are several forcasting and scenario have been established. The study by Bechtel - BPPT (1980) forcasted that the electric energy demand for the year 2000 will be 42000 MW if the growth rate of GDP is 6½%, and will increase to 60.000 MW if the GDP growth rate reachs 7½%. But the new study says that because of the economic crisis may be only 50% of the demand will be realized.

There are also several scenarios of the introduction of the nuclear power plant, one study proposes only 8% of the energy demand should be supplied by nuclear power plant and other propose up to 30%. Even time for the introduction is still discussed, it should be introduced before or after the year 2000. These many studies and scenarios shows how serious and how careful is Indonesia in the application of nuclear energy into power plant.

But even in the pesimistic consideration, the minimum nuclear power plant (energy demand 40.000 MW, 50% realized and 8% supplied by nuclear power plant) will be 1600 MW, which should be supplied by 1 or 2 power plant. And the time for the introduction, whether before of after year 2000, will not make big difference in the preparation of the utilization of nuclear power plant.

(2) Preparation for Introduction of the First Nuclear Plant.

The introduction of the first Nuclear Power Plant will call for some basic organizations/functions to be established even before bidding procedure becomes effective. Among others are :

1. institutional arrangement
2. development of infrastructure.

On the institutional arrangement it will be necessary to establish organizations capable of a safe handling of a nuclear power plant and its sourounding as well as nuclear waste. This concerns independent safety assurances on the plant from independent organizations that the safety aspect of the plant can be weighed in the most objective way. It will also be necessary to establish arrangement between the promoting/operating organization and organization which are cencern about safety.

Development of infrastructure should at least cover manpower training as well as the preparation of Indonesian industries to take up the responsibility of designing, manufacture and constructing the plant at whatever level they are feasible. Among the two the manpower training seems to be more difficult to tackle because it involves a quite large leading time if it is to cover area of activities ranging from design manufacturing, construction, operation as well as maintenance of the power plant and its related facilities and safety problems.

c. Area for International Cooperation

Being aware of the fact that Indonesia will nct be able to build up her own nuclear programme alone the country hopes for cooperation with our friendly nations. To mention just a few here are some of the areas which need be given attention :

(1) Education & training in the field of Nuclear Technology.

(2) Research in the application of nuclear technique in the field of industry, hydrology, medicine and agriculture.

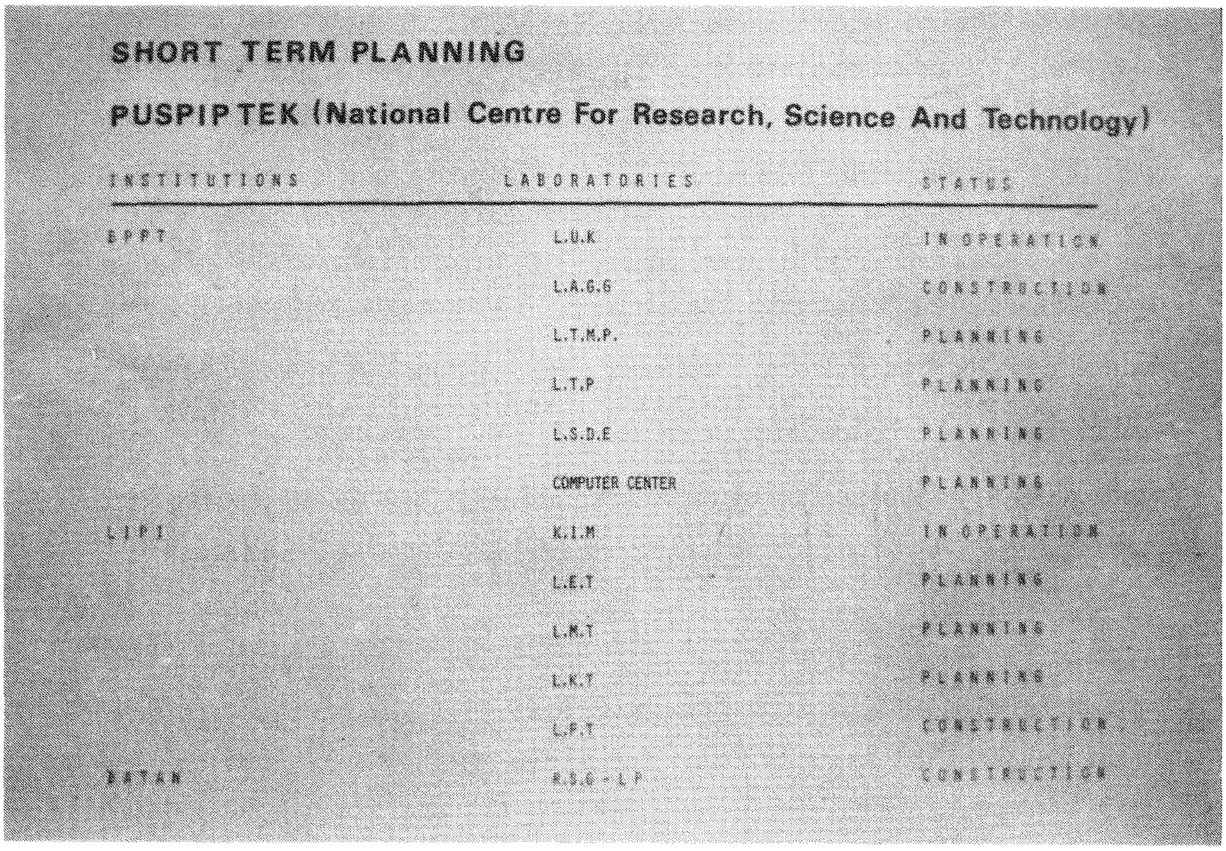
(3) Exchange of information related to nuclear technology and nuclear power.

(4) Joint research at MPR-30 in PUSPIPTEK, Serpong.

(5) Training in the field of Safety Assurance of a nuclear power plant.

V. CLOSING REMARKS

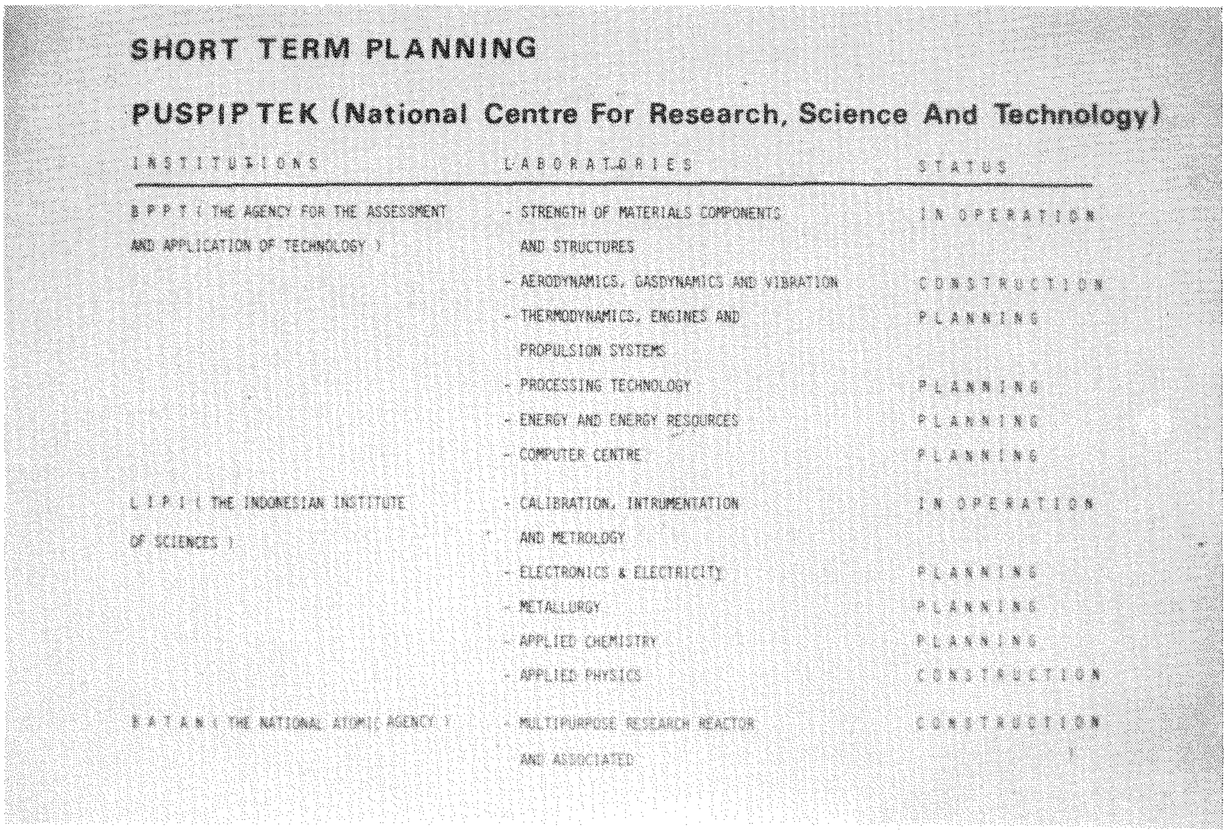
On this opportunity I would like to express our sincere hope that our cooperation in the field of Science and Technology which so far has gone so well can extends its wings to a wider coverage of Science and Technology to include the nuclear power technology. We have a great expectation that cooperations in this field, like what we have had in other fields of technology will be fruitful to both cooperating countries.



SHORT TERM PLANNING

PUSPIPTEK (National Centre For Research, Science And Technology)

INSTITUTIONS	LABORATORIES	STATUS
BPPT	L.U.K	IN OPERATION
	L.A.G.G	CONSTRUCTION
	L.T.M.P.	PLANNING
	L.T.P	PLANNING
	L.S.D.E	PLANNING
	COMPUTER CENTER	PLANNING
LIPI	K.I.M	IN OPERATION
	L.E.T	PLANNING
	L.M.T	PLANNING
	L.K.T	PLANNING
	L.F.T	CONSTRUCTION
BATAN	R.S.G - LP	CONSTRUCTION



SHORT TERM PLANNING

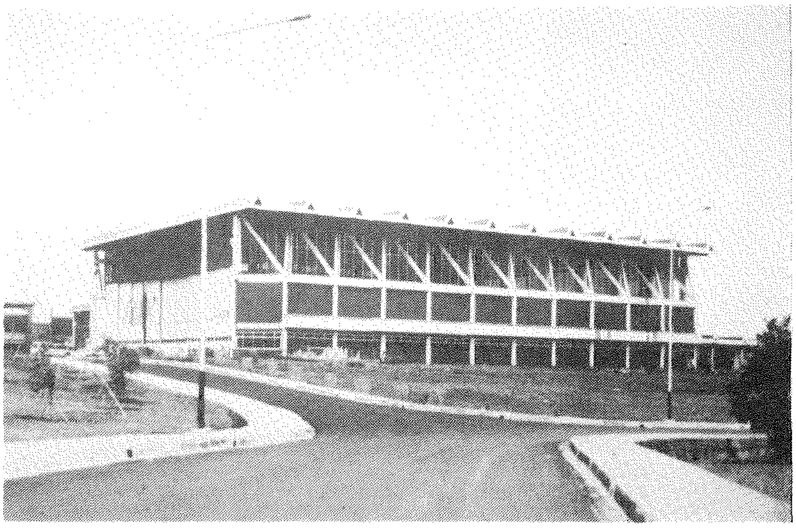
PUSPIPTEK (National Centre For Research, Science And Technology)

INSTITUTIONS	LABORATORIES	STATUS
BPPT (THE AGENCY FOR THE ASSESSMENT AND APPLICATION OF TECHNOLOGY)	- STRENGTH OF MATERIALS COMPONENTS AND STRUCTURES	IN OPERATION
	- AERODYNAMICS, GASDYNAMICS AND VIBRATION	CONSTRUCTION
	- THERMODYNAMICS, ENGINES AND PROPULSION SYSTEMS	PLANNING
	- PROCESSING TECHNOLOGY	PLANNING
	- ENERGY AND ENERGY RESOURCES	PLANNING
	- COMPUTER CENTRE	PLANNING
LIPI (THE INDONESIAN INSTITUTE OF SCIENCES)	- CALIBRATION, INTRUMENTATION AND METROLOGY	IN OPERATION
	- ELECTRONICS & ELECTRICITY	PLANNING
	- METALLURGY	PLANNING
	- APPLIED CHEMISTRY	PLANNING
	- APPLIED PHYSICS	CONSTRUCTION
BATAN (THE NATIONAL ATOMIC AGENCY)	- MULTIPURPOSE RESEARCH REACTOR AND ASSOCIATED	CONSTRUCTION

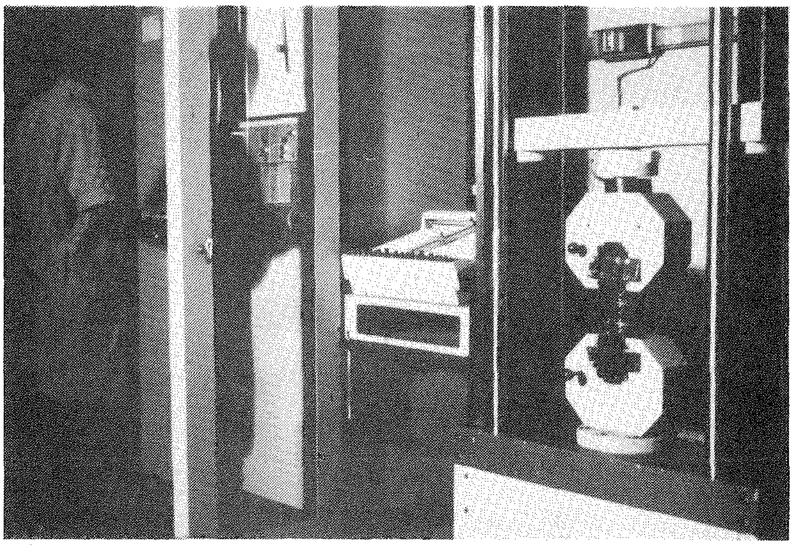
国立科学技術研究センター（PUSPIPTEK）に通じる道。
PUSPIPTEKはジャカルタから30kmほどのところにある。

同　上

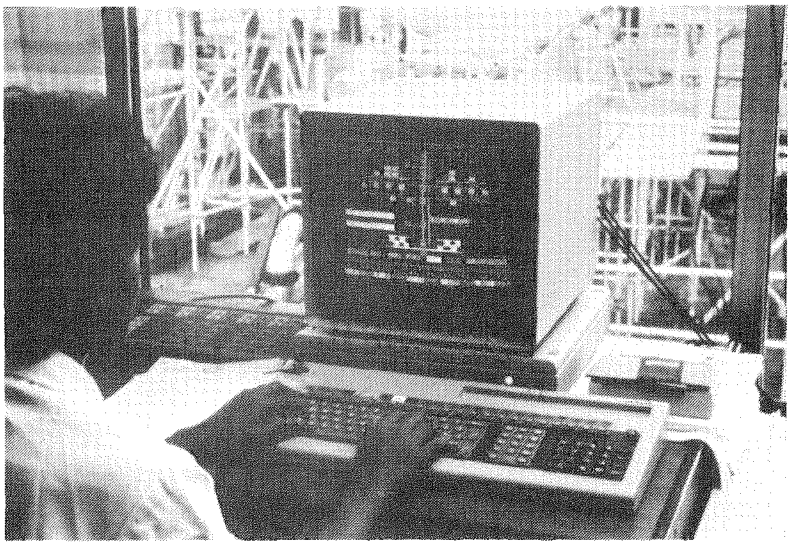
PUSPIPTEKの管理事務建屋。



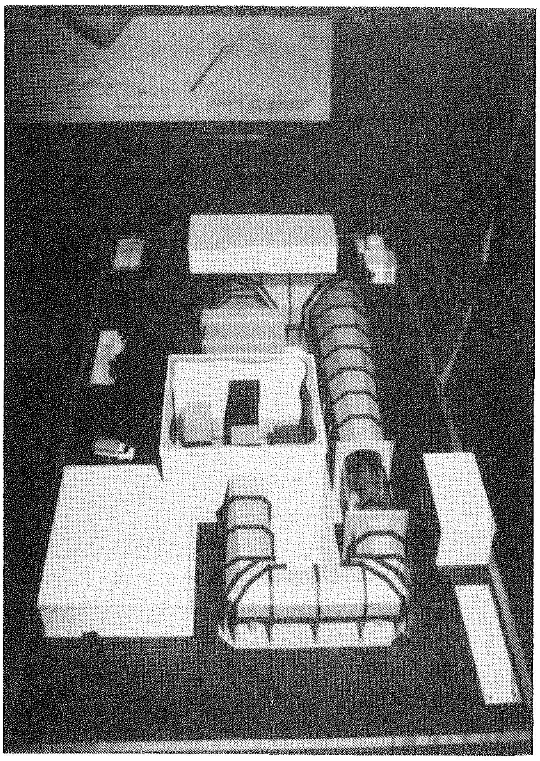
PUSPIPTEKの材料・機器・構造物強度研究所（LUK）



LUKにおける研究活動。材料試験をしているところ。

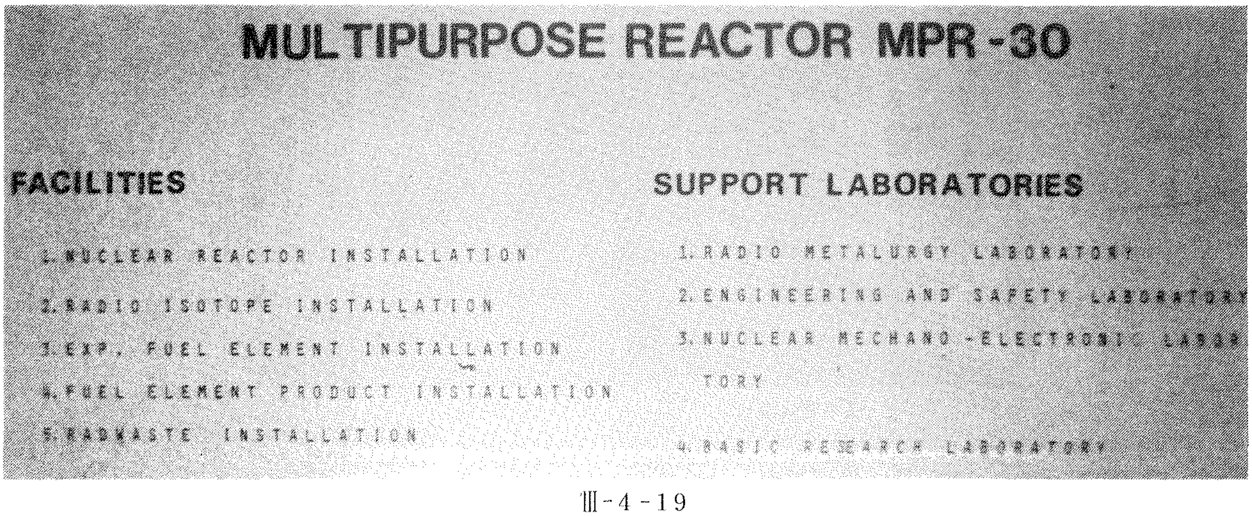


飛行機の疲労度試験をする施設。コンピューターを利用している。



空気力学・ガス力学・振動研究所の完成模型

建設中の空気力学・ガス力学・振動研究所



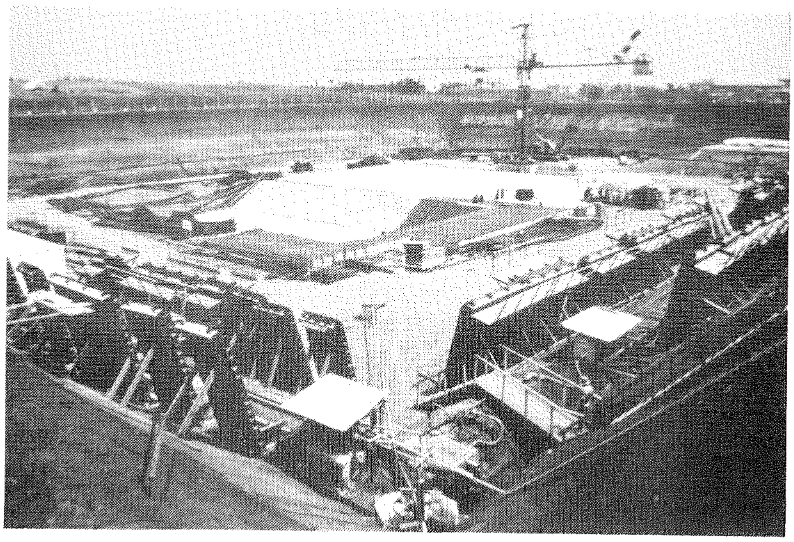
MULTIPURPOSE REACTOR MPR-30

FACILITIES

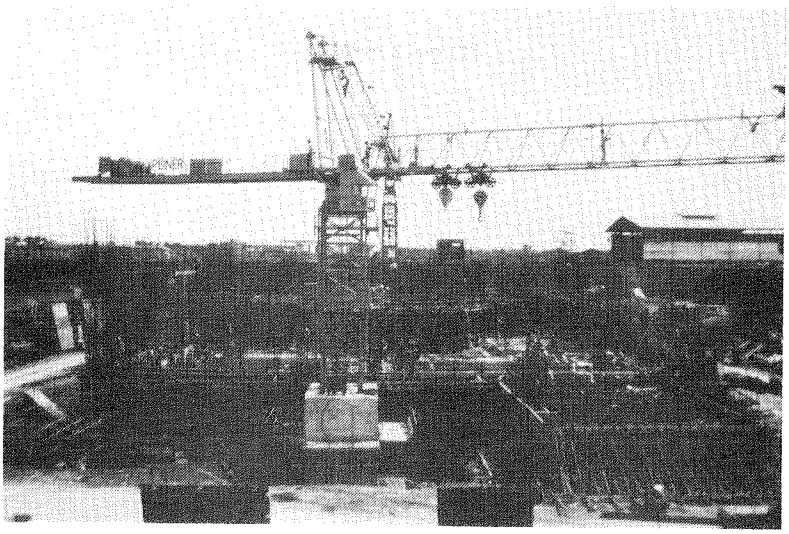
1.NUCLEAR REACTOR INSTALLATION
2.RADIO ISOTOPE INSTALLATION
3.EXP. FUEL ELEMENT INSTALLATION
4.FUEL ELEMENT PRODUCT INSTALLATION
5.RADWASTE INSTALLATION

SUPPORT LABORATORIES

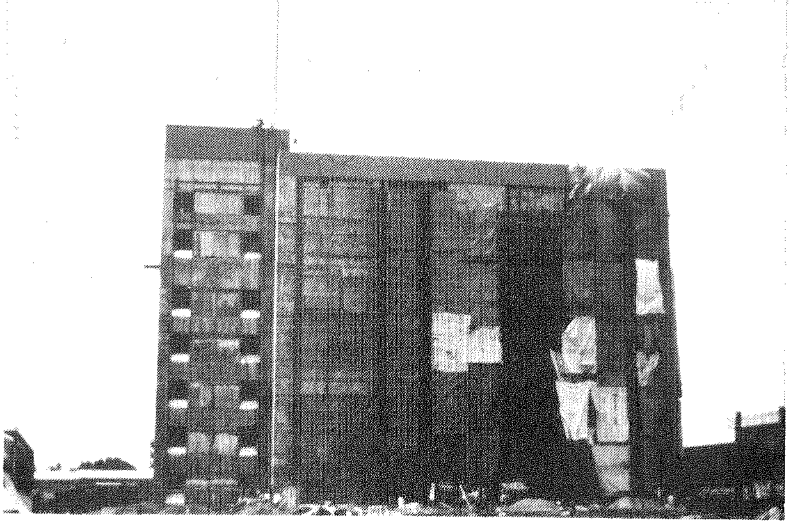
1.RADIO METALURGY LABORATORY
2.ENGINEERING AND SAFETY LABORATORY
3.NUCLEAR MECHANO-ELECTRONI LABOR
TORY
4.BASIC RESEARCH LABORATORY



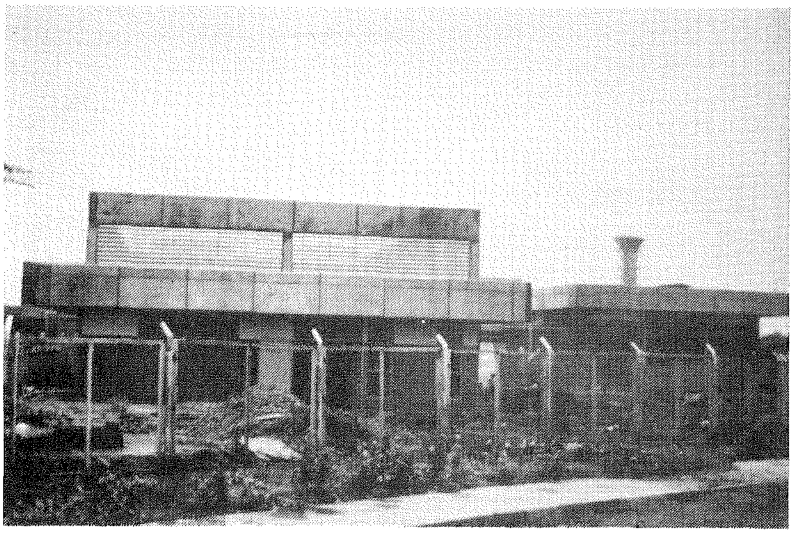
MPR－３０の建設が始まったところ。



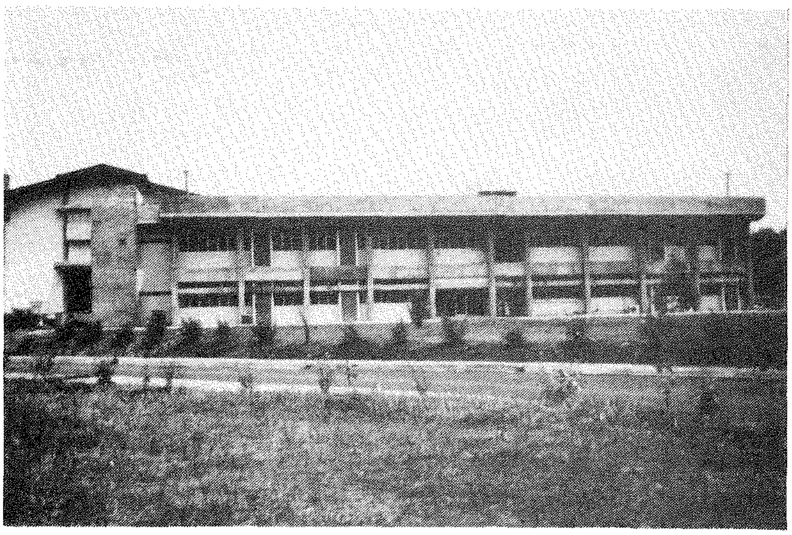
MPR－３０の建設が少し進んだところ。



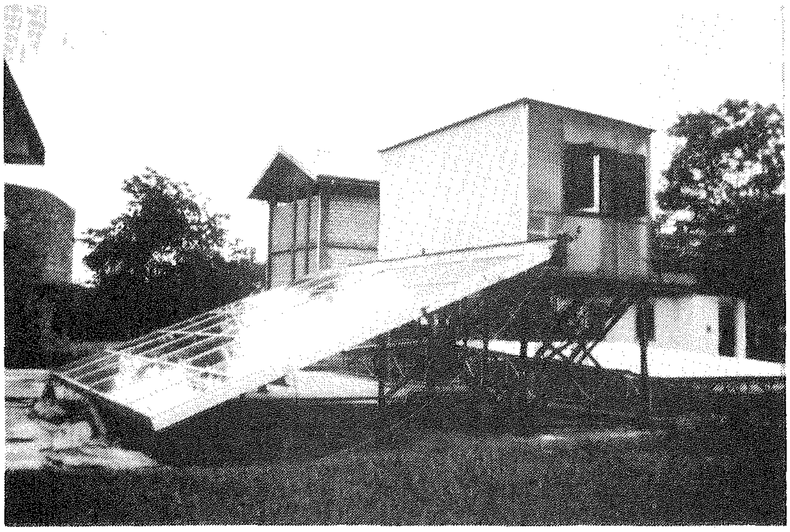
部分的に完成したMPR－３０の原子炉建屋



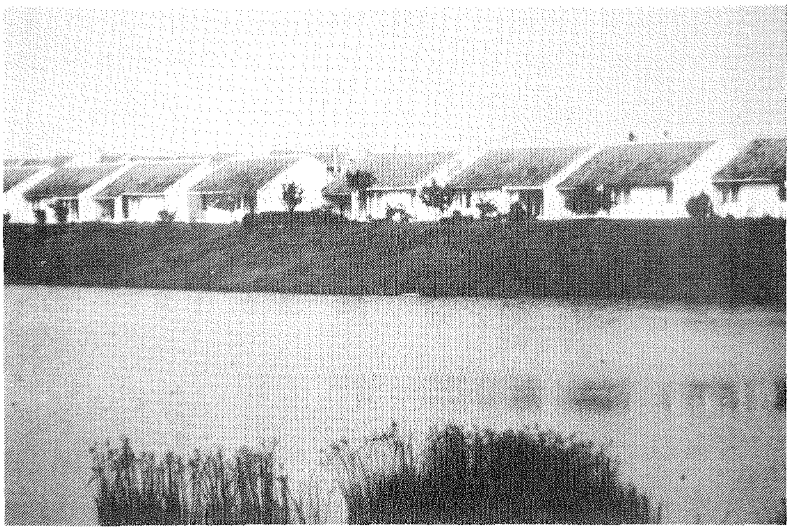
燃料製造施設



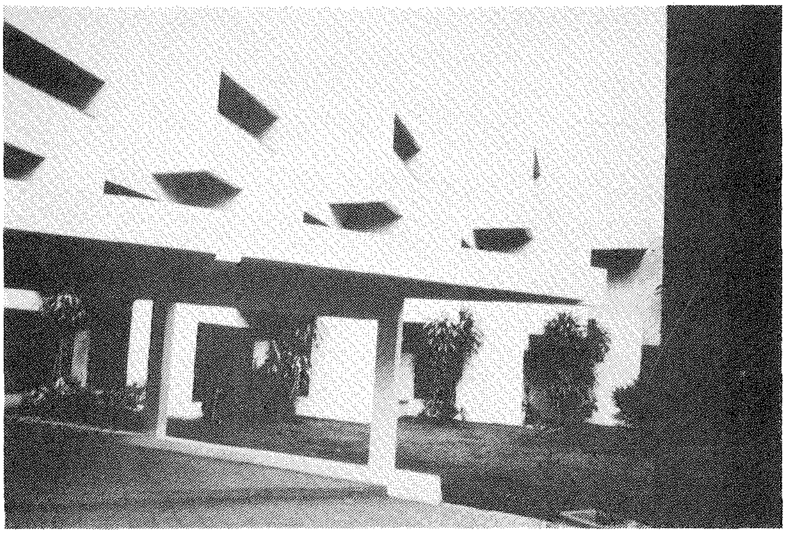
エンジニアリングホール



太陽エネルギーに関する試験を行っているところ



PUSPIPTEKで働いている人々，研究者達の住宅センター



ゲストハウス（共同研究者用の住宅）

ゲストハウスの内部

Dr. H. Frewer, W. Germany
Representative of the European Nuclear Society

"Nuclear Energy Development and International Cooperation - Prospects for the 21st Century"

For many countries the peaceful use of nuclear energy is an appropriate means of reducing their dependence upon imported energy sources, of conserving the available fossil reserves and of bridging the technological gap to the industrialized countries.

Since only a few industrialized countries have the necessary nuclear technology know-how, the other countries can only gain access to this know-how by cooperating with a competent and experienced partner who is not only willing to supply technology of a high quality standard, but who is also prepared to impart the associated engineering and manufacturing know-how by means of technology transfer. Furthermore, the management know-how for a complex engineering task is essential for handling nuclear technology properly.

The mature status attained by the European countries is apparent from the first figure which shows the development of the gross power generation structure in the European Community.

In past decade nuclear-generated electricity has already contributed substantially to meet the growing overall demand.

The nuclear share has already reached around 25% of the total generation and will increase to more than 40% by the end of this century. Coal and hydroelectricity will decrease to less than 50%, those of oil and gas to about 10% after the boom period in the seventies. In Western Europe about 125 nuclear power plants are already in operation and have accumulated more than 1000 reactor years.

A significant contribution in reaching the required high standard was the necessary basic research, e.g. in safety analysis, which was generally performed by government-owned research centers or under their sponsorship. In this area international cooperation proved to be a viable tool for harmonizing the results of R+D. This synergetic effort of fruitful cooperation in research and development in Western Europe pushed, for example, fast breeder technology to the top position in the Western World.

The vital nuclear industry in Western Europe makes these countries well-suited partners for cooperation, as is shown in the next figure which illustrates the major international partnerships with the European nuclear industry. Besides the long-term links with the U.S.A. and Japan, cooperation concepts have also been established for less developed countries (LDCs). Many of these countries in Asia, Africa and South America have already profited from such cooperation and established their own independent industry for the peaceful use of nuclear energy.

The role of the IAEA as a catalyst for technology transfer should also be mentioned. Based on an initiative of the IAEA about 10 years ago, Western European countries arranged an intensive manpower development program in the field of the peaceful use of nuclear energy. Courses for participants from LDCs are being held at educational centers in France, Germany, Great Britain and Spain.

In this context the manifold bilateral exchange of scientific and engineering know-how of the european nuclear community with Japan and the United States of America should also be mentioned. A special example of building up nuclear technology from scratch is the international cooperation with Indonesia which will be explained later in more detail.

A beneficial partnership implies not only years of experience on the part of the technology supplier, but also the elaboration of methods for transferring these technologies. Some of the experiences gained by the European industry in the planning of nuclear projects are shown in the next figure. This three-level concept for establishing a long-term partnership has the advantage of an integrated network of collaboration. An essential factor is the assistance provided by the governments at all three levels of technology transfer.

The first step in cooperation is an agreement between the governments of the two countries involved. This umbrella agreement on joint research projects and technical development programs may cover the entire spectrum of science. At a second level comprehensive agreements, for example in energy planning, can thus be concluded between research centers, universities, institutes and engineering companies. This cooperation normally comprises the exchange of scientists and may include investigations into energy planning or feasibility studies for the introductory phases of nuclear power.

The third step in technology transfer is industrial cooperation. The transfer of engineering and manufacturing know-how makes it possible to achieve a broad basis of industrial technology which can also be applied in non-nuclear sectors. The entire framework of industrial cooperation is governed by the motto "optimal use of the existing national structure combined with a comprehensive long-term technology transfer". The areas of competence, and even the individual training programs and time schedules can thus be geared to this objective from the very beginning.

The economic growth and industrial potential in the recipient country determines the supply and demand structure, as shown in the next figure. The governments concerned cooperate in establishing general conditions, such as defining the data for an overall energy program and support in research and development, licensing and financing. Questions related to closing the fuel cycle including the safeguard problems will also be handled by the governments in close contact with IAEA.

On the other hand the industry is active on the basis of the free market, e.g. as investor or supplier. They are responsible for the design, construction and start up operation of the plants. In the hardware field too, joint activities -such as co-production - are advisable.

An important point for the development of a reliable nuclear technology is the establishment of an integrated quality assurance system, as outlined in the next figure. In order to obtain a safe and cost-effective plant constructed in a defined period of time, a coherent system of integrated quality assurance is required. This is especially valid for the design which is subject to the given national laws, regulations and standards. Procurement and the follow-up of national manufacture should also be handled jointly. Carefully performed commissioning together with the recipient partner and well-trained operating staff are necessary to guarantee high quality and high availability.

Some examples of successful cooperation between different countries at the scientific research and development level and at the level of industrial cooperation will be shown for Indonesia, Latin America and for the fast breeder field as a prospect for the 21st century.

The next figure shows the international nuclear partnership in the PUSPIPTEK Research Center, SERPONG, in the Republic of Indonesia. Outlined are some of the interactions between the different departments of this research center and their cooperation partner countries (shown in red). The construction of a 30 MWth Multi-Purpose Reactor by the German industry is the center of all activities. On the basis of several areas of application as illustrated on the right, the figure demonstrates the manifold interrelationships between the different supplier countries and Indonesia.

Apart from the results and experience related to future power plants, many sectors of industry essentially involved in the development of materials can make direct use of the research work. Furthermore, medicine, agriculture, mining and geology as well as universities can profit considerably from these nuclear facilities. This allows to build up a qualified nuclear manpower potential as prerequisite for the later construction of nuclear power plants.

A very impressive example of international cooperation in the supply of components for nuclear power plants is the manufacture of the reactor pressure vessel and its internals for the PHWR Atucha II in Argentina, as shown in the next figure. Following the supply of all major forgings from Japan, manufacture of the reactor pressure vessel (RPV) was started about 1981 in Germany and Brazil where the lower parts 1 and 2 were manufactured separately. The assembly of these two parts will be performed by the German manufacturer in the Netherlands this year. Fabrication of the RPV closure head started in

Germany, machining is at present in progress in Spain and the closure head will ultimately be delivered to the Netherlands for hydro pressure testing. Fabrication of the RPV internals was performed entirely in Switzerland at the same time. The reactor pressure vessel and the internals will finally be shipped to the Argentine site for installation in the Atucha Nuclear Power plant.

The timely completion of the manufacturing activities in Brazil and Spain was mainly due to the fact that the technology had already been transferred by the German manufacturer to the local suppliers at an earlier date.

The third example of international cooperation covers the fast breeder development and is shown in the next figure. The lower part outlines the cooperation between six participant European nations (shown in blue). Their governments have committed themselves to cooperation based on guidelines. These guidelines are specified in contracts between the institutions concerned, including utilities, operating companies as well as research centers, shown in orange. The second inner circle (yellow) characterises the industrial cooperation. Finally in the red coloured center, the agreements for fuel reprocessing between British, French and German institutions are shown. These agreements provide the framework for long-term cooperation in breeder fuel reprocessing beyond the year 2000. This cooperation remains of course open to additional future partners as shown in the upper part of the figure. There are already cooperation activities between Japan, the U.S.A. and the six European partners based on the experience of Monju, Super Phenix and SNR-300. This shows the long term route and prospects for the 21st century.

Irrespective of all political and technological considerations, financing nonetheless constitutes one of the major obstacle faced at present by developing countries who wish to embark on a nuclear power program. Although nuclear power plants based on classical economic analysis methods are competitive, financing of nuclear projects in developing countries will remain a complex and controversial issue. It is remarkable that, for the majority of the projects seriously discussed, export financing would have been available. However, experience shows that financing of the local portion of a nuclear power plant often presents the major obstacle.

Thus a balanced approach between imported supply and local manufacture should be aimed at avoiding too large a financial burden in building up a costly infrastructure in the developing country.

New ways of mobilizing financial resources for the power sector in developing countries will have to be found. These models should include multi-country financing approaches, creation of joint ventures and the consideration of barter and countertrade deals. A key role is also to be assumed by the developing countries to make the overall environment attractive for international partnership, both for external financing as well as for the ability to raise domestic financial resources.

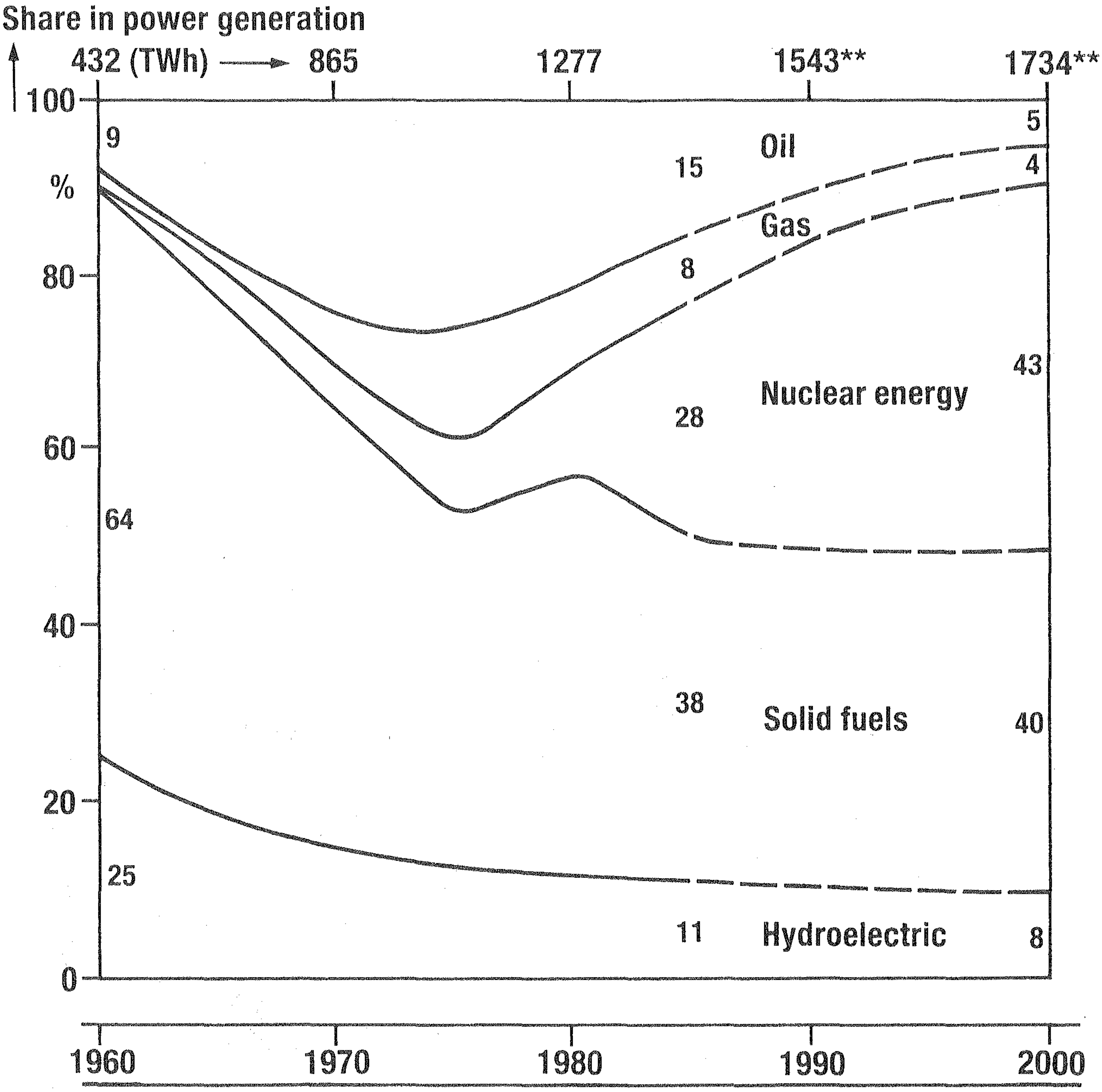
Last but not least, the goodwill of the cooperating partners is of decisive importance for the effective implementation of technology transfer. The code of conduct envisaged by the United Nations, as shown in the last figure, can serve as a guideline for a successful nuclear cooperation.

The principle statement of these guidelines is the mutual recognition of national independence of both partners. The keywords are:
Protection of sovereignty
- mutual benefits and
- no discrimination, of the other partner,

These are supplemented by
- respect for economic independence
- willingness to provide complete information and open exchange of technology
- adaptation to individual needs and
- no interference in internal affairs

The objective of these principles is, above all, to facilitate the exchange of technical information in order to enhance the growth of the scientific and technological capabilities of the countries involved.

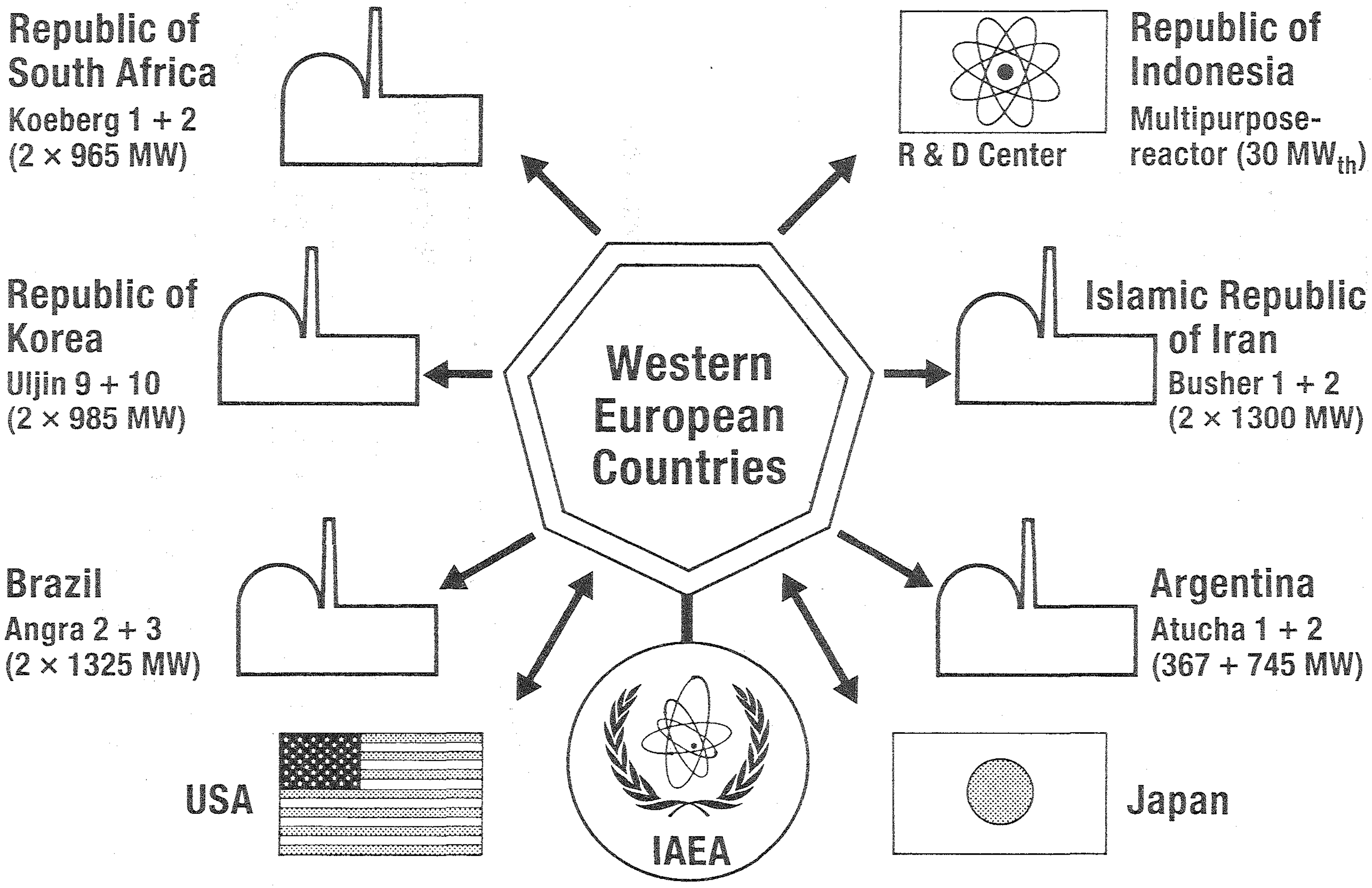
International cooperation in this form will pave the way towards the goal and prospects of nuclear energy development for the 21st century.



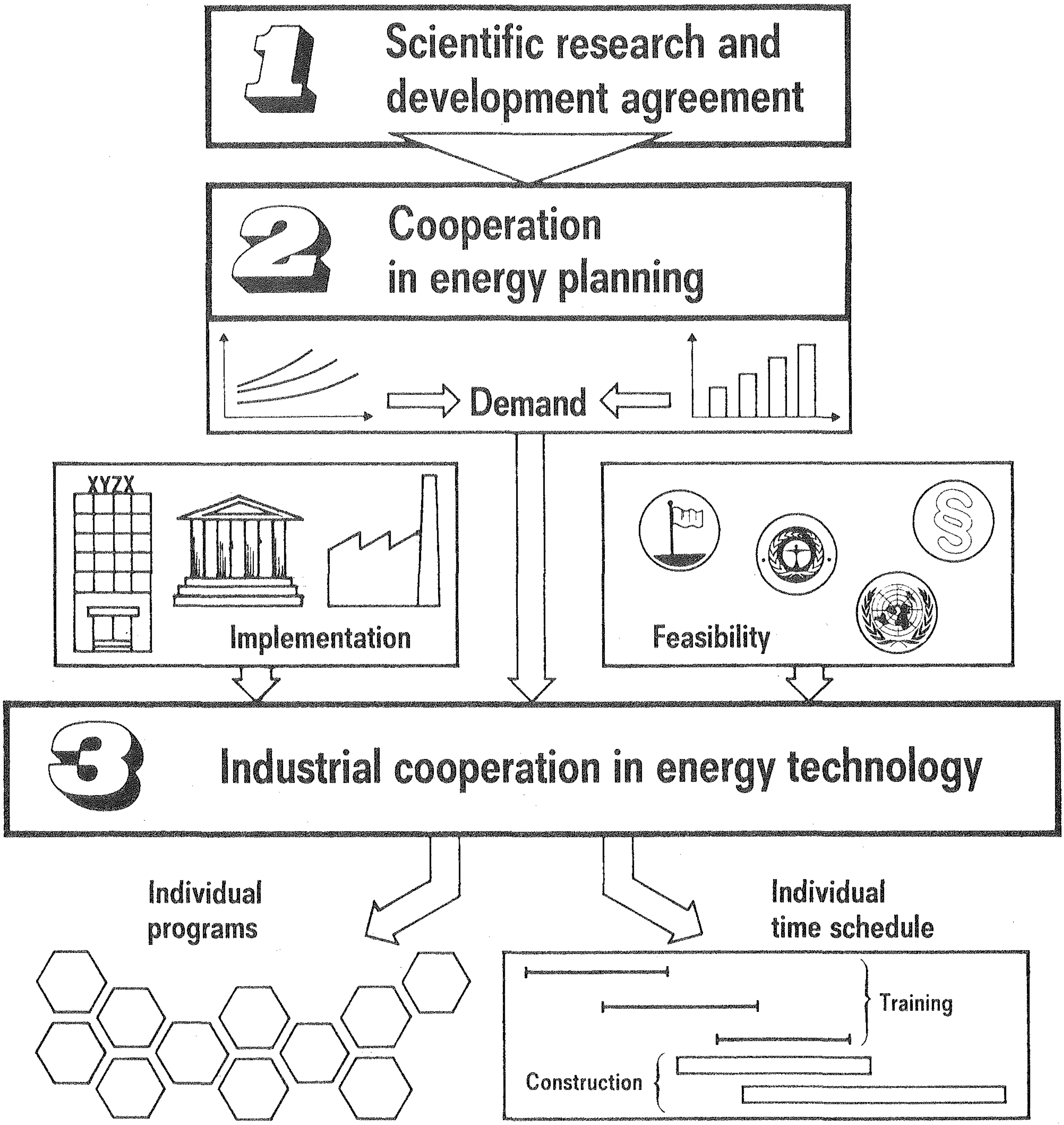
** estimated

Source: IEA

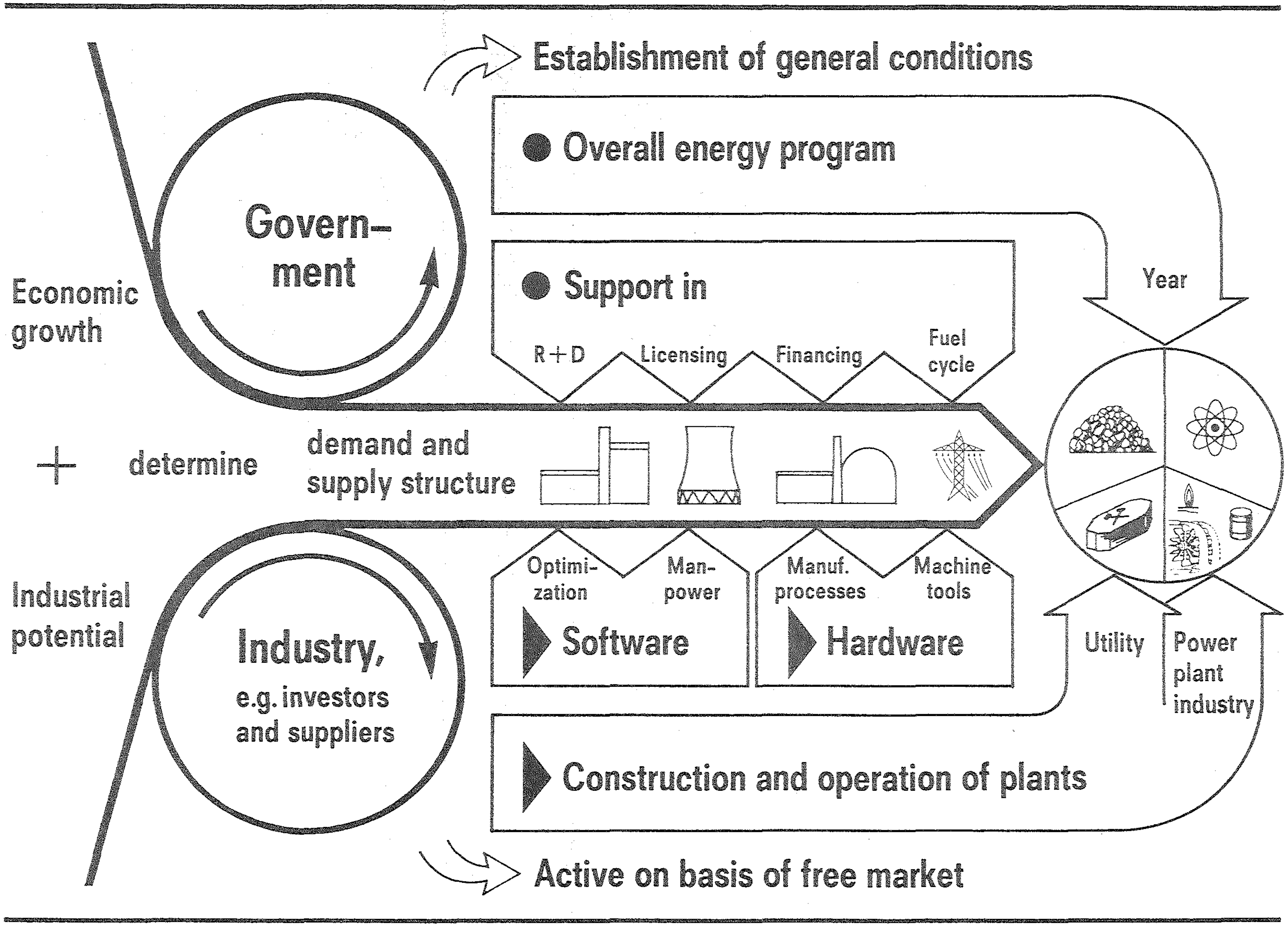
Structure of Gross Power Generation
in the European Community



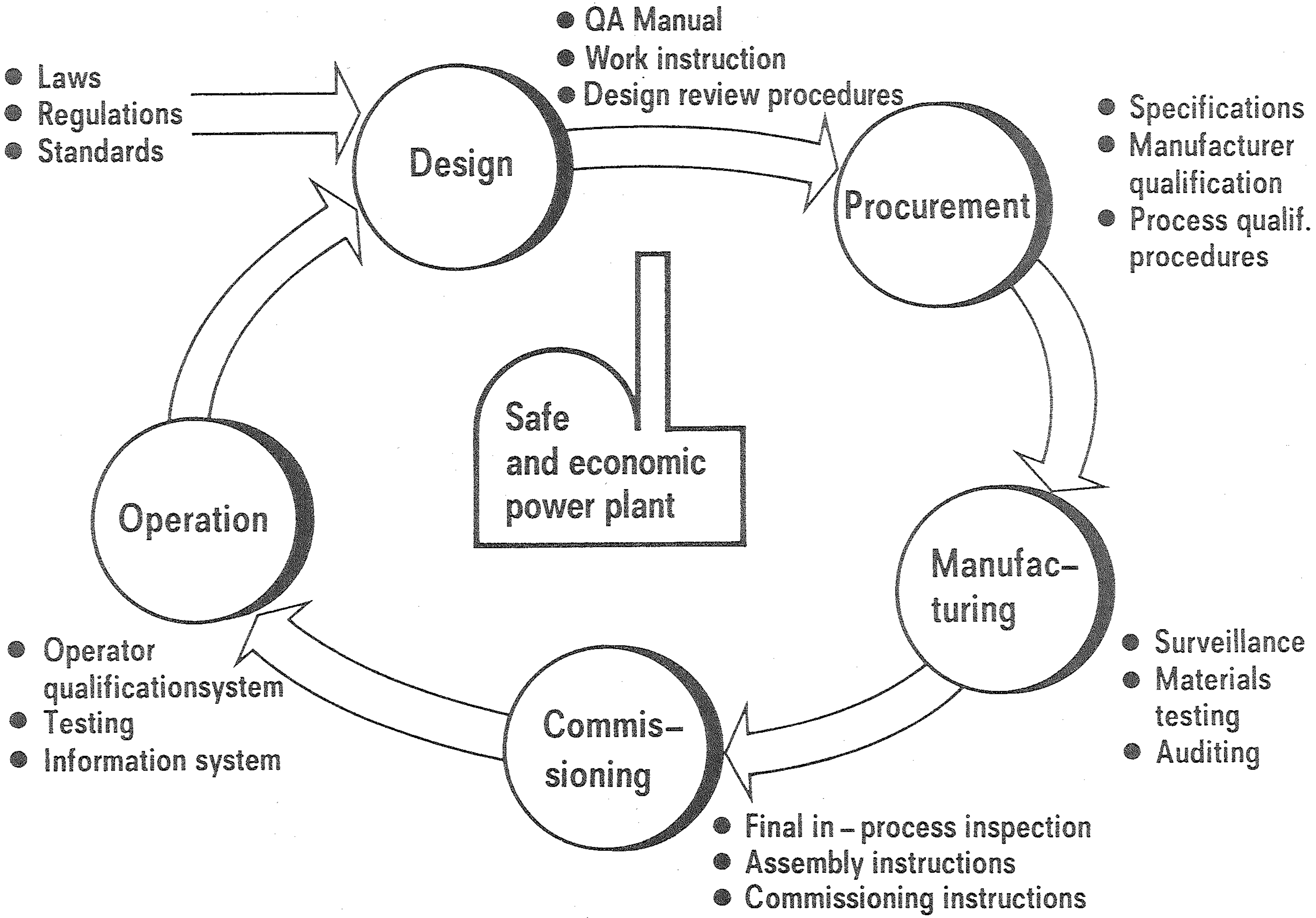
Major International Cooperations with the European Industry



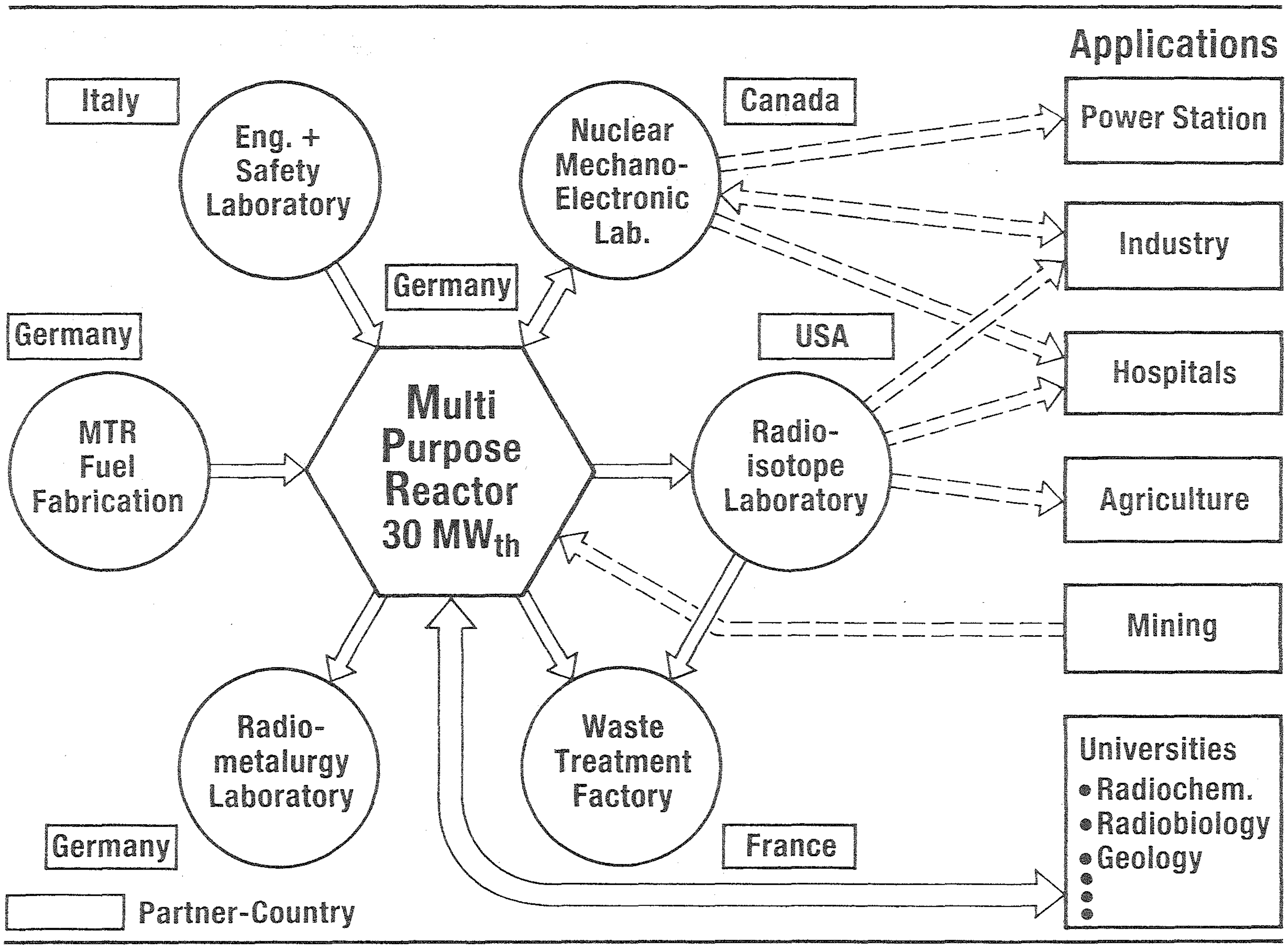
Introduction of Technologies on an Industrial Scale at the 3 Levels in the Establishment of Long-term International Cooperation



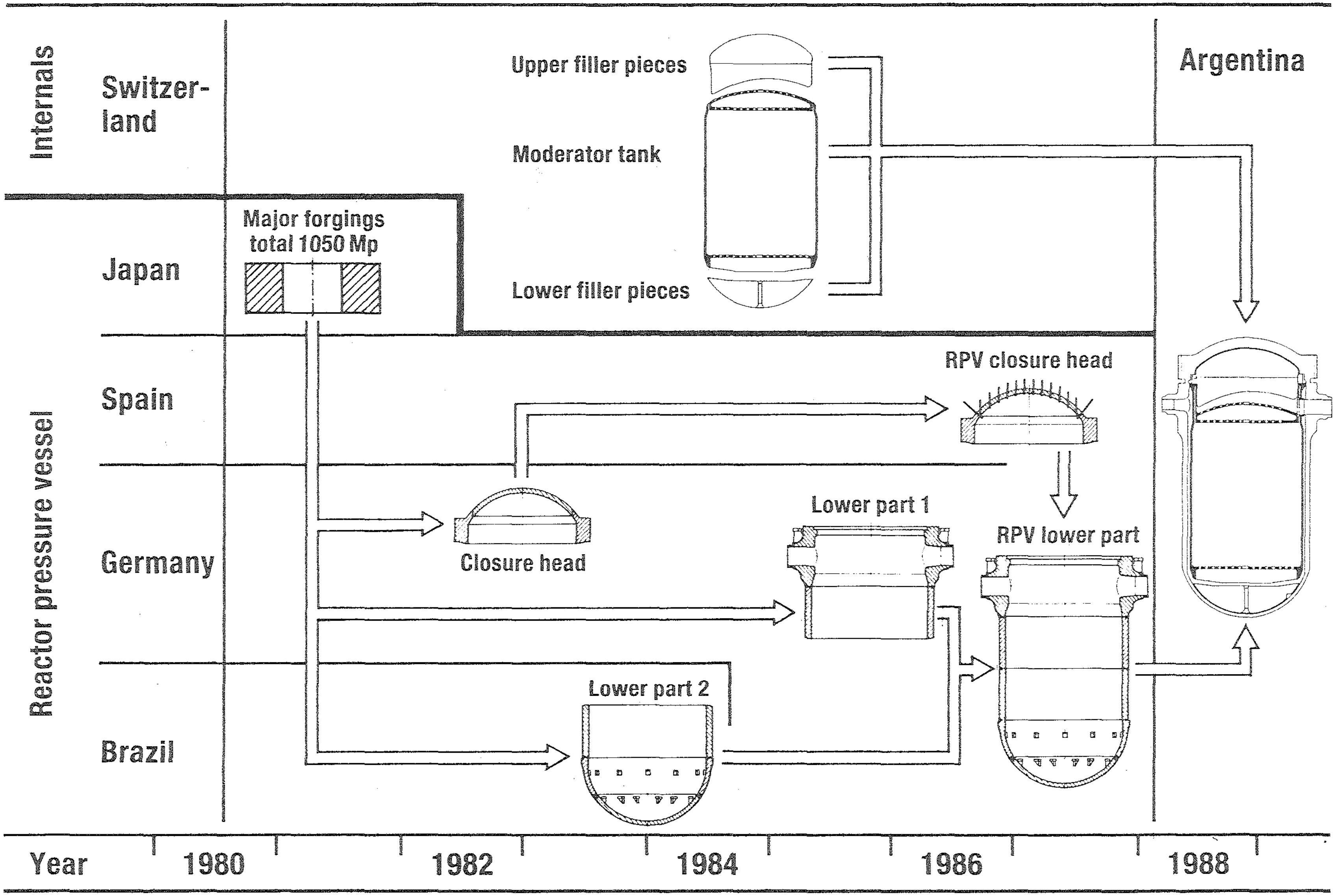
Roles for Government and Industry in Ensuring Economic Electricity Generation



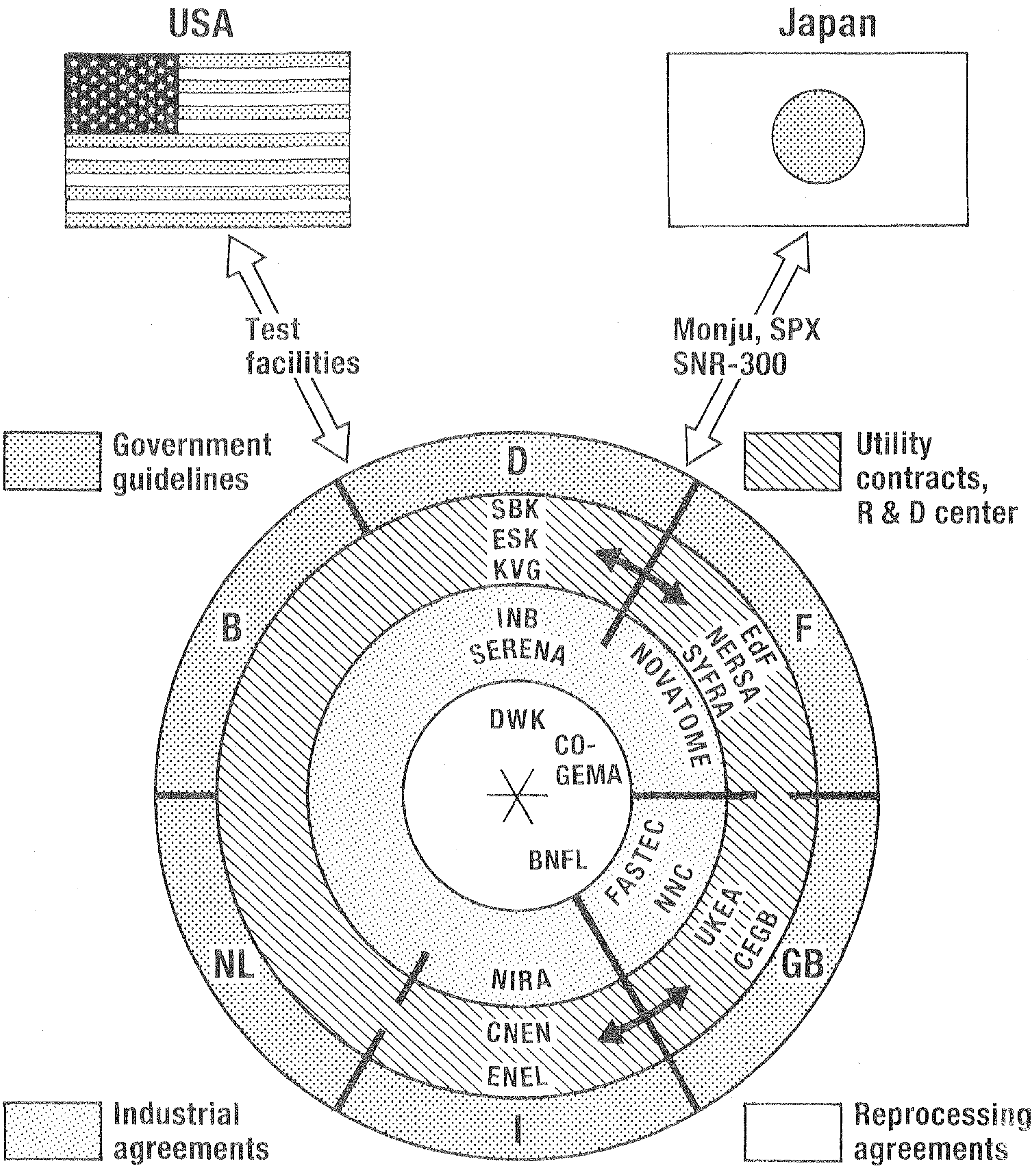
System of Integrated Quality Assurance



International Nuclear Partnership in the PUSPIPTEK-Research-Center SERPONG, Republic of Indonesia

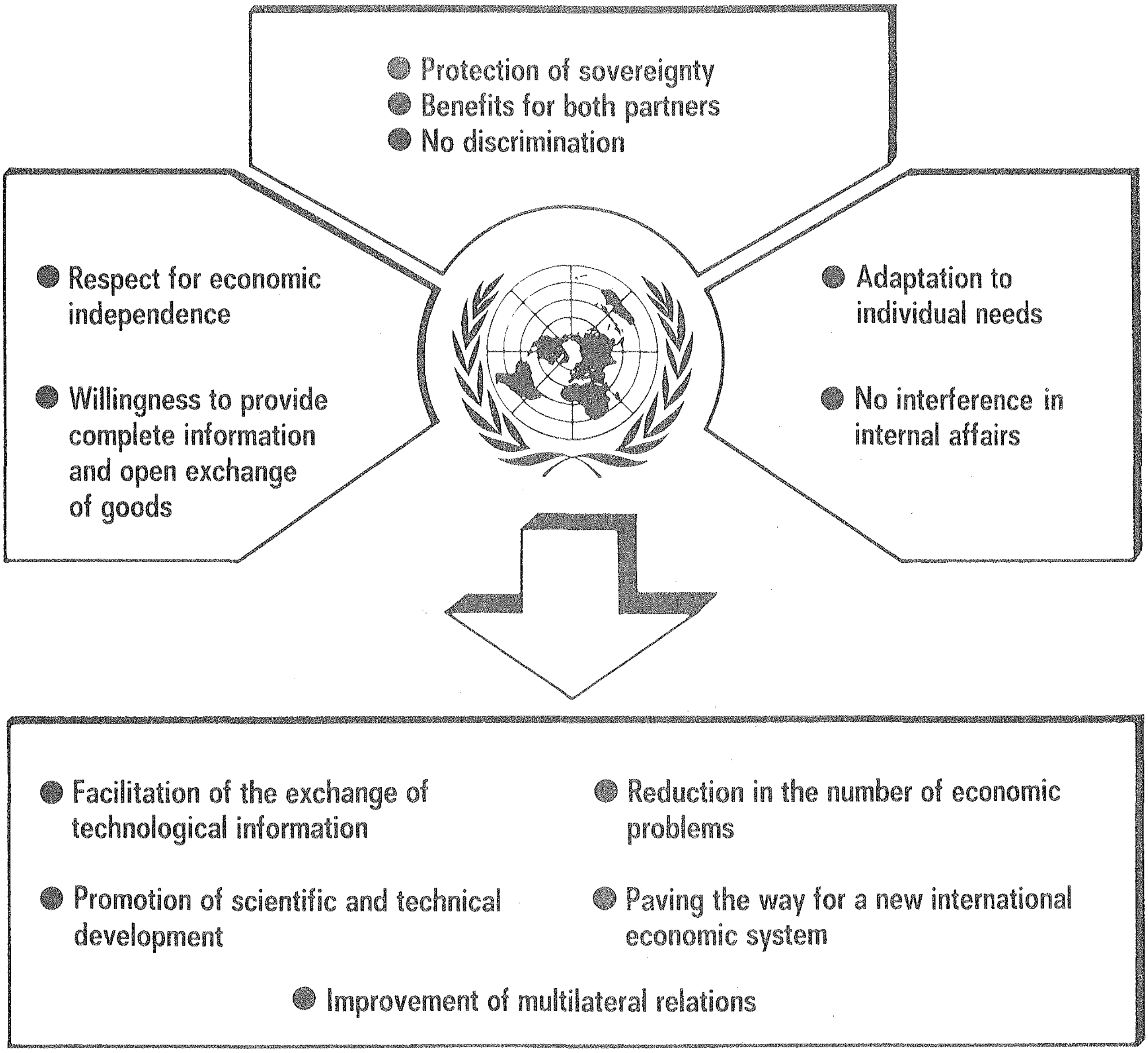


Reactor Pressure Vessel and Internals Atucha II (Argentina)
Manufacturing Steps and Engaged Countries



Envisaged Long Term Fast Breeder Cooperation between European Partners and Japan and the USA

Code of Conduct of the United Nations



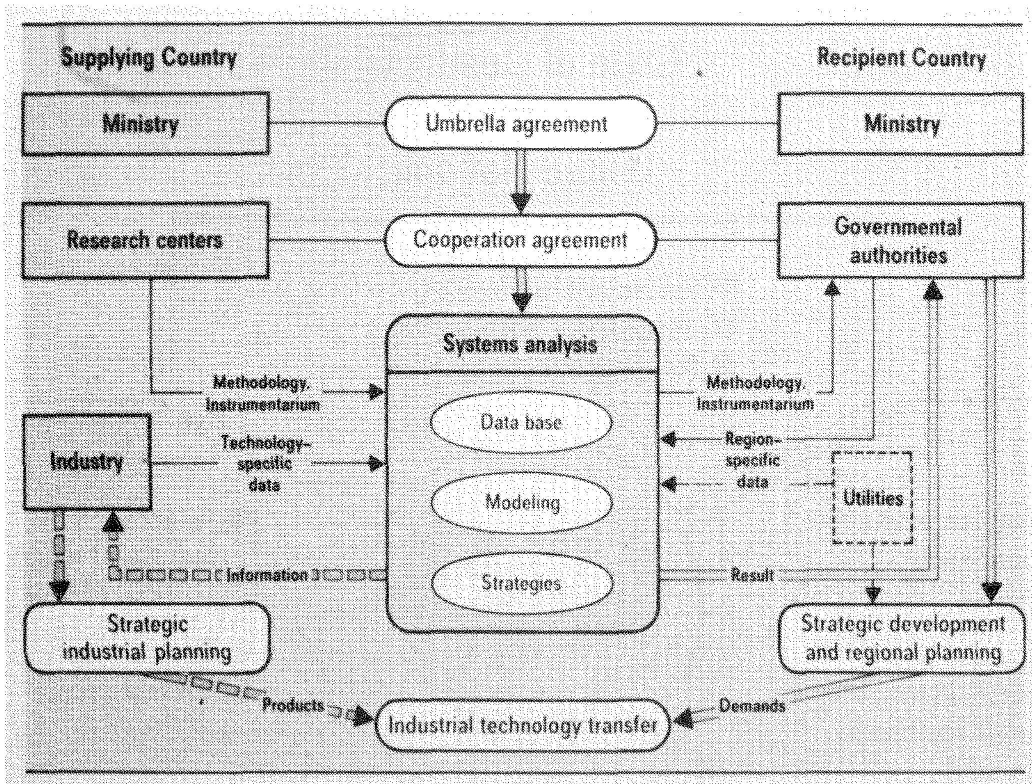
- Protection of sovereignty
- Benefits for both partners
- No discrimination

- Respect for economic independence
- Willingness to provide complete information and open exchange of goods

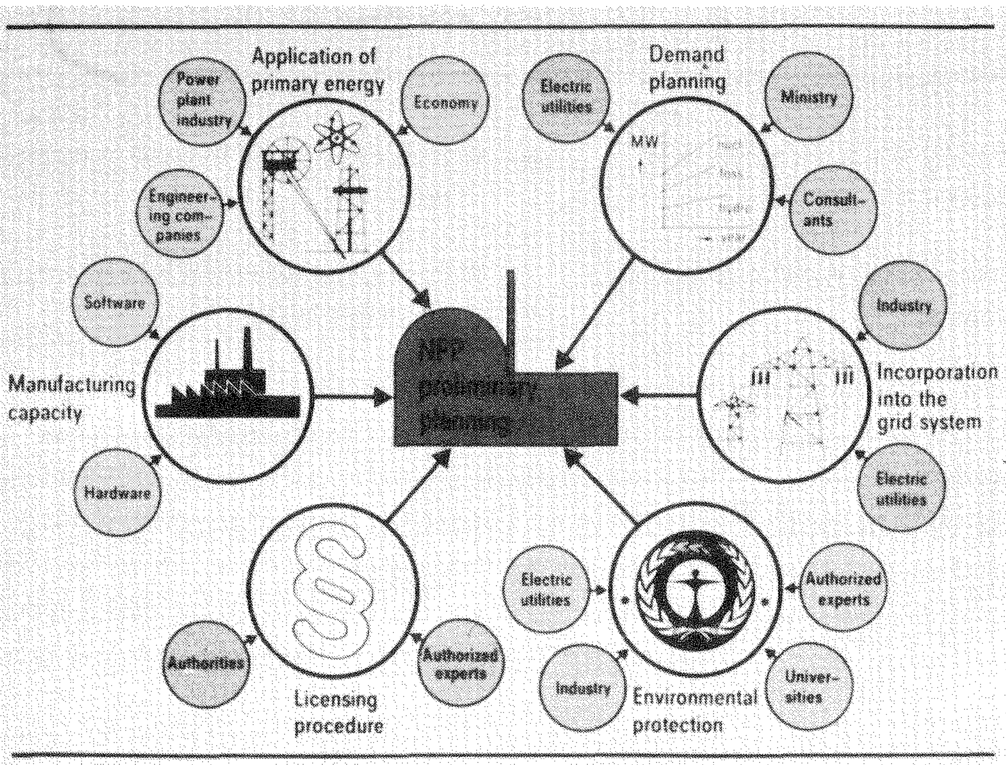
- Adaptation to individual needs
- No interference in internal affairs

- Facilitation of the exchange of technological information
- Promotion of scientific and technical development
- Reduction in the number of economic problems
- Paving the way for a new international economic system
- Improvement of multilateral relations

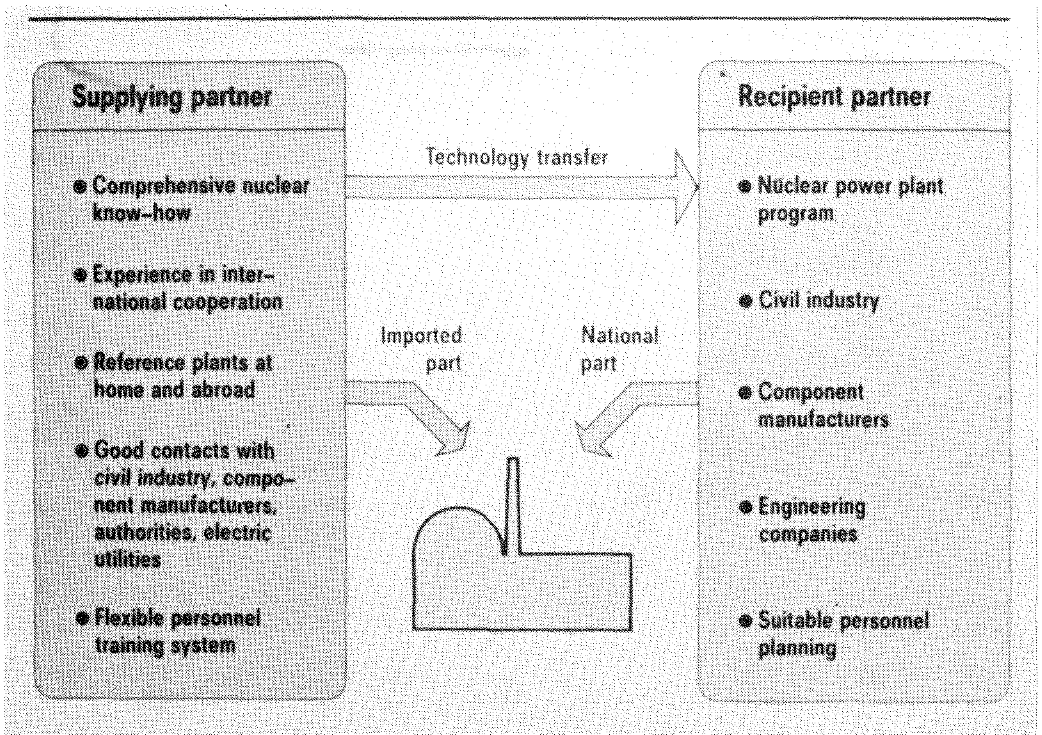
The Good Will of Both Partners is of Decisive Importance for the Implementation of Technology Transfer



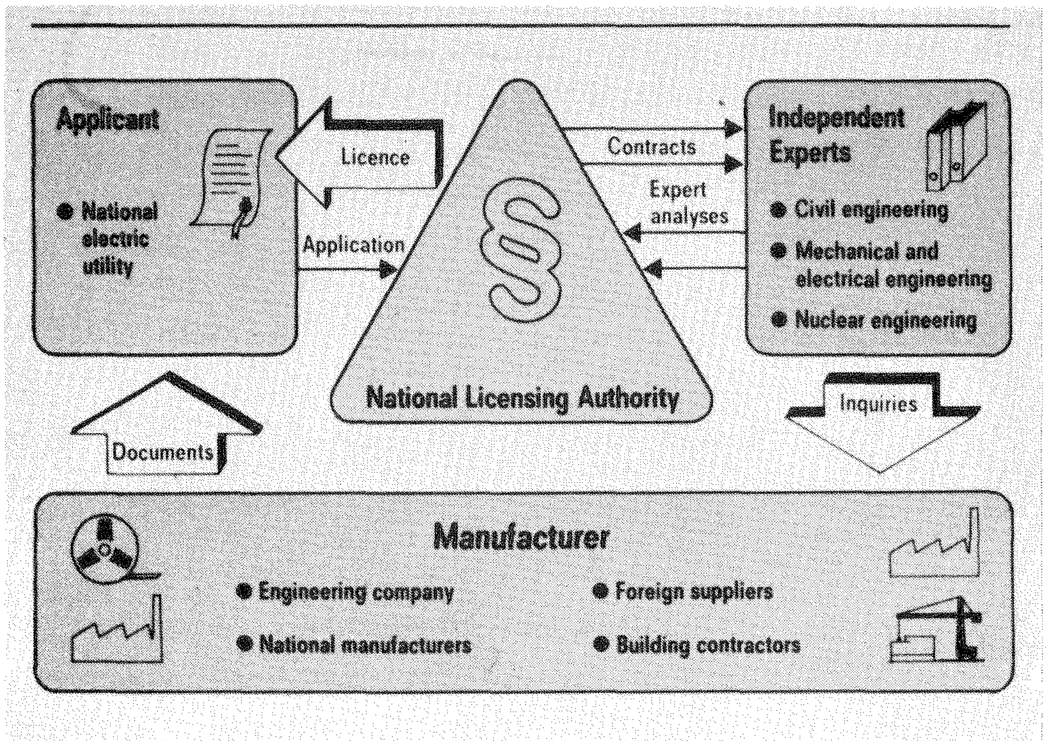
Sequence for Energy Planning as a Preliminary Stage of Industrial Technology Transfer



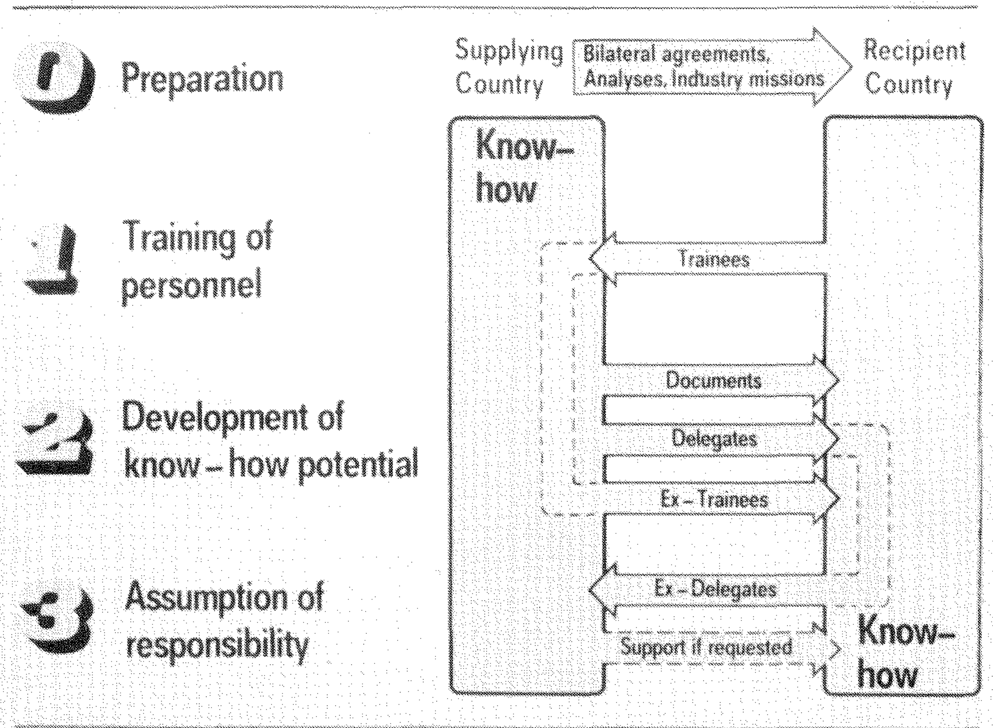
Transfer of Technology in the Preliminary Planning Phase



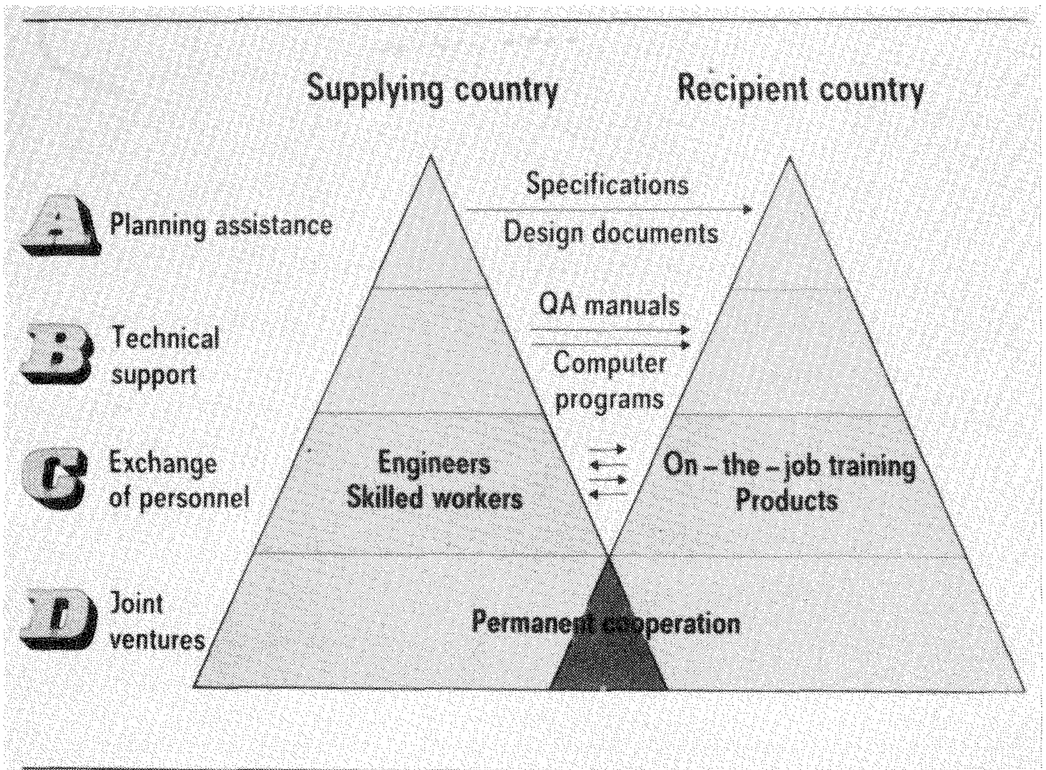
Criteria for Sucessful Implementation of Nuclear Technology Transfer



Interplay between Partners in a Licensing Procedure



Phases of Technology Transfer



Forms of Industrial Cooperation

Nuclear Power Construction in China and International Cooperation

Lu De Xian
President
Beijing Institute of Nuclear Engineering

At the moment of celebrating the 30th Anniversary of Japan Atomic Industrial Forum, on behalf of the Ministry of Nuclear Industry and the Chinese Nuclear Society, I'd like to express warm congratulations to JAIF friends, and sincere greetings to all of the attendants here. Today I am very pleased to have the honor to take the opportunity to talk about the nuclear power construction in China and international cooperation.

As it is known, China is carrying out a large scale economic construction and has an increasing demand on energy supply. As a second ministry of energy in China, the obligation of the Ministry of Nuclear Industry is to supply energy to meet the national demand. China's hydropower resources and coal are abundant, but they are not evenly distributed. Coal resources are mostly found in the north-west area and hydropower resources concentrate in the west-south area. There is the lack of energy in the south-east and other coastal areas of China where the population is dense, industry is well developed and the construction of nuclear power plants are urgently needed to supplement the additional energy demand.

During the period of Seventh Five-Year Plan, while developing fossil power plants and hydropower plants, the State will build nuclear power plants in an orderly fashion according to the priority. At present, China is paying more attention to small and medium sized nuclear power plants. Construction of large-sized nuclear power plant being imported in Daya Bay, Guangdong Province; assimilation of nuclear technology to be transfered; improvement of home-designed 300 MWe PWR nuclear power plant; and construction of 600MWe nuclear power plants--this way will be suitable for China's special case.

First, it is allowed to make full use of the local scientific and technical advantages and the infrastructure of local industry in nuclear field and develop China's nuclear power mainly through our own efforts and also through cooperation with the foreign countries. China has established its own nuclear industry for 30 years and a relatively complete nuclear industry system. We have experience in design, construction and operation of more than ten nuclear reactors. In the South-West Nuclear Power Research Institute there have been installed High Neutron Flux Testing Reactor, experimental coolant loops, some facilities for nuclear fuel research work, and so forth. A lot of research and design work has been done there on the small-sized PWRs. Besides, the other engineering and research institutes of the Ministry of Nuclear Industry also have a competent technical capability. The construction of home-designed Qinshan Nuclear Power Plant, 300MWe PWR, is well under way. The containment has been already erected up to 8m high above the ground. The plant construction will be finished and put into power generation in 1989. We believe that the construction of Qinshan Nuclear Power Plant will build up experience for developing the national nuclear power.

Second, as for building small and medium sized nuclear power plants, the equipment and instrumentation can be localized easily. China's machine building industry fits well in with the construction of small and medium sized nuclear power plants. After being reformed to a certain degree, some local manufacturing factories can produce most of the equipment for the small and medium sized nuclear power plants. Nowadays China has manufacturing experiences with two 600MWe turbine generators for fossil plant. As a result, in the anticipated construction of 600MWe nuclear power plants, the localization rates of the equipment will be increased.

Third, the small and medium sized nuclear power plants have more flexibility to match with electric power grids. Only a few grids out of more than ten power grids today in China can accommodate the nuclear power plant with 1000MWe capacity. The others are rather small. So the 600 MWe nuclear power plants can well fit in with most of the recent power grids in the east and northeast of China.

Finally I would like to emphasize that it is much easier to finance small and medium sized nuclear power plants. Even though the investment cost per KWe for 600MWe nuclear power plant is higher than the one for 1000MWe, the total investment is less. Due to the increasing localization rates, the total cost of such a nuclear power plant will become less than the one for which the whole set of the equipment is to be purchased abroad. Besides, the construction period is rather shorter and easily controlled that is in favor of generating power and regaining investment earlier.

Nowadays many countries, especially developing countries, pay more and more attention to small and medium sized nuclear power plants. Even in the U.S.A. the concept of the nuclear power plants with smaller capacities is under consideration. China also pays more attention to small and medium sized nuclear power plants, because in this way we can fully use the existing competent technical capability and let the existing infrastructure of industry play an important role.

While implementing the nuclear power plant construction program, we also pay attention to the nuclear power research and development work. We will develop advanced thermal reactors and fast breeder reactors in order to make full and rational use of nuclear fuel resources. Recently the Westinghouse of the U.S.A. and the Mitsubishi Heavy Industries of Japan are cooperating in the design and development of an advanced PWR (APWR) that causes great interest in China, such as design objects, design simplification of the fluid systems, improvement of instrumentation and control as well as improvement in piping analysis methodology are all attractive. In China research works on FBR have been already started and it is believed that in the next ten to twenty years FBRs will take a significant position in China's nuclear industry.

As China's commercial nuclear power is still in the beginning phase, it is necessary for us to learn the advanced technology and management experiences from abroad, and enhance international cooperation and technical exchanges. The Chinese government has signed governmental and ministerial nuclear cooperation agreements with many countries. The Ministry of Nuclear Industry of China and the Japan Atomic Industrial Forum signed the "Memorandum on Cooperation in the Field of Peaceful Uses of Nuclear Energy" in September 1981. Since then, the visiting and technical exchange between Sino-Japanese nuclear industry personnel has been increased. Japan has accepted Chinese professional persons as visiting scholars or trainees in Japanese nuclear power plants and research centers. Japan's Power Reactor and Nuclear Fuel Development

Corporation has provided cooperation in surveying China's uranium mineral resources in broad areas of China. Mitsubishi Heavy Industries has received an order on manufacturing a reactor pressure vessel for the Qinshan Nuclear Power Plant.

With the development of China's nuclear power, the localization rates in nuclear power plant construction will be increased further, the international cooperation and technical exchanges will be expanded as well. Currently, during the construction of small and medium sized nuclear power reactors, mainly based on self-reliance, however; technical consultation and co-production of nuclear power equipment with foreign companies; introduction of some key equipments and components from abroad; and personnel training for nuclear power plant operation are still needed. On the other hand, we are willing to cooperate with foreign countries in various ways. China is a developing country, and has her own experiences in nuclear energy utilization and her own infrastructure of nuclear technology and industry. We have the desire to cooperate with foreign countries based on equality and mutual benefit, to exchange experiences, and to learn from the advanced countries. Japan is a neighbor of China. I believe nuclear power cooperation between China and Japan will have very broad prospects.

パネル討論

（大島氏の基調講演に続き，各パネリストが以上のようなキーノートを発表し，その後パネル討論に入った。）

議長：　そこでまず最初に，ここに御出席のパネリストの中で，これまでお話しになったことで，何か特に補足的にコメントあるいは御意見をお持ちの方がおれば，お願いしたいと思います。

ウィリョスマルト：　インドネシアにおける原子力発電の活動が，すでにいくつかのレベルに分かれているということを申し上げたいと思います。大体は研究用の小型原子炉を使っているわけですが，現在いろいろな形で産業用にも使えるような原子炉に移りつつあるところであります。途上国についてはヨーロッパの方々が御説明になりましたように，資金繰りが問題でありまして，途上国が原子力発電所を建設する場合には，いかにその資金を調達するかということが大きな問題になります。

議長：　フレーヴァーさんどうぞ。

フレーヴァー：　中小型炉の途上国における開発についてお話ししたい。これは１０年以上世界中で検討されておりますが，技術的には３００MW以下の小型炉を，安全で信頼性の面においても大型炉と同じ位のものをつくることが可能であります。しかしｋＷｈ当たりのコストの問題がありまして，化石燃料というオルターナティブに比べまして，３００MWの規模ではどうも魅力が薄いということであります。現在化石燃料価格が落ちているということがその一つの原因であります。現在および近い将来において，中小型炉を発電のために使うことが，途上国でも大きな役割を果たすかどうかということが疑問になります。

しかし，地域暖房については，非常に広範囲な室内暖房を地域暖房として使う場合には，１００MWｔから４００MWｔ位が必要になります。この地域暖房用の熱利用炉が近い将来に導入できる可能性はあると思います。それから小型の高温炉でモジュラー型のものを，化学の方のプロセス・インダストリーに導入することができると考えます。例えば蒸気の注入によって石油の回収をするというような形です。

中小型炉による発電はごく限られた状況のもとで初めて化石燃料と競合可能になるとしか考えられません。そうでなければ特に熱を利用するということで，化学的なプロセスと地域暖房に利用できると思います。

議長：　ただ今，御発表の中で中小型炉のことに触れておられるのですが，何かコメントがございますか。

ネグロポンテ：　そうですね議長，やはり問題の解決といいましても，国際協力や技術協力で解決できる問題には限度があると思います。我々ができることは，やはり，その技術を利用するための法律的，技術的なフレームワーク作りをするわけですが，その枠組のもとにおいて，最終的に市場およびコストがどうなるかによって，そのフレームワークを使うか使わないかということになってくるわけです。技術の開発があったとしても，先進諸国が利用するのかまたは途上国が利用するのかということになりますが，皆様方には当然お分かりのように，最終的には原子力技術が世界中でより広範囲に使用されるようになるでしょう。これは疑いの余地がないわけであります。技術的な援助や国際協力でどの位のことができるかということ，つまり触媒作用としての国際協力の役割にはやはり限りがあると思います。

議長：　ジフェレロさんはＩＡＥＡで長らくこの技術援助計画に携わっておられるわけですが，先程の話の中にもあったＩＡＥＡでやっておられる中小型炉の開発援助計画について，また呂さんからお話のあった，あるいはフレーヴァーさんのご意見などに対して何かご意見がございますか。

ジフェレロ：　フレーヴァーさんがおっしゃったことですが，ＩＡＥＡは中小型炉の可能性について２０年間位検討してきております。各地域の調査をしましたが，どうもこの点は残念ながら成功とは言えないわけです。これまで輸出ということを考えましても，インドでは２００～４００MWのものを作っておりますし，その他にＣＭＥＡ（東欧経済相互援助会議）諸国ですが，ソ連のプラントを経済的なベースから考えて可能なレベルのもの（ソ連製）で使っているところもあるわけです。

今新しい傾向が散見されるわけですが，それはもう少し追加的にこの問題をトライしてみてもいいんではないかと，それが正統化できるのではないかと思われる節があります。ネグロポンテさんがおっしゃいましたように，アメリカおよびその他先進工業国の大手の会社，企業からのサポートもあります。

サプライヤー側から考えて，新しい２つの点が出てまいりました。一つは，国内の原子力発電所に対する需要が縮小したため，企業が新たに別の観点から市場のポテンシャルを注視しなければならなくなりました。これまで企業としてフォローできなかったような所に目を向けるようになってきました。例えば輸出にしましても，それは

国内の市場から波及的にスピンオフとして考えられていたわけでありますが，そういうところにも注意を向けまして，中小型炉にも目を向けるようになったわけです。しかし，まだ技術的な不確実要因もあるために，十分に開発が進んでおりません。

先進工業国におきましても，中小型炉はどうかという考え方が徐々に浸透してきております。一つはリスクの分散ということからです。ＴＭＩではもちろん人身の死亡事故はありませんでしたが，企業そのものはほとんど破産状態になったわけで，リスクが大きいわけです。そこで投資のリスクを分散しなければならないということで，完全に投資計画の見直しを始めた国々があるわけです。例えばアメリカのＥＰＲＩ（電力研究所）は今長期研究プログラムで，内在的に非常に安全であり，しかも環境的に安全であり安価であるような中小型炉の開発について評価をしているということで，非常にそれは価値のある目標を掲げていると思います。

今度はバイヤーの方ですが，そこにも一つの革命的なものが起こっていると思います。数年前まではＩＡＥＡにアドバイスを求めてきた途上国のほとんどは，原子力発電所を建設することが，例えば航空路線を引き込むのと同じように一つのステータスシンボルだと考えたわけです。しかし，最近では，人材開発のプログラムおよび適切な科学技術基盤，産業基盤（インフラ）をつくることが必要であると気がつき，これはウィリョスマルトさんもおっしゃったことでありますが，教育的な側面を考慮しなければいけないという認識が広まってまいりました。

そこでＩＡＥＡとしては，別の道をとるということになりまして，つまり加盟国のいろいろなばらばらの要求にあわせるのではなく，その国のプログラムにあわせた形で，加盟国がエネルギーのニーズを満たしていくという観点から評価するやり方を援助しております。発電能力を年間どの位増加させるかということ，例えば，毎年の増分が３００ＭＷｅ位であるならば原子力発電所を建設する見込みは高くなりますが，１００ＭＷｅ以下では非常に薄いという評価をしております。

１９８３年にこういうプロジェクトをスタートさせ，コンサルタントを使いまして二種類のアンケートを行いました。一つはサプライヤー側に，もう一つはバイヤーにアンケートをとったわけです。このアンケートはまったく２つの違った質問を含んでおりまして，これを加盟国に出しまして，２３のサプライヤーからの回答を得ております。例えばデザインコンセプトの詳細についての説明やコスト見積り等を得ております。それにバイヤーの方からは１７の回答が寄せられ，そのうちの１６が途上国か

らのものでありました。こうしたアンケートの結果を分析いたしまたが，これはフレーヴァーさんがおっしゃったように，原子力発電の経済性についてはそれほど良好な結果が出ておりません。これは一時的な状況かも知れませんが，どなたか他の方が現在の石油の状態が永久に続くかどうかを予測できる方がいるかどうか，いないと思いますが。

この我々のプロジェクトの第１フェーズが終わりましたところで，アンケートの調査結果を使い，ポテンシャル・マーケットの概算の予測をいたしました。それと平行して，ＮＥＡが行っている価格の調査と協力をし，どういう要求がＯＥＣＤの先進国からくるかというようなことの答えを出して解析しております。いろいろな仮説をたてておりますので，その結果は暫定的なものにすぎません。中小型炉の市場分析を少しご披露しますと，調査対象年度は１９９２年から２００１年までです。１９９２年というのは，ちょっと長期的でもあると同時に現在の資金市場を考えますと十分に分析に足る近い未来でもあると思います。１９９２年から２００１年までの間に，２５か国位の途上国が，2,000～ 6,000MW位のグリッド（送電網）を持つことができると考えます。

このうち２５か国を特に３つのパラメーターで評価しました。第１は技術的なフィージビリティーで，果たして原子力を導入することがいいかどうかという，これは年間にどの位の発電容量が追加的に必要かということで，１００ＭＷｅ以下の場合についてもそれがペイするかどうかということも含めて，検討しました。第２はその国のインフラの評価であります。人材開発の能力や，産業界のサポート，法規関係，さらには資金調達能力についてであります。第３のパラメーターはどの位の緊急性を持ってその国の担当省庁が原子力発電所を考えているか，つまりコストとの比較において，例えば石油を輸入することのコストがどのくらいになったときに原子力発電所を導入しなければならないかといったようなパラメーターです。そうしますと２５か国のうちの１０か国のみが，我々の意見といたしましては，この調査対象期間の１９９２年から２００１年までの間に原子力発電を導入するということになるそうであります。３００ＭＷレンジの中小型炉について，これが経済性のあるものであれば，もちろん経済性以外の他のパラメーターも考慮しなければならないわけですが，１０か国位に導入される可能性があるという調査結果であります。

それからＩＡＥＡの電力関係の調査の結果にかんがみまして，この１０か国のうち

の21,000MWの発電能力を持っている国で，１９９２年から２００１年までに単基発電出力が３００MWのレンジで５０基位がベースロードをカバーし，そのうちの１５～２０％位が原子力発電所になると思います。これがマーケットとしては7～１０基位の原子炉にあたるということです。またＣＭＥＡ地域では５～６基位のプラントがこの期間に考えられるということで，どちらかと言えば低目に見積っていると思います。我々の調査結果によりますと，トータルマーケットとしてこの１０年間の途上国を見ますと，せいぜい１０～１５基位になると思います。これでもまだ十分に関心のあるマーケットだと思います。

ＯＥＣＤ・ＮＥＡのパラレルスタディーによりますと，マキシマムの状況で２００～３００ＭＷｅで化石燃料，原子力を全部含めて考えますと，1年間に１０基位のレベルになると考えられます。そのうちの1部は中小型炉でまかなうということになると思います。もちろん状況は徐々に変わってきておりますので，もっと慎重に目をすえて，途上国からの可能性ばかりでなく，先進工業国の可能性も考えなければなりません。もちろんこうしたものに対しては，マーケットがあるという結論であります。

大島：　ジフェレロさんのＩＡＥＡの話は大変興味深くうかがいました。私も確か2回位，初期か途中の段階で会議に出たことがありますが，この問題に関連して一つ重要なことは，日本でも確かスタディーがあったと思うのですが，特別に発展途上国の要求にあうような炉というものを目的として開発するという努力はなかなかやれないで，今あるものをスケールダウンするというような形があるんではないかと思うのです。今のお話のように，かなりマーケットがはっきりして，これは大きいか小さいかの問題になるんですが，時には先進国の努力というものをそこへ向けるということが非常に大事ではないか。その場合に努力の向け方の一つに，ただ炉だけではなくて，いろいろなそれに関連するメインテナンスやオペレーションといった問題を含めて考える必要があります。

いろいろ状況が変わってこられたというお話がございましたし，フレーヴァーさんのお話にもそういった中小型炉あるいはＨＴＲの問題が出ていたのですが，ＩＡＥＡの努力と先進国の努力・関心の結び付け方というものを何かもう少し積極的にやる必要があるのではないかと思います。その点に関して，ＩＡＥＡとして何か新しい計画をお持ちでしょうか。結局ＩＡＥＡは国際的機関であり，２国間協力がいろいろ行われますが，その２国間協力とＩＡＥＡの多国間協力等の整合性というのか，共同とい

うのが今後一つの大きな課題ではないかというように思っているわけです。

議長：　先ほどフレーヴァーさんのお話にもありましたように，国際原子力機関の役割というのは，確かに国際協力における触媒的な役割だろうと思うんですね。それで例えば中小型炉について，どこまで具体的な計画に入っていくか，いろいろ要望もあるでしょうし，他方では制約もあるだろうと思います。この辺で時間もだいぶなくなってきましたので，せっかくの機会でありますから，フロアーの方からも何かコメントを出していただければと思っております。ちょうどＩＡＥＡの前事務総長のエクルンド博士がお出でになっておられると思いますので，エクルンド名誉事務総長からひとつ何かいただけましょうか。

エクルンド：　議長どうもありがとうございます。今朝のセッションで経済的に成立する原子力産業というふうな話をしておりました。一つのマーケットとしての開発途上国ということを，もう一度考えてみたいと思います。ＩＡＥＡとしても私自身も，この会議でそういった問題をもちろん取扱いたいと思います。私からしますと，ここ２，３時間，現実的な状況の評価というものがなされていると思います。１５０以上の国連の加盟国があり，その中で２６か国が原子力発電を行っております。ここ２，３年のうちにあと３か国（メキシコ，フィリピン，キューバ）がこのグループに加わることでしょう。しかし，もうちょっと将来を見てみますと，フレーヴァーさん，ネグロポンテさん，ウィリョスマルトさん，ジフェレロさんがすでにおっしゃいましたように，その発展というのはテンポの遅いものでありましょう。その一つが中小型炉ということになろうかと思います。これは非常に真剣に考えるべきことだと思います。このような中小型炉というものがどこでつくられ，そして何らかの経験が積まれていくことになろうと思います。

もう一つの重要な問題としては，受け入れ国のインフラストラクチャー（産業基盤）ということになります。今や 2,000人以上の人がＩＡＥＡで訓練を経ているということは，非常にすばらしいことだと思います。他方，しかしながら，はっきりしていることは，実際に運転を担当しメインテナンスを検討する人のことを考えてみますと，原子炉というものは非常に複雑なものであり，そういった人はやはり技術的に直接体験をした人でなければならないと思います。そういうふうな能力が達成されるまでには時間がかかると思います。そうしますと，原子力が発展途上国でどういうふうに発展していくかということは，先進工業国の状況にも依存するのではないかと思います。

つまり，これからの２０～３０年間，注文あるいは援助という形で係わってきます。１９７０年代中期以降そういうふうな形になってきていると思います。この原子力産業の発展が途上国でどうなるかということを考えてみますと，成長のテンポは非常に遅いものでありましょう。経済的要因，それから必要性，つまり運転する能力の必要性ということから考えて，そういうふうに思います。

議長：　それでは，もうひとかた，アジアにおいて原子力発電をすでに実施している有力な国の一つである韓国から，韓国原子力産業会議の前副会長だった金さんがお見えになっておるかと思いますが，金鍾珠さんよろしくお願いします。

金：　どうも議長ありがとうございます。パネリストの方ありがとうございます。この国際協力ということで非常に励まされております。

まず私のコメントの冒頭に，ごく大まかに，私共の韓国における原子力産業について述べたいと思います。今５基，4,000MWが運転しております。４基，3,800MWが建設中です。それから２基が今提案の段階で，評価の過程にあります。技術の移転，自立，設計等の原子力工学の自立ということを強調しております。開発途上国にとりまして，原子力産業を始めるときにいろいろ重要な要因があるんですけれども，これらはすでにパネリストの方がおっしゃったことです。

しかし，私はここでもう少し別の点を強調したいと思います。それは，原子力の平和利用の重要性の理解，認識ということであります。国のトップに立つ大統領あるいは首相といった人がその重要性を認識することがきわめて大切だと思います。私共がこの原子力についての研究を始めましたのは１９５７年です。もしよろしければ少し我々の歴史を語らせていただきたいと思うのですが。１９５６年にシスラーさんが，お昼の午餐会でもご挨拶をされましたが，韓国に来られ，私共の韓国電力会社にも来られました。そして，ひとつ話をされました。これは非常に希望に満ちたものでありました。原子力の将来の希望というものを述べられました。この再生可能なエネルギー源としての可能性でありました。その話をうかがいました者は非常な関心を抱いたわけであります。その後でシスラーさんが大統領を訪れ，同じことを説明されました。注意深く我々の大統領は聞きまして，シスラーさんにこうたずねました。いつこの原子力発電所を持てるでしょうか。シスラーさんはこうおっしゃいました。今から正当で正しい準備をしていけば，つまり原子力関係の政府の役所をつくって，いろんな選択をし，若い科学者，エンジニアの訓練をしていけば，２０年後には原子力発電所が

できるだろうということを言われました。私共の最初の原子力発電所が１９７８年にできております。（ですから実際には２１年ということで，わずか１年間のエラーでありました。）

韓国の歴史を今申し上げたのですけれども，それはなぜかと言いますと，一つ強調したいのは国際協力なくしては，つまり先進国からの援助がなければ，この原子力産業をスタートさせることができないということです。そして先進国の方も原子力というものを強力に進めていく。それから途上国の方が原子力の必要性というものを認識する。これがきわめて必要であります。それからＩＡＥＡが１９６０年代に一つのチームを送られまして，韓国において原子力発電所の立地を調査して下さいました。この調査団の勧告に基づきまして，我々は１号機の場所を選んだわけであります。これもまた国際協力の一つの例だと思います。

韓国と他の国との関係には深いものがあります。我々は，日本と韓国との協力関係の一つの表れとして，互いに合同セミナーを日本，韓国の順に毎年開いております。それからまた強力な協力，支持をカナダ，フランスそれから台湾からも得ております。途上国にとりまして，少しばかり原子力発電あるいは原子力産業の経験があるところもあるでしょう。

ここで強調したいことは，国際協力がやはり大事であるということです。原子力発電所のコストの削減もそうだし，安全性や廃棄物の管理についても，同じことが言えると思います。先進国と途上国の国際協力については，十分論議されていることと思います。韓国，台湾，あるいは南アメリカの国の中では，先進国から原子力の技術を受け入れ，消化，吸収したというところもあるでしょう。このような経験は，他の途上国もまたやっていけるものだと思います。原子力産業を起こしたいという国にとりましてはこのような経過をやはりたどることができるでしょう。他の方も強調されましたように，国際協力というものは不可欠であります。これは先進国にとっても途上国にとってもそうであります。互いに助け合うだけではなくして，互いに守りあうという点でも大切だと思います。

議長：　他にもまだ御意見があるかと思いますが，ちょうど予定した時間になってまいりましたので，このあたりで議長のとりまとめをやらせていただきたいと思います。

本日のセッションは２１世紀を見通した国際協力についての問題を取上げました。国際協力と申しましても，従来から非常によく行われております先進工業国間の国際

協力ももちろん大事でございますけれども，これから２１世紀へ向けての世界の情勢を考えますと，先進工業国と発展途上国との間の国際協力をどのように進めるかということは，非常に大きな問題であろうと思います。そういう意味で各パネリストからいろいろ適切なコメントをいただき，さらにフロアーからもエクルンド博士ならびに金前副会長からも有益な御意見をいただいたことを感謝いたします。

発展途上国と先進諸国の間の国際協力の動向といたしましては，もちろんこれまでも行われてきております原子力のノン・パワー・ユース，いわゆるアイソトープ・放射線利用分野の協力の推進はございますけれども，やはり２１世紀のエネルギー事情，あるいはその時の原子力発電の必要性が拡大していくことなどを考えますと，発展途上国側におきましても，お隣の中国などからの例もございましたように，今後原子力発電を推進していくことになると思いますので，そういった面での国際協力，特に技術移転の問題がどのように有効に円滑に行われるかということが大きな問題だと思われます。

そのような有効な国際協力を進展させるためには，もちろん経験を有する先進工業国からの技術移転がうまくいくことが一番大事でありますけれども，同時に本日は時間の関係もありまして，十分な討論ができませんでしたが，資金面の問題，フレーヴァーさんが確かアジア開発銀行の活用というようなことも示唆されましたが，そういうような資金面での問題，国際協力の枠組づくり，これはＩＡＥＡからもご説明がございましたが，そういった面についても，この際，２１世紀をめざしてのしっかりした戦略を持つ必要があるように思ったわけであります。

具体的には，特に発展途上国との今後の原子力発電分野における協力において，中小型炉の開発ということが討論の焦点として取上げられました。いろいろのご意見がございましたように，中小型炉の開発にはメリットもある反面，一種のデメリットもあります。その一つは，経済性の問題です。ただ経済性といっても，先進工業国における経済性と発展途上国における経済性は，必ずしも同じものではないかも知れません。そういった意味で，今後の先進工業国と発展途上国の間の協力の一つのポイントとしてこの問題にどういうふうに取り組んでいくか，ということが今後の課題の一つであろうかと思われるわけであります。

一方，先進工業国間の協力につきましては，各メンバーから高速増殖炉ならびに核融合のような，いわゆるアドバンスト・ニュークリアー・テクノロジーの国際協力の

必要性が述べられました。核融合のような非常に長期の研究開発を必要とするものは当然でありますが，現在の情勢からみましても，高速増殖炉の開発ということにつきまして，今後これまで以上の国際協力が進展されることが，２１世紀にわたっての原子力エネルギーの地球規模での発展ということにはやはり必要であるかと思います。

昨日のご講演でコロンボさんが２０５０年までの見通しを述べられましたが，軽水炉時代と言われますけれども，やはり先をみた新しい原子炉の研究開発という点についての一層の国際協力が望まれると思われます。

以上，たいへん要領を得ませんでしたけれども，この本日のセッションのとりまとめをいたしますが，最後に，これも，フレーヴァーさんが申されたとおり，いかなる国際協力もその底に「グッド・ウィル」（good will）がなければ発展しないものであります。今後国際社会面において，原子力分野における「グッド・ウィル」がさらに発展することを期待いたしまして，このセッションを終わりたいと思います。長時間どうもありがとうございました。