THE 22ND JAIF ANNUAL CONFERENCE

第22回原産年次大会

APRIL 12～14, 1989

JAPAN ATOMIC INDUSTRIAL FORUM

日本原子力産業会議

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第２２回原産年次大会総括プログラム

基調テーマ：原子力と人間社会 ── その融和をめざして

平成元年４月１２日（水）～１４日（金）

於　東京郵便貯金ホール（東京都港区芝公園）

	第　１　日 ４月１２日（水）	第　２　日 ４月１３日（木）	第　３　日 ４月１４日（金）
午前	<u>開会セッション</u> 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	<u>セッション２</u> 「社会のなかの原子力」 （講演とパネル討論）	<u>セッション４</u> 「スウェーデンの脱原子力政策をめぐって」 （講演とパネル討論）
午前	<u>セッション１（前）</u> 「現代史における原子力：その使命と課題」		
午後	（昼休み）	<u>午餐会</u> 通商産業大臣所感 〔特別講演〕 ………………………………… 原子力映画上映	（昼休み）
午後	<u>セッション１（後）</u> （講　演）	<u>セッション３</u> 「原子力技術の新展開」 （映像と解説）	<u>セッション５</u> 「原子燃料新時代へ向けて」 （講　演） <u>閉　会　挨　拶</u>
午後	<u>レセプション</u>		

４月１２日（水）

開会セッション（9:30〜10:20）

議長：林　政義　　動力炉・核燃料開発事業団理事長

大会準備委員長挨拶

岸田純之助　　（財）日本総合研究所会長

原産会長所信表明

圓城寺次郎　　（社）日本原子力産業会議会長

原子力委員長所感

宮崎茂一　　原子力委員会委員長，科学技術庁長官

セッション１「現代史における原子力：その使命と課題」（10：20〜17：40）

議長：中野友雄　　北海道電力㈱会長

「原子力開発の世界的意義と課題」

Ｈ．ブリックス　　国際原子力機関（ＩＡＥＡ）事務局長

「原子力界への女性の参加」

Ｇ．ド．プランク　　米国原子力学会（ＡＮＳ）会長

「エネルギー確保と原子力発電の役割」

Ａ．クルンニクル　　チェコスロバキア燃料・エネルギー大臣

議長：関本忠弘　　日本電気㈱社長

「原子力開発の今日的な意義 ── 原子力は人間社会に貢献できるか」

那須　翔　　電気事業連合会会長，東京電力㈱社長

「２１世紀へ向けてのエネルギー確保と原子力の役割」

Ｊ．Ｄ．レビ　　フランス工業省エネルギー資源庁長官

「ソ連の軽水炉開発計画と安全性向上対策」

Ａ．Ｌ．ラプシン　　ソ連原子力発電省次官

議長：飯田庸太郎　　三菱重工業㈱社長

「パキスタンにおける原子力開発：政策、展望ならびに課題」

Ｍ．Ａ．カーン　　パキスタン原子力委員会委員長

「本格化する中国の原子力発電開発」

黄　斉陶　　中国原子力工業総公司副総経理

「グラスノスチとソ連の原子力開発」

Ｖ．Ｓ．グーバレフ　　ソ連「プラウダ」紙科学部長

レセプション　18：00〜19：30

於：東京プリンスホテル２階「鳳凰の間」

４月１３日（木）

セッション２「社会のなかの原子力」(9：30～12：30)

議長：柳　瀬　丈　子　　　　フリージャーナリスト

＜講　演＞
「原子力論争この一年」
田　原　総一朗　　　　評論家
「わが国の市民運動の特徴」
田　中　靖　政　　　　学習院大学法学部教授

＜パネル討論＞
パネリスト
小　中　陽太郎　　　　作家
犬　養　智　子　　　　評論家
山　﨑　　　魏　　　　中部電力㈱副社長
田　原　総一朗　　　　評論家
田　中　靖　政　　　　学習院大学法学部教授

午餐会 (12：50～14：50)　於：東京プリンスホテル２階「鳳凰の間」

通商産業大臣所感
三　塚　　　博　　　　通商産業大臣
特別講演　「現代人の生き方」
曽　野　綾　子　　　　作家

原子力映画上映 (13：30～14：40)　於：東京郵便貯金ホール

・世界との対話　ＯＳＡＲＴ
・原燃サイクルと地域社会（フランスの実情）
・巨大地震に耐える（第３部）－ＢＷＲ原子炉格納容器－

セッション３「原子力技術の新展開」(15：10～18：00)

議長：長谷川　謙　浩　　　　川崎重工業㈱会長
「燃料供給技術 ── ウラン濃縮と改良型乾式転換法」
Ｗ．Ｌ．ウィルキンソン　イギリス原子燃料公社（ＢＮＦＬ）副社長
「ＦＢＲ燃料サイクル技術」
佐々木　壽　康　　　　動力炉・核燃料開発事業団理事
「未来のための革新的設計の液体金属炉」
Ｂ．ウォルフ　　　　　ゼネラル・エレクトリック社（ＧＥ）副社長

議長：玉　置　正　和　　　　千代田化工建設㈱社長
「原子燃料のリサイクル利用 ── 技術革新への挑戦」
Ｒ．ラルマン　　　　　フランス原子力庁（ＣＥＡ）原子力研究開発計画局長
Ｊ．Ｐ．ルジョー　　　コジェマ社（フランス核燃料公社）副社長
「原子力ロボット」
井　元　一　彦　　　　極限作業ロボット技術研究組合技術委員会原子力部会長

議長：原　　　禮之助　　　　セイコー電子工業㈱社長
「クリーンな環境をつくる放射線」
町　　　末　男　　　　日本原子力研究所高崎研究所長
「がん治療での放射線の医学利用の最前線」
柄　川　　　順　　　　国立がんセンター病院放射線治療部長

４月１４日（金）

セッション４「スウェーデンの脱原子力政策をめぐって」(9：30〜12：30)

議長：　生田豊朗　　（財）日本エネルギー経済研究所理事長

＜講　演＞

「スウェーデンのエネルギー政策」
　Ｈ．ローデ　　スウェーデン・エネルギー庁長官

「産業および国際的視点からみたスウェーデンのエネルギー政策」
　Ｌ．ﾌｫｰｹﾞﾙｼｭﾄﾛｰﾑ　　ＡＢＢアトム社社長

「スウェーデンのエネルギーの将来：政策ｖｓ政治」
　Ｔ．Ｒ．ヤールホルム　　ストックホルム大学教授

＜パネル討論＞

講演者ならびにつぎのパネリストによる

Ｂ．ハリス	米国エネルギー啓発協議会(USCEA) 副理事長
Ｊ．Ｄ．レビ	フランス工業省エネルギー資源庁長官
末次克彦	日本経済新聞論説委員
秋山喜久	関西電力㈱専務取締役

＜議長まとめ＞

セッション５「原子燃料新時代へ向けて」(14：00〜17：00)

議長：　小林庄一郎　　関西電力㈱会長，㈳日本原子力産業会議副会長

「技術による世界の変容と燃料サイクル」
　Ｊ．Ｎ．ヨーケルソン　　米国国際戦略問題研究所副理事長

「原子力産業の環境影響総合評価」
　Ｄ．Ｂ．キーロック　　米国ﾊﾞｯﾃﾙ・ﾊﾟｼﾌｨｯｸ・ﾉｰｽｳｪｽﾄ研究所副所長

「科学技術としての原子燃料」
　鈴木篤之　　東京大学工学部教授

「原子力の人間論的展望 ― その思想論的位置づけの試論」
　Ｋ．リーゼンフーバー　　上智大学哲学科教授

＜議長コメント＞

閉会挨拶

　小林庄一郎　　関西電力㈱会長，㈳日本原子力産業会議副会長

22ND JAIF ANNUAL CONFERENCE

PROGRAM

—— BASIC THEME ——

TOWARD HARMONY OF NUCLEAR ENERGY AND HUMAN SOCIETY

12-14 April 1989
Tokyo Yubinchokin Hall

WEDNESDAY, APRIL 12

9:30am - 10:20am
OPENING SESSION

Chairman:
Masayoshi Hayashi
President
Power Reactor and Nuclear Fuel Development Corporation

Remarks by Chairman of Program Committee
Junnosuke Kishida
Honorary Chairman
Japan Research Institute

JAIF Chairman's Address
Jiro Enjoji
Chairman
Japan Atomic Industrial Forum

Remarks by Chairman of Atomic Energy Commission
Moichi Miyazaki
Chairman
Atomic Energy Commission
Minister of State for Science and Technology

10:20am - 12:20pm

SESSION 1: NUCLEAR ENERGY IN MODERN HISTORY: MISSIONS AND ISSUES

Chairman:

Tomoo Nakano
Chairman
The Hokkaido Electric Power Co., Inc.

"The World's Needs for Nuclear Power"
Hans Blix
Director General
International Atomic Energy Agency

"Women's Entry into the Nuclear Community"
Gail de Planque
President
American Nuclear Society

"The Role of Nuclear Energy for Energy Security in CSSR"
Antonin Krumnikl
Minister of Fuel and Energy
Czechoslovakia

Chairman:

Tadahiro Sekimoto
President
NEC Corporation

"Meaning of Nuclear Power Development in Today's World : Can Nuclear Energy Contribute to Society of Mankind ? "
Shoh Nasu
Chairman
The Federation of Electric Power Companies
President
The Tokyo Electric Power Company., Inc.

"Assurance of Energy Sources and the Role of Nuclear Power for the 21st Century"
Jean- Daniel Levi
Director General
Energy and Raw Materials
Ministry of Industry
France

"The Main Guideline and Technical Measures with the Purpose of Improvement of the Safety of Nuclear Power Plants with VVER-1000 Reactors"
Alexandor L. Lapshin
Deputy Minister
Ministry of Nuclear Power
USSR

Chairman:

Yotaro Iida
President
Mitsubishi Heavy Industries, Ltd.

"Nuclear Energy Development in Pakistan -- Policy, Prospects and Problems"

Munir A. Khan
Chairman
Pakistan Atomic Energy Commission

"Starting the Development of China's Nuclear Power"

Qi-Tao Huang
Vice President
China National Nuclear Corporation

"Glasnost and Nuclear Power Development in the Soviet Union"

Vradimir S. Guvalev
Science Editor,
"PRAVDA"
USSR

6:00pm - 7:30pm

JAIF CHAIMAN'S RECEPTION

Room " HO-O "
2nd Floor, TOKYO PRINCE HOTEL,

THURSDAY, APRIL 13

9:30am - 12:30pm

SESSION 2: NUCLEAR POWER AMONG SOCIETY (Lectures and Panel)

Chairwoman:

Takeko Yanase
Journalist

Lectures:

"Nuclear Disputes in the Past One Year"

Soichiro Tahara
Critic

"Characteristics of Current Anti-Nuclear Protest Groups in Japan"

Yasumasa Tanaka
Professor
Gakushuin University

Panelists:

Yotaro Konaka
Writer

Tomoko Inukai
Critic

Takashi Ymazaki
Executive Vice President
Chubu Electric Power Co., Inc.

Soichiro Tahara
Critic

Yasumasa Tanaka
Professor
Gakushuin University

12:50pm - 2:50pm

LUNCHEON

Room "HO-O"
2nd Floor, TOKYO PRINCE HOTEL

Remarks:

Hiroshi Mitsuzuka
Minister for International Trade and Industry

Special Lecture:

"Life of Modern People"
Ayako Sono
Writer

1:30pm - 2:40pm

FILMS

CONFERNCE HALL

Most recent films on nuclear power development will be shown.

3:10pm - 6:00pm

SESSION 3: NEW PROSPECTS OF NUCLEAR TECHNOLOGIES

Chairman:

Kenko Hasegawa
Chairman
Kawasaki Heavy Industries, Ltd.

"Fuel Supply Technologies: Uranium Enrichment and Integrated Dry Route"
William L. Wilkinson
Deputy Chief Executive
British Nuclear Fuels plc

"FBR Fuel Cycle Technology "
Toshiyasu Sasaki
Executive Director
Power Reactor and Nuclear Fuel Development Corporation

"An Innovative LMR Design for the Future"
Bertram Wolfe
Vice President
Nuclear Energy Operations
General Electric Company

Chairman:

Masakazu Tamaki
President
Chiyoda

"Nuclear Materials Recycling: The Great Challenge"

Robert Lallement
Director for Nuclear R and D Programs
Commissariat a l'Energie Atomique
Jean-Pierre Rougeau
Vice President
Compagnie Generale des Matieres Nucleaires
France

"Nuclear Power Robot"

Kazuhiko Imoto
Chairman
Subcommittee on Nuclear Power Plant
Technology Committee
Advanced Robot Technology Research Association

Chairman:

Reinosuke Hara
President
Seiko Instruments Inc.

"Radiation Technology for Clean Environment"

Sueo Machi
Director General
Takasaki Radiation Chemistry Research Establishment
Japan Atomic Energy Research Institute

"Recent Trend of Medical Use of Radiation in Cancer Therapy"

Sunao Egawa
Chief
Dept. of Radiation Therapy
National Cancer Center Hospital

FRIDAY, APRIL 14

9:30am - 12:30pm

<u>SESSION 4: ON NUCLEAR PHASE-OUT POLICY OF SWEDEN (Lectures and Panel)</u>

Chairman:

Toyoaki Ikuta
President
Institute of Energy Economics, Japan

Lectures:

"Sweden's Energy Policy "

Hans Rode
Director General
Swedish National Energy Administration

"The Swedish Energy Policy in an Industrial and International Context"

Lennart Fogelstroem
President,
ABB Atom AB
Sweden

"Sweden's Energy Future--Policy vs Politics"

Tor R. Gerholm
Professor
The University of Stockholm
Sweden

Panelists: (In addition to the above Speakers)

Bill Harris
Senior Vice President
US Council for Energy Awareness

Jean- Daniel Levi
Director General
Energy and Raw Material
Ministry of Industry, France

Katsuhiko Suetsugu
Editorial Writer
The Nihon Keizai Shimbun

Yoshihisa Akiyama
Senior Managing Director
The Kansai Electric Power Co., Inc.

General Comments by Chairman

2:00pm - 5:00pm

SESSION 5: TOWARD NEW ERA OF NUCLEAR FUEL

Chairman:

Shoichiro Kobayasi
Chairman
The Kansai Electric Power Co., Inc.
Vice Chairman
Japan Atomic Industrial Forum

Lectures:

"The Nuclear Fuel Cycle and Global Technological Change"
John N. Yochelson
Vice President
Center for Strategic & International Studies
USA

"Environmental Issues of the Nuclear Industry"
Dennis B. Cearlock
Director
Battele Pacific Northwest Laboratories
USA

"Nuclear Fuel Seen from the Aspect of Scientific Technology"
Atsuyuki Suzuki
Professor
The University of Tokyo

"Atomic Energy in an Anthropological Perspective: Towards an Evaluative Understanding of the Place of Nuclear Technology"
Klaus Riesenhuber
Director
Institute of Medieval Thought
Professor
Dept. of Philosophy
Sophia University

General Comments by Chairman

CLOSING REMARKS:

Shoichiro Kobayashi
Chairman
The Kansai Electric Power Co., Inc.
Vice Chairman
Japan Atomic Industrial Forum

開会セッション

大会準備委員長挨拶
（財）日本総合研究所会長
岸　田　純之助

原産会長所信表明
（社）日本原子力産業会議会長
圓城寺　次　郎

原子力委員長所感
原子力委員会委員長，科学技術庁長官
宮　崎　茂　一

大会準備委員長挨拶

㈶日本総合研究所

会長　岸田純之助

ご臨席の皆様、第２２回原産年次大会の開催にあたり、大会準備委員会を代表してご挨拶を申し上げる機会を得ましたことを、大変光栄に存じます。

本日は、国内から宮崎茂一国務大臣・原子力委員会委員長、また海外からはブリックス国際原子力機関（ＩＡＥＡ）事務局長、ドプランク・アメリカ原子力学会会長、クルンニクル・チェコスロバキア燃料・エネルギー大臣、レビ・フランス工業省エネルギー資源庁長官、ラプシン・ソ連原子力発電省次官、カーン・パキスタン原子力委員会委員長、ローデ・スウェーデン・エネルギー庁長官をはじめとする国際機関、各国政府代表、ならびに国内外の多くの権威者の皆様のご参加を得まして、本年次大会をここに開催する運びとなりましたことを深く慶んでおります。

ここにあらためて、本年次大会における議長、スピーカーをご快諾戴きました大会関係者各位に厚くお礼を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皆様に、深甚なる感謝の意を表する次第であります。

今年はスリーマイルアイランド事故から１０年が経過し、チェルノブイリ事故からまもなく３年目を迎えようとしております。その影響はいまも残り、むしろ拡がりを増しているところもあるように思われます。わが国では最近原子力反対運動がきわだった盛り上がりをみせております。また、海外の一部の国では原子力発電からの撤退の動きも出始めるなど、原子力問題が政治の場のみならず、女性や若い人々を含め一般の人々の間でもより活発に議論されております。

今日、原子力は単にエネルギー問題、技術の問題としてよりも、人間社会と原子力は共存できるのかというところまでさかのぼって問題提起されております。原子力は人間性に適応しないとの指摘も一部にあります。　巨大先端技術である原子力を人間はうまく使いこなすことができるのか、数千年、数万年にも影響の及ぶ高レベル放射性廃棄物の処分はいま計画されている方法でいいのか、等々の懸念や疑問が出されております。

このように、日本のみならず世界の原子力開発をめぐる情勢は大きく動いており、人間社会および人類の生存（の歴史）の中で原子力をどのように位置づけするのかについての問題を、原子力関係者は避けて通れなくなっております。

今大会の基調テーマを「原子力と人間社会－その融和をめざして」としておりますのも、まさにそうした点を踏まえてのことでございます。毎年定期的に開かれている年次大会として、従来からの継続性を十分念頭に置きなが

ら、さらに、いま世界的に原子力が直面している課題を、鋭い感受性を持って取り上げたいと考え、やや枠組みを拡げた形で、原子力以外の他の分野の多くの人々の意見が反映されるような視点も入れて、プログラムの編成を行ないました。

本年次大会は、この開会セッションに引き続き、3日間にわたる5つのセッションのもとに、原子力開発が直面する諸問題とその対応について議論を行なうことにしております。

セッション1「現代史における原子力：その使命と課題」では、国際機関をはじめ、アメリカ、チェコスロバキア、フランス、ソ連、パキスタン、中国そして日本の代表から、エネルギーおよび原子力の役割とそれぞれの国における原子力政策について、見解を伺います。これらの講演を通じて、経済、社会文明の発展に不可欠なエネルギー、およびその中での原子力の位置付けが明らかにされると思います。ここではまた、最近クローズアップされてきた地球環境の問題への対応も含めて、あらためてエネルギー・原子力問題について考えることになりました。

最近原子力に対して、女性の関心が高まっていることを冒頭に述べました。人口の半数を占める女性を抜きにして、いまや原子力というものは考えられなくなっております。この面から自らも女性であるアメリカ原子力学会

会長のドブランクさんからは、原子力と女性のかかわり、パブリックアクセプタンスと女性とのかかわりに焦点をあてて、きわめて示唆に富む講演が伺えるものと期待いたしております。

また、原子力開発当事者であるわが国の電気事業者を代表して、電気事業連合会会長の那須さんからは「なぜ原子力か」についての見解が表明されるものと思います。

さらに、ソ連の原子力開発事情に詳しく、自らチェルノブイリ事故を取材したプラウダ紙科学部長のグーバレフさんからは、最近のグラスノスチ（情報公開）と原子力開発について興味ある講演が伺えるものと期待いたしております。

次に、2日目のセッション2「社会のなかの原子力」では、現在非常に大きな社会的関心事となっている原子力について、原子力関係者以外の方々の参加も得て、広く意見を伺いたいと考えております。

電力会社や原子力関係の人々は、「技術的には日本の原子力は良い」と思っておられるようですが、原子力関係者と一般の人々の考えていることの間にはかなり隔たりがあり、原子力に対する社会的なイメージには相当な幅があります。　さらに、一般の人々の原子力に対する不安や疑問に対して、原子力関係者から必ずしも十分満足のいく回答が与えられてはいないのが実情であると思います。

本セッションでは、最近のわが国における反対運動および原子力論争の実態、一般の人々の認識を分析するとともに、原子力関係者と原子力関係者以外の人々の主張がなぜかみ合わないのかについて討議していただき、社会のなかでの原子力開発にたずさわる者が今後取り組むべき課題をさぐりたいと考えております。　パネル討論に参加される有識者の方々から、原子力、および原子力関係者に対して腹臓ない意見が出されることを期待しております。

同日午後のセッション３「原子力技術の展開」では、原子力と関連先端技術との組合せによる新しい展開、原子力関係者がたゆみなくつづけている開発努力の姿が、映像と解説によって紹介されます。

原子力は、人類の英知によって創り出した技術エネルギーであり、その技術の進歩は、将来の原子力の利用分野を拡大し、産業の発展や国民生活に貢献するだけでなく、科学技術全体の発展の索引車としても役割を果たすことが期待されております。

本セッションでは、現在研究開発段階、実用化段階にある原子力技術の中で、燃料サイクルおよび高速増殖炉関係、原子力ロボットの分野、また、日常的に無意識にすごしておりますが、環境保全および医療面で貢献している放射線利用の分野について、内外の発表者からそれぞれの最新の技術とその将来展望が紹介されるでありましょう。

続いて３日目午前のセッション４「スウェーデンの脱原子力政策をめぐって」では、スウェーデンの３人の代表が、それぞれ政府、産業、および学界の立場から自国のエネルギー政策およびエネルギーの将来について見解の発表を行い、その後でアメリカ、フランスおよび日本の代表を加えてパネル討論を行います。

わが国の原子力論争でもスウェーデンの例がよく引き合いに出されます。これが「日本も原発なしでやっていくことができる」との主張のバックグラウンドとして使われてもおります。そこで、本セッションでは、スウェーデンにおける政策論争の過程や政策選択の背景をはじめ、工業先進国が将来のエネルギー供給手段から原子力をとり除くことが実際に可能かどうか、そのためにいかに苦労されているか、新たに生ずる課題は何か。経済社会的インパクト、代替エネルギー技術の評価など、スウェーデンで実際に行なわれている議論が、より具体的、客観的に再現されることと思います。さらに、直接の当事国以外の幅広い立場の人々からの質問、コメントを通じて、一国のエネルギー政策の枠を越えて、エネルギーの中の原子力の位置づけについて、地球規模であらためて吟味する機会となると思います。

これまで原子力は軽水炉をはじめウラン235 の利用による原子力発電に力点がおかれてきました。いまでは、世界で 400基余、３億ｷﾛﾜｯﾄ 余の発電施設が動いているところまで発展してきました。さらに一歩を進めて、わが国

でもいよいよ商業用燃料サイクル施設の建設に着手し、再処理のプルトニウム利用が具体化していく、原子燃料新時代ともいうべき非常に重要な段階に至ろうとしております。この時期に、原子燃料サイクルのもつ本質的な意義や今日の文明における位置付け等について、あらためて考えてみることが技術エネルギーとしての原子力の役割を再確認するためにも非常に時宜を得たものと思います。最後のセッション５では、こうした原子燃料新時代が社会に定着し、成熟していくための筋道について、国際関係、地球環境、科学技術、また、現代文明といった広範な視点に立って、４名の発表者から議論が展開されます。

以上、本大会の概要とねらいにつきまして概略をご説明いたしました。３日間にわたる本年次大会を通して、大会基調テーマの趣旨に沿って、示唆に富む意見の表明と活発な議論が展開され、それらの発表や論議がこれからのわが国および世界の原子力開発に役立つことを念願し、私の挨拶にかえさせていただきます。

以　上

第二十二回原産年次大会

会長所信

平成元年四月十一日

東京郵便貯金ホール

議長、ご臨席の皆様、第二十二回原産年次大会の開幕にあたり、主催者を代表して所信を述べる機会をえましたことは、私の大きな喜びであります。

ちょうど五十年前のウランの核分裂の発見は、我々の運命を規定する極めて重大なインパクトを生みました。以来、悲惨な軍事利用で始まるという不幸なスタートを切りつつも、人類は平和利用に道を開き、その歴史を刻んでまいりました。

二十一世紀への入り口をま近にして、国際社会は、ようやくにして核軍縮推進への糸口を見出したように思われます。人類は平和利用の象徴である原子力発電技術を掌中におさめ、それによる多大の恩恵を享受してまいりました。

世界で稼働中の原子力発電所は、今日四百二十基を数え、その設備容量は三億二千万キロワット、その電力量は全世界の発電量の六分の一を占めるにいたっております。原子力発電は、管理さえできれば環境を汚さずに巨大なエネルギーが取り出せるところに大きな特色があります。

石油資源の限界を見通し、あるいは二度にわたる石油危機を教訓として、先進工業諸国は、原子力発電に対する依存の度合いを徐々に高めてまいりました。このことは結果的に莫大な量の化石燃料の温存に人類が成功したことを意味します。

今や世界の原子力発電は、年間四億トン余の石油を節約していますが、

これはＯＰＥＣ最大の産油国であるサウジアラビアの生産量の約二倍にあたるものです。

このように、世界の石油貿易量の三分の一相当を原子力が代替するという現実をみれば、原子力が石油価格の安定に、いかに寄与しているかが分ると思います。大規模な原子力開発は、対原油戦略上、有力なバーゲニングパワーを形成し、そのことが、原油価格の高騰を抑制し、その結果インフレのない経済成長、ひいては豊かな生活水準の達成を可能としてまいりました。

このような状況の具体例は、わが国に見ることができます。一九七三年の第一次石油危機当時、一次エネルギーの七八％までを輸入石油に依存していたわが国経済は、生産に必要とするエネルギーの原単位を低く抑えるという世界有数の省エネルギーの実践と、原子力発電を主軸とする代替エネルギー政策の積極的な展開によって、石油への依存度を五六％にまで減らしております。

ところで、約二千九百万キロワットの設備容量を備え、約三〇％の電力を供給するというわが国の原子力発電の現況は、開発規模あるいは時代の要請に応じた諸課題に対する原子力産業の果敢な取組を必要としております。

なかんずく、安全の確保は最優先の課題であります。この数年来のわが国の優れた運転実績は世界的にも誇りうるものですが、これに慢心することなく、トラブル防止のために関係者が自戒を重ね、継続的に安全の実績を積み上げることが何より大切であります。

原子力発電プラントの信頼性の向上は、世界的にも新たな進展を見せて

おります。我々が不幸にしてこの十年間に遭遇したＴＭＩ、チェルノブイリの二大事故は、その教訓として運転技術や手順の改善を各国に促しました。チェルノブイリ事故後、国際原子力機関のもとで原子力事故の早期通報と緊急時援助に関する二つの条約が成立したことは記憶に新しいところですが、さらに電気事業者による運転情報のネットワーク化が提案され、相互の運転、故障情報の交換によるプラントの予防保守体制づくりが世界的規模で進んでおります。

このような実績をもとに、わが国は今日、原子力国際協力により大きな役割を担うことが要請されております。原産の国際協力センターは、海外電力調査会とともに発展途上諸国との協力の窓口機関となり、実施については、民間会社、日本原子力研究所、動燃事業団等の協力を得て活動しております。これらの機関を中心に、わが国は昨年度六百人を超える途上国からの研修員を受け入れ、原子力技術者の養成に寄与しています。

我々は、原子力発電に伴う放射性廃棄物の負担を後の世代に残さぬよう、技術面、制度面での努力を着々と続けております。一方、最近、化石燃料の燃焼から生ずる炭酸ガスが、この百年の莫大な燃料消費で、どうやら後の世代に大変深刻な負担を残しつつあることが憂慮され始めています。このことは人類が国境を越えて相互依存関係にあり、地球という運命共同体のなかで、環境を保全し豊かな生活を維持・実現する最適な方策を追求していくことが、ますます重要になることを示唆しています。と同時に、このような状況と対比して、放射性廃棄物への我々の努力が理解され、評価される日も近いと思われます。

わが国ではこの一、二年、反原子力運動が広がりを見せております。「危険な話」などの出版物に誘発されて一部の人々があたかもファッションの如く草の根運動に身を投じていく様は尋常ではありません。科学的根拠に基づかない、原子力批判や放射能の恐怖をいたずらにあおりたてる感性が、この運動の原動力となっている以上、我々はこれを座視せず、敢然と闘わなければなりません。我々は間違いの多い意図的な『汚染された』情報を排し、正確な情報をさらに積極的に市民に提供しなければなりません。

「原子力情報をもっと公開せよ」という声が、反対派のみならず原子力関係者の中からも聞かれます。私は、情報の公開は進めるべきであり、またある程度進んでいると思います。とくに問題があるとすれば、その取扱いや受けとめ方にあるのではないかと考えます。通産省は、昨年から法律上は報告義務のないマイナー・トラブルについても、電力会社からの報告の都度、マスコミに公表するようになりました。その結果、最近原子力に事故が多いという一般的な印象につながっているとしたら、それは情報を伝える側のスタンスに問題があると言えます。

一方、原子力関係者は、このような厳しい最近の状況の中で、安全の確保を最重視するという従来からの、自らの姿勢をより厳格に律することが求められております。従って、そのような姿勢を疑わせるような行動は厳に慎むべきであります。

日本の原子力開発は三十年の歴史を経て、いまや一産業、一コミュニティの域を出て、国民の問題としての広がりをもつようになりました。このことは国民一人ひとりの意思がより重みをもつことでもあります。我々

は、エネルギー政策の選択にあたって国民が誤った判断を下すことのないよう原子力の必要性を説かなければなりません。

さて、我が国の核燃料サイクル計画の考え方について一言申し述べたいと存じます。かえりみますと、我々は、いまだ五十年という比較的短い期間原子力を扱ったにすぎません。今後も人類は存続する限り永遠にエネルギーを必要としております。皆さん御承知のとおり、核燃料サイクル技術は、原子力利用において、ウランのみならず人工の燃料であるプルトニウムを利用して貴重なウラン資源から何十倍かのエネルギーを引出そうとするものであります。

我々がこの技術の実用化に情熱をもって取組んでいる理由は、単に我が国が無資源国だからというだけでありません。世界の長期的なエネルギー資源のいわば「技術による増大」に挑戦しているわけであり、それによってエネルギーの大消費国である日本として、将来の世代にいささかのお返しをしたい、という願望があってのことであります。各国の高速増殖炉計画が必ずしも順調でない今「もんじゅ」などの計画を進めようとしているのも、また再処理でも商業規模の施設の建設を進めつつあるのも、このような考え方に基づいているのであり、世界の関係者の御理解と御協力を切にお願いするものでございます。

ご承知のように、我が国が原子力の平和利用に踏み切ったのは、原爆のような軍事利用は絶対にこれを排除し、平和利用に限って原子力の開発を進めるという核不拡散の原則を確立したうえであります。我が国は、この原則を国内はもとより、国際場裡においても貫いたうえで原子力開発協力を進めていく考えです。

資源のない我が国が、産業活動や文化を維持し発展させるために、また、二十一世紀の人類がエネルギー不足による混乱や紛争を回避し、平和であり続けるために、原子力利用を育てあげていくことが、我々に課せられた重大な責務であります。この原産年次大会が将来への課題を大胆に提示し、それへの挑戦について虚心に話し合える場となることを願ってやみません。

最後になりましたが、準備委員、議長の方々さらには本大会のため海外からご参集下さいました発表者、また国内発表者の方々、そして会場の皆様に心よりお礼を申し上げ、私の所信とさせていただきます。

以上

Twenty-Second JAIF Annual Conference

Address
by
Chairman Jiro Enjoji
of
Japan Atomic Industrial Forum

Mr. Chairman, distinguished guests and participants, I am honored to have the opportunity to open this 22nd Annual Conference with an address on behalf of JAIF.

Exactly 50 years ago, the discovery of nuclear fission reaction had so great an impact as to affect our whole future. Since then, though it began unfortunately with military applications with disastrous consequences, nuclear energy has made history with progress in mankind's efforts to establish its peaceful uses.

Now, as we approach the 21st century, international society seems to have found a clue to nuclear disarmament Mankind has taken hold of nuclear power technology and derived tremendous benefits from it as the evidence of its peaceful applications.

The world has 420 nuclear power units operating, with a total installed capacity of 320,000 MW, now supplying about one-sixth of total generated electricity. The remarkable thing about nuclear power is that it has the characteristic of producing vast amounts of energy without polluting the environment, if under proper management.

Predictions of limited oil resources and lessons from two oil crises have led industrialized countries to turn more and more to nuclear power. This results in success of mankind's efforts to save vast amounts of fossil fuel.

Nuclear power plants around the world now effect a saving of some 400 million tons of oil a year -- approximately twice the amout of oil production in Saudi Arabia, OPEC's largest oil-producing country.

The fact that nuclear energy can replace one-third of the amount of oil in world trade indicates how is contributes toward stabilizing international oil prices. Massive nuclear developments have provided significant bargaining power as a strategic counter to crude oil, making it possible for countries to maintain their economic growth and raiser living standards without fear of inflation from soaring crude oil prices.

A good case in point is the steady economic growth of Japan. When the first oil crisis occurred in 1973, the Japanese economy was dependent on imported oil for 78% of its primary energy needs. Bringing energy conservation to the highest level in the world by reducing specific energy consumption to the minimum necessary for production, and letting nuclear power take the lead in an active alternative energy policy, Japan has lowered its oil dependency to 56%.

The Japanese nuclear industry has an installed capacity of some 29,000 MW, supplying about 30% of the nation's electricity needs. The reality is that bold steps are necessary from the industry to handle all the tasks that go with its scale of development to meet the needs of the times.

The assurance of safety, among other things, must be given top priority. Our operating records over the past several years are excellent enough for us to be proud of this before the world. But it is advisable for our nuclear interests with no self-conceit, for the prevention of trouble to enforce further self-discipline and continue building up high records for safety.

A new phase has been reached in the effort to improve the reliability of nuclear power plants world-wide. The major TMI and Chernobyl accidents that unfortunately have occurred in the past ten years taught us all the grim lesson that operating procedures and practices must be improved. After the Chernobyl accident, it will be recalled, the International Atomic Energy Agency established two conventions: on early notification of nuclear accidents and on emergency assistance. In addition, it was proposed that the electric utilities build a network of operational information, and at a world-wide level promote exchanges of operational and accident information so that preventive maintenance arrangements can be made for nuclear power plants.

Japan's achievements have led to Japan being asked to play a greater role in international cooperation. JAIF's International Nuclear Cooperation Center is working as an operating agency for cooperation with developing countries, as are also the Japan Electric Power Information Center, private companies, the Japan Atomic Energy Research Institute and the Powe Reactor and Nuclear Fuel Development Corporation. Acting through these organizations, Japan last year received more than 600 trainees from developing countries to help in the training of nuclear engineers.

We are endeavoring within both the technical and institutional frameworks to ensure that no burden of radioactive waste from nuclear power plants will be passed on to posterity. But carbon dioxide is now emerging as a source of concern because the burning of fossil fuels in the past 100 years is believed to have produced enough CO_2 to effect posterity., as a serious burden. In this respect, people's relationships allow no one to cross the border to independence from others. There is every reson to believe that the earth is a fate-sharing community in which human beings must seek the best way to preserve the environment and achieve and maintain an affluent life. At the same time, I believe that the day is not far off when our efforts for the disposal of radioactive waste, seen in contrast with these circumstances, will be understood and appreciated.

The anti-nuclear movement in Japan has expanded over the past few years. Sensational publications have led some people to join the grass-roots movement in an unusual rush, as if to keep in fashion. Supplying unscientific grounds for criticism of nuclear energy and the fear of radioactivity, this movement may be motivated by the logic of aestheticism, which we find it hard to endure and must resolutely struggle to dispel. We need to supply the people with correct information, instead of anything "polluted" with fallacies and special intentions.

Cries for "more freedom of nuclear information" have been heard not only from the opponents but from among the nuclear interests as well. I recognize the desirability of freedom of information, and I see it has made some headway. If any problems remain, it is with the way such information is treated and received. The Ministry of International Trade and Industry has since last year undertaken to let the news media have any report from the electric utilities even if about only some minor trouble which they are not required by law to report to the government office. If this results in the general public feeling that nuclear plants often have trouble these days, I would say it is up to those who supply the information to reflect on their assessment of it.

At the same time, the nuclear interests are called on, under these stiff circumstances, to further enforce self-discipline in their sustained primary efforts to assure safety. So they should refrain from any action that may cause others to doubt their attitude toward safety.

Over the 30 years that have passed since the development of nuclear energy began in Japan, it has taken on such universal, extensive dimensions as to pose a problem to the people on a scale that goes beyond the limits of a single industry or a single community. This means that the industry depends heavily on the will of each member of the public. We must emphasize the need for nuclear energy to ensure that the people exercise proper judgment in the choice of energy policies.

I would like to tell you about the philosophy of the nuclear fuel cycle in Japan. We have been with nuclear energy for the relatively short term of 50 years, and mankind will be in need of energy for all the future years of existence. As you well know, nuclear fuel cycle technology provides the possibility of producing ten-times more energy from valuable uranium resources by the recycling of plutonium, a man-made fuel. The reason why we undertake the commercialization of this technology so keenly is not only because Japan is a resource-scarce country; it is our wish that Japan as a big energy consuming country will contribute to some extent to future generations. The promotion of the prototype FBR Monju, and proceeding with the building plan for a commercial reprocessing plant, are both based on this philosophy. We expect that we will have the understanding and cooperation of world nuclear interests in the application of this philosophy.

As you know, Japan adopted the principle of only the peaceful uses of nuclear energy, and the principle of nuclear non-proliferation; that this country would absolutely exclude military uses and promote only the peaceful uses of nuclear energy. Japan will apply this principle not only in the domestic sphere but also internationally.

Promoting the utilization of nuclear energy is an important responsibility that we have to fulfill to ensure the Japan overcomes its scarcity of resources to maintain and develop its industrial and cultural activities and that mankind lets no energy shortage bring confusion on contention into its peaceful living in the 21st century. I earnestly hope that this JAIF annual conference will provide an opportunity for frank discussions on bold challenges that may be put forward and grappled with for the years ahead.

In concluding my address may I express special thanks to the members of the organizing committee and the chairmen of the Conference sessions, as well as those who have come from abroad to speak at this conference, the speakers from within Japan and all other participants in the conference.

日本原子力産業会議大臣所感

本日、第２２回日本原子力産業会議年次大会が、内外から多数の原子力関係者の出席のもと、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。圓城寺会長を始め、大会の開催に御尽力された皆様方に心からお祝い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とこの場に会する事ができ、大変嬉しく思っております。

世界のエネルギー需要は、近年の緩やかな経済成長などにより、その伸びは鈍化する傾向にあります。

一方、供給に関しても新規油田の開発などにより供給能力に余裕があ

ることなどから、石油をはじめとしたエネルギー資源の価格は低水準で推移しており、全体としては世界のエネルギー需給は緩和基調にあります。このような中で、原子力に関しては、現在、世界全体で４２０基、約３億３千万キロワットの原子力発電所が運転中であり、世界全体の総発電電力量に占める原子力の割合は毎年着実に増加してきており、電力供給の主要な担い手としての地位を築いてきております。

今後、発展途上国を中心とした人口増加や生活水準の向上等により、世界のエネルギー需要は着実に伸び、中長期的には、世界の石油需給は再びひっ迫することが予想されております。従って、今後とも石油依存度を低減し、世界のエネルギー需給の安定化を図るためには、引き続き原

子力をはじめとした石油代替エネルギーの開発を積極的に推進していくことが重要であります。

また、最近、二酸化炭素、窒素酸化物等による温室効果や酸性雨などの地球規模での環境問題に対して、世界的に関心が高まってきております。石油、石炭等の化石燃料は、その燃焼に伴い、温室効果や酸性雨の原因となる二酸化炭素、窒素酸化物等を発生させることから、これらに過度に依存することは好ましくありません。

一方、原子力に関しては、環境影響の観点において、二酸化炭素、窒素酸化物等を発生させないという優れた特長を有していることから、地球規模の環境問題の解決に重要な役割を果たすことが期待されております。

最近、我が国においては、原子力に対する反対運動が、原子力施設立地地域だけでなく、都市部の主婦層や若年層をも含んで全国的に広がっております。これらの中には、原子力に対する漠然とした不安に基づくものや、原子力に関する誤解に基づくものなども多いのが現状であり、誠に残念であります。　申し上げるまでもなく、原子力の開発利用を円滑に推進していくためには、国民の皆様の理解と協力を得ることが不可欠であります。このため、今後とも、安全確保により一層努力し、安全運転の実績を積み重ねるとともに、政府及び関係機関が一丸となって、従来にも増して、国民の皆様の原子力に対する正しい理解の促進に努めていくこととしております。

その際、従来のような新聞、テレ

ビ、ラジオ等のマスメディアを活用した、ともすれば一方的になりがちな広報だけではなく、対話形式などにより国民の皆様の疑問や不安に懇切丁寧に答えていく草の根的な広報活動にも力を入れていくこととしております。

また、パブリック・アクセプタンス対策の推進に当たって、海外諸国や国際原子力機関等との協力の強化を図っていくこととしております。

原子力をめぐるこの様な厳しい状況において、自主的な核燃料サイクルの確立を目指し、現在、青森県六ヶ所村において核燃料サイクル施設計画が進展しております。政府としても３０年余にわたり蓄積された我が国の研究開発の成果を最大限に活用するための体制整備を図り、民間

における核燃料サイクル事業化計画が円滑に進められるよう、積極的な支援を行っていくこととしております。また、先月３０日に日本原燃サービス株式会社より再処理事業の指定申請及び廃棄物管理事業の許可申請が出されましたが、政府としても、厳重な安全審査を行い、安全確保に万全を期する所存であります。

将来の原子力発電の本命の炉である高速増殖炉については、２１世紀前半の実用化を目指して引き続き研究開発を推進しております。その一環として開発を行っている原型炉「もんじゅ」については、１９９２年の臨界を目指して建設を進めているところであり、現在の進捗率は６５％に至り、早期の完成が望まれるところであります。今後は長期的視点

に立って、技術的基盤の強化等を図ることが重要であります。

一方、今後の原子力の研究開発については、創造的な科学技術の育成が必要との観点から、技術革新の牽引車としての先導的な役割を果していくことが期待されております。

特に平成元年度においては、高い固有の安全性等優れた特性を有する高温工学試験研究炉の建設に着手するための予算が計上されたところであります。本原子炉は高温ガス炉技術の基盤の確立・高度化及び高温工学に関する先端的基礎研究を行うための中核となる施設であり、熱エネルギー供給による将来の原子力利用分野の拡大を図るものとして産・学・官の期待を担っております。

また、人類の究極のエネルギー源である核融合についても、日本原子

力研究所の臨界プラズマ試験装置（ＪＴ－６０）が臨界プラズマ条件の目標領域に到達したことを踏まえ、現在、その高性能化のための改造等、実用化に向けた研究開発が進められております。

このほか放射線利用の一層の普及・拡大及び利用技術の高度化を図るため、放射線医学総合研究所における重粒子線がん治療装置の建設、日本原子力研究所及び理化学研究所の協力による大型放射光施設の建設計画等も着実に進んでおり、放射線が国民生活に益々身近なものとなりつつあります。

原子力船の研究開発については、将来の原子力利用の拡大を図る上で重要であり、本年度は原子力船「むつ」による出力上昇試験等を行い、実験航海に向けての所要の準備を進

めることとしております。

さらに、材料、人工知能、レーザー等に関する基盤技術の開発についても産・学・官の研究交流の下に積極的に行っていくこととしております。原子力を今後とも魅力あるものとするためには、原子力分野における優秀な人材の育成に努め、これまで述べてきたような研究開発を積極的に推進することが重要であります。

原子力分野における我が国の国際貢献については、我が国と地理的、経済的に密接な関係にある近隣アジア地域と我が国を含めた地域ぐるみの協力が有効であり、本地域全体の原子力技術水準の向上に貢献することとしております。このため、本年中には近隣地域の代表者が参加し、情報交換を行う国際的な場を設ける

等により地域協力についての具体的な検討を進めていくこととしております。さらに、先進諸国との間においても核融合、高速増殖炉及び高レベル放射性廃棄物の処理処分等の技術開発に関する研究協力を積極的に進めていくこととしております。

また、我が国における原子力開発利用を推進していくうえで最も重要な基盤となる法律の一つとして「原子力損害の賠償に関する法律」がございますが、今国会におきまして賠償措置額の引き上げ等を内容とする本法律の改正法案が、全会一致で可決しましたことは、私としても大変嬉しく思っており、これも皆様方の御協力の賜と認識しております。

以上、最近の私の所感を御披露致しましたが、本日から三日間、「原子力と人間社会－その融和をめざして」という基調のテーマのもとで、内外の多数の有識者・専門家の方々の間で忌たんのない活発な意見交換が行われ貴重な提言がなされ、本大会が盛況のうちに成功を収められんことを心から祈念いたしまして、私の挨拶を終わらせていただきます。

国務大臣
科学技術庁長官　　宮崎　茂一
原子力委員会委員長

セッション１
現代史における原子力：その使命と課題

THE WORLD'S NEED FOR NUCLEAR POWER

H. Blix
Director General
International Atomic Energy Agency

Japan Atomic Industrial Forum
Tokyo, 12 April 1989

Will the world need more energy?

Before we can discuss whether there is a need for more nuclear power, we must address the broader issue of whether there is a need for more energy. Twenty years ago this was not a question, but an axiom. The world is now using almost five times more energy than in 1950, and about eight times more than in 1925. After the oil price shock in 1973, events took a dramatic new turn. The price increases, the recession and predictions about the future depletion of oil resources had a profound impact. A more efficient use of oil and a switch from oil to electricity - often produced by nuclear power - led in the industrialized OECD countries to a levelling off of the demand for primary energy. In spite of an increase in the gross domestic product of over 30% between 1974 and 1986, primary energy demand did not increase. However, electricity demand increased in parallel with increases in GDP - namely by a steady 3% per year. That increase, however, was weaker than the 6 to 7% per year increases which had prevailed in most of the OECD countries before 1973.

There are, of course, variations between individual countries, but the main lessons are two: first, that there existed a potential for energy savings - or conservation as it is often called; and second, that electricity as a refined secondary energy form with a very high efficiency in end uses helped to achieve those savings.

In the developing countries the situation was very different. In most of them both primary energy and electricity consumption increased even faster than the gross domestic product. In many developing countries the term demand is not very meaningful, as the capacity to supply energy is so often the factor determining the "demand".

The stagnation of the primary energy demand in industrialized countries, the awareness of the finite nature of oil and gas resources, and lately, the fears for the environmental consequences of an accelerated use of fossil fuels have led to some serious questioning of the conventional wisdom that increased energy use must go hand in hand or can even be allowed to go hand in hand with further economic development and rising standards of living.

Just about two years ago the World Commission on Environment and Development published a report entitled "Our Common Future". It calls for "sustainable development", that is to "meet the needs of the present without compromising the ability of future generations to meet their own needs". In the field of energy it recognizes that "the risk for global warming makes heavy future reliance upon fossil fuels problematic". The Commission's ambition to promote development especially in the Third World without an increased global use of fossil fuels was not helped by a negative attitude towards the use of nuclear power, which is said to be "only justifiable if there are solid solutions to the presently unsolved problems to which it gives rise". In passing, I might remark that the nuclear community would confidently hold that many of the "unsolved problems" which the Commission points to are not really unsolved. The Commission is obliged to limit its advice to the world to the need to find a "low energy path" and to the development of renewable sources of energy. The "low energy path" is not traced. One can only assume that it would comprise drastic policy measures to promote energy conservation. It concludes that, if such measures were to be taken everywhere, primary energy consumption in industrialized countries by 2020 could be cut to one half of its present level while still providing essentially the same energy services as now. In developing countries the per capita consumption would increase by 10 to 15% and the total world consumption of primary energy would increase by about 10% over the present value.

As this scenario is now being cited extensively and has attained a certain status by being used by the World Commission, there are good reasons to subject it to analysis. We have done so in the IAEA, and our conclusions, which are critical, are being submitted to the United Nations.

Firstly, it should be said, the scenario is a theoretical construction of what could be achieved under certain special conditions. Even if some countries were willing and able to create such conditions, it is not likely that all, or even a majority, would be ready to do so.

The low energy scenario does not really consider what is likely to happen between now and that future year of 2020 when the goals would be achieved. If we start by looking at what actually has been happening in the world of energy since the scenario was worked out in 1984 and what the short term plans are in many countries, we find an energy path that is not sloping down or level, but is going up. For the next few decades, the plans in most countries are aimed at meeting an increased - not a constant - level of demand for both primary energy and electricity. This is particularly true of developing countries. Let me just quote a few figures by way of example. China - which is already the biggest user of coal in the world and where coal provides 78% of primary energy - plans to double its production of coal between 1986 and 2000. India, where coal now yields 70% of the commercial primary energy, plans to more than triple its coal use by 2000. By that time these two countries alone, with more than one third of the world's population, plan to use more coal than all the OECD countries together - i.e. all of Western Europe, the USA, Canada, Japan and Australia.

The World Energy Conference, the International Energy Agency of the OECD, the Commission of the European Communities and International Institute of Applied Systems Analysis are all unanimous in expecting increased global energy demand - an increase of about 50% over 1986 levels by 2000 is a typical forecast; for electricity an even faster rate of growth must be expected. In the IAEA we consider an increase by 50 to 70% over the same time period as likely. In my further discussion, it is primarily this electricity use that I address.

The Role of Electricity.

Electricity has become the most widely used secondary form of energy. It is easy to understand why. It offers a very high degree of flexibility, it is extremely efficient, very safe for the consumer, and it is environmentally benign in the end use. Although there are conversion losses in the production of electricity in thermal power stations, the efficiency is high in the end use. To take an example, electric heating can be applied exactly where it is needed, which means little energy waste in various metallurgical processes. This quality has enabled electricity to bring about savings in primary energy in some processes where fossil fuels were used earlier.

It is notable that all conservation scenarios rely on an expanded use of electricity. Even the scenario which the WCED relies on assumes a doubling in the world use of electricity between 1980 and 2020.

Electricity has one major disadvantage, namely that the presently available storage systems are cumbersome and expensive. This is certainly the main reason why we are not yet driving electric cars. If there were to be a technological breakthrough in this matter - which is not excluded - there would be an even faster expansion of electricity use. Even while we wait for this event, we can see some signs of mass transportation becoming increasingly electrified. It is not only rail transport that uses electricity; trolley buses are slowly coming back in the cities, and I am told that manufacturing industries are also planning for a more general return of trolley buses. In my view, there is a great potential for increased electricity demand in the area of public transport. This development should be welcomed also for environmental reasons.

If we can thus assume that demand for electricity will continue to increase and do so faster than demand for primary energy, the question is: how will it be produced?

Options for Production of More Electric Energy.

A result of the drop in the rate of increase in electricity demand from some 7% before 1973 to some 3% after 1973 was that in many industrialized countries the plants which were on order or under construction at that time, in response to an assumed high expansion rate, turned out to be sufficient to meet the actual lower than expected demand for a long time - indeed, until now. However, in a number of countries capacity is now being outpaced by demand and new orders for power plants will have to be placed, e.g., in Finland, the Netherlands, the US, the UK, Sweden and Italy. The new orders have to be placed in an entirely new climate. Economic considerations are only one aspect. Governments are often influenced by environmentally motivated public pressures as well. So far, this influence has worked against the choice of nuclear power in several countries, but it also sometimes works against the use of coal-fired power stations and, indeed, often against hydro power projects.

There are several possible electricity sources: fossil fuels - coal, oil and gas; hydroelectric power; nuclear power; renewable sources such as wind, sun and biomass; and geothermal power. All these sources will be used but the proportions in which they come into play are of importance both from the economic and environmental point of view. Let me briefly survey the relative potential importance of these various options and then focus on the most important ones, namely fossil fuels and nuclear power.

Hydroelectric power is the most important renewable resource. In some developing countries, considerable hydro power is still available and it will surely be exploited where it is economical. In most industrialized countries there is not much more to exploit. Besides, environmental considerations often create opposition to a number of conceivable projects. Projects on the river Danube are cases in point. Mini hydro power stations are often talked about as desirably decentralized and environmentally preferable to large installations. I am not personally convinced that 1000 mini hydro power stations of 1 MW are to be preferred on environmental grounds to, say, one 1000 MW nuclear power plant.

It is striking that although news about wind-generated electricity attracts a good deal of media coverage, nowhere do authorities reckon that this renewable source will make any significant contribution to the production of electricity within a foreseeable time. Denmark is considered to have an ambitious programme for wind-generated electricity. In 1987, wind generators covered 0.5% of the country's electricity requirements. Thermal power plants, practically all of them coal-fired, covered around 85%. Denmark has decided to set up 10 wind power plant parks and is counting on obtaining 100 MW(e) from them by 1990. It may be mentioned by way of comparison that in the same period Denmark will obtain 500 MW from new coal-fired thermal power plants.

Solar cells supply electricity to satellites, clocks and calculators, where costs are not a major factor, but despite the progress which has been made solar cells are not expected to provide significant amounts of electricity economically before well into the next century. Nevertheless solar power has a great potential and it is a technology to which substantial research and development resources should be allocated.

In the longer term, two other large scale sources of energy could become of great interest. Hydrogen as a secondary source of energy would be storable and could be used in transport and heating without any damaging emissions to the atmosphere. But a rich primary source would be needed to produce the hydrogen. Nuclear power could be such a source. The other source I have in mind is fusion, to which considerable research and development efforts are devoted, some of them under IAEA auspices. However, commercial use of fusion to generate electricity is deemed to be several decades away.

In the world of electricity system planners, there is hardly any division of opinion that the real alternatives for increased large scale and economic electricity production at present are nuclear power and fossil fuels, above all coal. I propose to examine these main options side by side from a variety of viewpoints such as economy, infrastructure requirements, reliability, safety, waste and environmental consequences.

From the economic point of view, the alternatives of coal and nuclear power are fairly equal in many countries. Reasonable construction times of about six years are assumed in the cost calculations for nuclear power plants. Included also are the costs of handling nuclear waste from the plant and for its decommissioning. In the case of coal-fired plants, the costs are included for modern systems to abate emissions of dust, SO_2 and NO_x. It should be added that in most - but not in all - countries where nuclear energy is used, it has turned out to be extremely important for general economic development. In France, where 70% of electricity is generated by nuclear power stations and in Sweden, where the figure is close to 50%, cheap nuclear power and old hydro power have resulted in stable and low costs for the production of electricity.

This has undoubtedly been a competitive advantage for the industry of these countries. In addition, it kept their oil expenditures low when the price of oil went up. Here in Japan, nuclear power is now the biggest single contributor to electricity production, accounting for about 30% and, according to a recent statement by MITI, it is also the cheapest source of kilowatthours. The spectacular - almost tenfold - increase in nuclear production between 1974 and 1987 has certainly been a decisive factor in decreasing the nation's dependence on imported oil. In the case of Korea, the expansion of nuclear power has had strategic importance for rapid industrialization.

As to infrastructure requirements the differences are great between coal and nuclear power. In many countries without coal mines, it is necessary to locate coal-fired power plants at sites on the coast, where there are special harbour facilities so that the delivery of the enormous amounts of coal can take place. In countries like China and India with their own coal deposits in the "wrong place", so to speak, the railways even now are overloaded with the transportation of coal. Nuclear fuel, on the other hand, is extremely modest in volume and can easily be transported, even by aircraft. On the other hand, nuclear power requires a certain degree of industrial infrastructure and - of course - specialized and trained manpower as operators.

Gas can be transported either cold in liquid form or in pipelines. In no case is the infrastructure problem insurmountable, but the pipelines require very large investments.

Reliability of supply is an important consideration in utilities' choice of electricity source. Coal is produced in many countries and the risk of a market cut-off is small. The quantities involved are so large, however, that stocking is not practical for any lengthy production periods; any disruption in supply can therefore constitute a risk. Gas cannot be stored for any appreciable period of demand either. The consumer at the end of the gas pipeline is dependent on conditions along the pipeline and at the sources. Such dependence may be reduced by reliance on two or more sources and pipelines.

Nuclear fuel affords great assurance of supply. Several producers are available and storage for many years' consumption is possible. For nations like Japan and France, which have large industries but lack sizeable indigenous energy sources, nuclear power offers a valuable degree of energy independence.

As regards operational reliability, there are no significant differences between coal- and gas-fired plants and nuclear power plants. In Western Europe, the operational reliability is about the same in nuclear power plants as in coal- and oil-fired ones. In Japan, with 36 nuclear power plants, it has proved possible to reduce unplanned operational shutdowns to fewer than one per reactor year. Indeed, there are reactors in Japan which have not experienced any unplanned shutdown for several years. In most countries, the trend has been in the direction of steadily improving operational results in nuclear power plants, with a routine availability of over 80% in countries like Sweden, France, Canada and Finland. South Korea, until recently a developing country, last year had a reactor with an extraordinary availability of 99.6% and an average of 88% for all the country's reactors.

The three most common objections to nuclear power relate to safety, waste disposal and non-proliferation. I shall discuss these issues and compare.

The Safety Requirement

Our increasingly urbanized societies are vulnerable. Energy installations which can have an impact on the lives and health of many people must operate at a very high level of safety. It is generally understood that hardly any human activity can be totally without risk, but there seems to be very real difficulties in conveying to the public a perception of risk that corresponds to the reality.

Even with the handicap of the public's poor understanding of nuclear problems, or perhaps especially because of this handicap, particular efforts must be made in the information sector to help the public place the risks connected with nuclear power into a proper perspective. One can hardly claim that these efforts have been very successful as regards the TMI and Chernobyl accidents.

The Three Mile Island accident, where no human being was injured and where the radioactive emissions were insignificant, had a profound impact. People did not see the accident as it actually was. What they saw was a confirmation of their own fear that a big accident could occur. The Chernobyl accident, in which 31 persons died, a few hundred received high radiation doses and significant amounts of radioactivity were released was probably the most publicized industrial accident in history, and it is imprinted in people's memory. By contrast the name of the oil platform in the North Sea which last summer experienced an accident with 160 deaths has most likely been forgotten, and the same is true of the name of the coal mine in West Germany where earlier in the year 57 miners lost their lives.

It is, of course, difficult to make precise comparisons between risks in different fields of activity. We know that hydro power has taken thousands of lives when dams have burst; we know that the big gas explosions in Barcelona and Mexico City each took hundreds of lives, and we frequently read accounts of accidents in coal mines. A proper comparison between the risks to life and health in the production of electricity by gas, coal and nuclear energy respectively would necessarily have to begin at the mines or the gas deposits; it should follow the transport of the raw material, its conversion, its use as a source of energy and it should, lastly, evaluate the health hazards from the waste. The risk of accidents, of course, must be included. Some studies of this kind have been made. It is my conviction that more comprehensive studies of the question will confirm the results of studies already carried out, indicating that nuclear power, per amount of electricity produced, has had very little impact on life and health. I feel more uncertain as to whether such conclusions will affect people's attitudes. Most people are more afraid to fly than to ride in automobiles, although the risks both per trip and even more per kilometer travelled are much greater in the case of automobile travel. Our intellectual capacity seems unable to prevail over our feelings. Perhaps only experience over a longer period of time is able to do so.

The conclusion I want to draw for nuclear energy is by no means that all we have to do is wait and see. Two types of action are needed. We should give as correct a picture as possible of risks and of damage that has occurred. Engineers, scientists, planners and politicians should contribute facts which can help the public make comparisons between the advantages and risks of various types of energy.

Secondly, we must actively strive to reduce the risks further and take steps to ensure that the consequences of radioactive releases, should they occur, are minimal. Continuously increasing safety, of course, is required also in the mining, transport and burning of coal and the exploitation of gas or of hydro power.

A number of international programmes have been introduced or expanded by the IAEA for the purpose of enhancing the safety of nuclear power plants throughout the world. Agreement has thus been reached on comprehensive revised and strengthened international nuclear safety standards (NUSS). A recent questionnaire sent to our Member States showed that most countries consider that their national standards are compatible with NUSS, even if they often go further in specific aspects.

Through the IAEA's International Nuclear Safety Advisory Group (INSAG), a systematic and integrated safety concept was presented last year and from this concept recommendations have been formulated which, if they are followed by designers, operating personnel and supervisory authorities, will with time lead to the further improvement of safety. A new service for Members is that the IAEA, upon request, sends international teams of experts for a period of a few weeks to review operational safety at a nuclear power plant, hold discussions with the staff and give advice. Nearly all our Member States that have nuclear power plants make use of this service - and they pay for it. Last year, OSARTs visited Japan, the USSR and Hungary for the first time. Further visits to the USSR and many other countries are envisaged. We would like to see this service used routinely by Member countries, with a frequency that is related to the number of nuclear power plants in the country.

I shall not prolong this account of what is going on internationally to enhance safety and generally reduce the risk of accidents in nuclear power plants. However, one point remains to be dealt with, namely the question whether new types of nuclear power plant can be expected to be even safer than those now in operation. The answer to this is that, in nuclear power plants as well in aircrafts and automobiles or any other technology, safety is never a static concept. The new models now proposed for pressurized-water and boiling water reactors are improved and simplified versions and, from the point of view of safety, are a stage of development ahead of their predecessors. A considerable amount of work is also going into the construction of new types of nuclear power plant with a greater measure of passive safety. Discussion relating to these types - e.g. the high-temperature reactor, the Swedish PIUS and the ISER concept here in Japan - is certain to be lively. An important question, however, is who in the present-day world is willing to meet the costs of building the prototypes that will be required before as yet unproven models can be marketed.

Let me turn now to a comparison between nuclear power and the fossil fuel alternative from the viewpoint of waste. The term "alternative energy" has been propagated for a long time. By the same token, one could coin the expression "alternative waste". Which waste do we prefer? Small amounts of radioactive waste that can be isolated practically 100% from the biosphere, or huge amounts of emissions or waste on the ground when coal, oil or gas are used? I have no hesitation what answer I would give. It was the realization that the damage to lakes, forests and the land were related to the burning of coal and oil that led me eighteen years ago to support nuclear energy.

The view is often expressed that the "nuclear waste issue is unsolved". This contrasts sharply with the views of the scientists and experts active in the field. After 50 years of storage at ground level, spent fuel will have only about one twentieth of the radioactivity and one twenty-fifth of the heat generation which it had one year after discharge from the reactor core. This very much facilitates design and engineering of both the waste container and the depository. The greatest problem the experts currently see in the disposal of highly radioactive waste is not technical, but one of public and political acceptance.

I would like to mention also that while it is true that radioactive wastes may be dangerous for thousands of years and therefore must be safely isolated, it must be remembered that part of the waste resulting from the burning of coal, namely the toxic heavy metals such as arsenic, cadmium, lead, vanadium and mercury, remains dangerous forever. The toxicity of these stable elements does not decrease over time as does the toxicity of radioactive materials. The quantities of toxic metals released in the burning of coal are not small. The total amount of spent fuel resulting from civilian nuclear power in 1987 was about 6000 tons. If coal had been used instead to produce the same amount of electricity, at least 90,000 tons of toxic heavy metals would have been set free - in addition to huge quantities of CO_2, SO_2 and NO_x. A major difference in the two energy systems is that the nuclear wastes, but not the wastes of coal, are fully isolated from the environment.

Environmental Considerations.

In talking about the wastes of nuclear fuel and of fossil fuels, one is in fact talking about environmental consequences, i.e., the extent to which any wastes are released into the environment. There are - as shown by experience here in Japan - very efficient methods for reducing SO_2 and NO_x in emissions from the combustion of coal and oil - though at a cost. There is no economically feasible way to remove or reduce the CO_2 from the burning of fossil fuels.

Scientists are becoming ever more convinced about the seriousness of the threat of global warming and climate change from the increasing emission of so-called greenhouse gases, e.g., CFCs, methane and CO_2. Governments have to recognize that action will have to be taken even before the final results of scientific research are in. International co-operation is indispensable and some is already underway in the International Panel on Climate Change set up by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO).

It is estimated that about 25% of the greenhouse effect is due to chlorinated fluorocarbons, or CFCs. Fortunately an international agreement was reached in 1988 to reduce the production of CFCs in order to prevent further damage to the ozone layer, and there have been recent commitments to accelerate this reduction - aiming at a zero emission by 2000. There is thus a mechanism to reduce CFC emissions and it seems to be working.

Methane is an important and very effective greenhouse gas, now estimated to account for about 20% of the global warming effect. Its origins are ruminating cattle, rice paddies and wetlands, coal mining and tapping of natural gas fields. A large part of the emissions will depend on the world's population size and no feasible, large-scale methods have been proposed to control and limit them.

CO_2 is responsible for about half of the greenhouse effect. It comes mainly from the combustion of fossil fuels, but more than 10% is estimated to come from the deforestation which now is accelerating in many developing countries. CO_2 is one greenhouse gas which could be controlled. It is certainly desirable to stop deforestation and start major reforestation programmes, but even these would be too slow to produce significant effects on the atmospheric CO_2 content within the next several decades. Even now there seems to be agreement that there must be a limitation and even a reduction in the world's use of fossil fuels. A conference organized last summer under the sponsorship of the Canadian Government recommended that total emissions of CO_2 up to the year 2005 should be reduced by 20% of the present level. The conference offered three prescriptions as to how this should come about: States should: (1) Switch to fuel emitting less CO_2; (2) Review strategies for introducing renewable fuels; (3) Examine the nuclear power alternative once again.

I cannot avoid the conclusion that a new and highly significant argument has emerged in favour of the nuclear energy alternative. Nuclear energy cannot become a universal remedy against the greenhouse effect, but the increased use of nuclear energy, together with a number of other measures, can have a moderating effect on the frightening development we are now facing. Obviously, use must be made of all means that are effective.

The measure that is universally mentioned - and accepted - is energy saving. It is very improbable, however, that savings alone can result in a reduced global use of fossil fuels. As I have already explained, the developing countries will need to expand their use of fossil fuels because they simply have no alternatives, and this expansion is going to be significant. It will fall mainly on the industrialized countries to reduce the CO_2 emissions by all means available, that is, energy efficiency and savings, developing new renewable energy sources like solar power, and using more non-CO_2-emitting sources, mainly nuclear power.

Opponents of nuclear power today assert that nuclear power is such a small part of the world's energy balance that the absence of CO_2 in nuclear power is of no significance in relation to the efforts to reduce the emission of CO_2 and the greenhouse effect. Considering that nuclear power now produces 5% of the world's energy and the commercially usable renewable energies (excepting hydro power) contribute less than 0.5%, it is rather curious to maintain that nuclear power is too small a source of energy to play any part and at the same time to insist that increased use of the renewable energy sources should be one of the main methods for reducing the emission of CO_2! At least within the next ten to twenty years, it will certainly be considerably easier, with reasonable economy, to increase the production of energy by nuclear means than with renewable energy sources. That is not to say that we should neglect the potential of these energy sources. On the contrary - we should intensify research and development work to make them available on a large scale in an economic fashion, but we should not be misled by oversimplified statements about how easy it will be to reach that goal.

Even when we look at concrete figures, it is difficult to understand the assertion that present-day nuclear power is too small a factor to be of relevance as regards CO_2 emissions and the greenhouse effect. The total emission of CO_2 from the burning of fossil fuels is at present approximately

20,000 Mt per annum. The Toronto Conference proposed a reduction of 20%, or 5000 Mt. If the 16% of the world's electricity that was produced with nuclear power in 1987 had been generated instead by the burning of coal, that would have resulted in some 1600 Mt of CO_2. Compared with the 5000 Mt which the Toronto Conference wanted to eliminate over a 17 year period, these 1600 Mt CO_2 that we do not release into the atmosphere would not seem to be insignificant. Nor does it require any great imagination to realize that increasing nuclear power could help us forgo a fair amount of coal-, gas- and oil-based electricity generating capacity, which emits CO_2.

Non-proliferation

It remains for me to discuss the issue of proliferation.

The risk of the spread of nuclear weapons to further countries is certainly real, and significant efforts are needed and are being made to reduce it. However, that risk would not be reduced significantly by a moratorium on further nuclear power. Rather, it should be noted that transfer of nuclear technology, hardware and fuel for the peaceful production of electricity through nuclear power has been and remains one of the principal methods of obtaining legally binding - and verified - commitments to an exclusively peaceful use. The spread of civilian nuclear power has allowed, and prompted, the establishment of the world's first on-site inspection system - the IAEA's safeguards system. The proliferation risks which are commonly pointed to are not in the main the result of the transfer of peaceful nuclear technology, but of indigenous technological efforts of some countries. To shut down safeguarded civilian nuclear power plants in order to reduce the risk of proliferation, as has been argued by some, would really mean closing a branch of industry which is unique in the world in that assurance of its exclusively peaceful use is given to the world through the Agency's safeguards. Further reduction of the risk of proliferation can be achieved if there is further nuclear disarmament and further adherence to the Non-Proliferation Treaty. It should be remembered, lastly, that a heavy global reliance on fossil fuels also has security implications. It is the presence of huge oil resources that has made the Middle East one of the most explosive areas in the world.

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WOMEN'S ENTRY INTO THE NUCLEAR COMMUNITY

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Introduction

Since the end of the Second World War, the Japanese and American people have moved closer together in their social and business lives, and yet the older Japanese and American traditions are still evident as the underlying fabric of each nation. The recent death and funeral of Emperor Hirohito represented a seam in the passage of time for both countries - a period in which to pause and compare the changes that have taken place during his reign. It has signaled an opportunity to examine and reflect on our differences and similarities.

Japanese and American Perceptions of Each Other

Polls taken in 1982 and 1988 in America by Louis Harris and Associates, Inc., and in Japan by the newspaper *Asahi Shimbun*, have consistently shown that two of three Americans and one of two Japanese think relations between their two countries are good overall. The same would be true today.

Seven of every ten Americans have purchased a Japanese product. Half of all Americans think Japanese products sell well because they are inexpensive, while the other half say the reason is their high quality.

Ten percent of Americans have visited Japan, and more than 60% of Americans feel the Japanese government and people are friendly and cooperative toward the United States.

A vast majority of Americans, 76%, believe Japanese parents are stricter in the discipline of their children; only 5% thought Americans were stricter. On the other hand, Americans think the United States is more advanced in science and technology by a 20% margin, and 58% of Japanese agree.

Japan is viewed by Americans as discriminatory toward women, with 66% of Americans stating that women are discriminated against more in Japan than in the United States; only 9% of Americans feel women are discriminated against more in the United States. A slightly greater percentage of Japanese than Americans believe Japan is more discriminatory toward women. These figures were reported by the Asahi News Service in their joint public opinion poll conducted in both countries in October 1986 by ***Asahi Shimbun*** and Louis Harris Associates, Inc.

Japanese Women in the Work Force

Today almost 40% of the Japanese work force is made up of women - many of them employed as teachers, nurses, or office workers. Many housewives are working at least part time in light industry, chiefly to boost the family income. But, increasingly, Japanese women want to have jobs rather than being, as they were in the past, confined to the home.

Because many of the better-paying jobs are closed to them, women find it very difficult to advance into positions of real power. In all of Japan, only 120,000 women hold any kind of managerial rank, mostly low. Women fill only 5.3% of Japanese managerial positions. Many companies do not even interview women for executive positions.

Japanese Women at Home

Although, according to the Time-Life Book, ***Japan***, more than 50% of Japanese women under 30 years of age would like to have careers, they also want marriage and would, on balance, forgo a career for a home and the raising of children. The maintenance of the traditional role also derives in part from a conviction among Japanese women that running a house and bringing up children constitute a sufficient challenge.

The ***Japan*** book also reports that at home Japanese housewives are in charge, in part because their hard-working husbands are there so little. Today, these women are tough-minded administrators who bring up the children, and manage not only the household, but the entire budget.

The American Women's Movement

The majority of American women were preoccupied with similar household matters prior to the 1970s. But the emergence of the women's liberation movement brought about a head-spinning transition from their previous domestic world to the public world of business, industry, and the professions.

By the 1980s, as with the civil rights movement of the 1960s, changes had occurred that could not be retracted. Women had made great strides in education, opened up new employment possibilities, and gained a new public image. Young women now assume responsibility for their own future in a way that could not have been imagined by their mothers and grandmothers.

Decline in the U.S. Birthrate

Today, a real demographic change is taking place in America, presenting even greater opportunities for women in the workplace. Fertility rates have dropped from a high of 3.7 births per 1,000 females in 1957 to a stable low of 1.8 births. The result will be a severe shortage of talented, educated, competent individuals. Even a few years ago, companies recruiting from the top 10% of the best business schools in the country could hire all males. Now a third of those men have been displaced by women graduates.

Increase of Women in the U.S. Work Force

Research done for the U.S. Department of Labor claims that women will make up about three-fifths of new workers in the labor force between 1985 and 2000, and that only 15% of new workers between now and the end of the century will be native-born white men. By the 21st century, approximately 47% of the work force will be made up of women, and 61% of all women will be in the paid labor market.

In addition, the proportion of women receiving higher academic degrees has been steadily rising. In 1984, for the first time in history, the number of women exceeded the number of men receiving doctorates in education. A similar shift in male-female student ratios in law, medical, and engineering schools is being mirrored in the declining proportion of men to women in those professions.

Falling Enrollments in Science and Technology

Not only is the proportion of men in scientific and engineering programs shrinking, but overall enrollments in these areas are declining, even though jobs are plentiful. Freshmen enrollment in engineering schools has fallen well below 95,000, from a peak of 115,000 in 1981.

The reasons behind the falling enrollments in science and technology are varied and complex. First, fewer children are growing up on farms with tractors and other machinery. Fewer children are exposed to scientific toys and books, so that an interest in science, mathematics, or engineering does not come naturally to them. Now they grow up in suburbs and with television, and go into marketing. Second, students have the perception that other careers are easier, are more glamorous, and in the long run, pay better. And, to be honest, hard work is involved, and students today have to learn a lot of new material along with all the traditional skills. As technological advances make the world more complex, engineering and science have become more difficult. A third reason these jobs are losing their appeal to young people is that few educators or parents are doing anything significant to convince children that learning mathematics and science can indeed be pleasurable, and that in any case, it is vital to their future success and well-being. Because of this lack of support from parents and teachers, we are encountering poor science and mathematics training in some of our schools, leaving students ill-equipped to enter these fields.

Why Women Drop Out of Science and Mathematics

America's falling enrollments in science and technology courses is also due to society's discouragement of girls and young women who would make good scientists and engineers. Although Americans are committed to equality of opportunity, public attitudes perpetuate stereotypes that "girls don't really need that much math or science". As long as these stereotypes persist, young women will continue to drop these courses prematurely, thereby losing opportunities for future careers.

As elementary school students progress through the science and mathematics curriculum, girls and boys show little difference in ability, effort, or interests until the adolescent years when course and career choices begin influencing school effort. As social pressure increases and career goals are formed, girls' decisions to reduce effort in the study of science and mathematics progressively cut women off from any professional careers in those fields. These same attitudes will tend to follow the female scientist or engineer throughout her career. Along the way she may encounter similar obstacles.

Overall, women receive approximately one-third of the university degrees now being granted in science and engineering. The highest percentages of women are found in those sciences with the least mathematical prerequisites: psychology, biology, and sociology. The lowest percentages of women enter fields requiring the most mathematics, namely, physics, engineering, economics, geoscience, and chemistry. One important point about all this is that people who do not understand how science works or know the meaning of a few fundamental technical terms must take information on faith, often from politicians or spokespersons who have vested interests, making citizens easy prey to the purveyors of simple solutions to complex problems.

A former president of the American Association for the Advancement of Science, Dr. Sheila E. Widnall, recently commented, "...we should concern ourselves with the issue of future public support for science on the part of groups who perceive that they have been excluded from full participation in the scientific enterprise. The years ahead may be troublesome for the support of science, and the image of science as a community accessible to all will be important to maintain public support".

Women and the Antinuclear Movement

In the early 1970s, the civil rights movement and the Vietnam War protests had made conflict, reassessment, and change a part of all American lives. In this turbulent context, the emergence of a politically organized women's movement, and the resultant backlash, did much to define and alter the social fabric of everyday life.

At the same time, the controversy over nuclear power development in the industrial western world was gaining momentum. The antinuclear movement arose from public anxiety over the environmental and health risks associated with the construction and operation of nuclear power plants, the same anxieties now found in Japan. Despite the rapid growth of the American nuclear industry during the 1960s, community preoccupation with other politically sensitive issues, notably civil rights and the Vietnam War, may account for the relatively dormant public involvement in nuclear matters. By 1968, however, a rapidly-growing environmental consciousness was beginning to make itself felt in the nuclear arena. This movement moved beyond purely local and specific environmental concerns to more generic economic and philosophical issues by the early 1970s.

During the 1970s and into the 1980s, as Joseph Camilleri in his book, ***The State and Nuclear Power: Conflict and Control in the Western World***, quoted a senior Westinghouse official, "nuclear power (came to represent) the ultimate symbol of economic power, military power...in the hands of the established institutions - the electric utilities, the large corporations, and government agencies" - all hostile to any perception of dissent. This obviously white-male-dominated nuclear technocracy represented, then, for the ecological movement a fundamental threat to individual freedom.

Women's Liberation and the Antinukes

The rise of both the women's liberation and the antinuclear movements coincided, and they shared a mutual hostility toward most male power holders. Grass-roots activity on both fronts fostered a network of individual citizen action groups using peaceful as well as violent demonstration tactics. The result was a new form of politics in which citizens were able to participate in the public debate, to raise objections to government planning, and, where possible, to engage in a series of public demonstrations and court actions.

While public questions put to voters in the United States have been consistently decided in favor of nuclear power, polls taken regarding nuclear power often indicate more opposition among women than men. For example, a recent poll taken by ***U.S.A. Today*** indicated that women, more than men, are more concerned about living near a nuclear power plant, and a majority say it heightens the risk of cancer. Women are less familiar with the greenhouse effect and they would oppose nuclear power growth to reduce its effects.

One cannot help but ask the question if women were as well-educated in science as are men, would there then be any differences in attitude toward nuclear power? We think there is a high probability that the scientifically literate woman will be pronuclear, and in pursuit of this concept, the American Nuclear Society is working to attract women to the nuclear field and to educate them about the need for nuclear power in the United States energy mix.

The Work of the American Nuclear Society

In 1981, the American Nuclear Society (ANS) published the booklet "*Women Professionals in the Nuclear Industry*" promoting the industry as a good career choice for a woman engineer or scientist. Since then, a Professional Women in ANS Committee has been formed and today the ANS Public Education Program (PEP) has produced a wide variety of programs aimed at communication with the educational community, the media, legislative decision makers, and the public.

With the help of their local sections, ANS-sponsored teacher workshops provide the much needed opportunity for educators at the elementary and high school levels - traditionally women - learn the facts about nuclear issues: radiation, risks, waste disposal, and transportation. These workshops also provide time for an exchange of opinions and ideas with other educators and a chance to participate in hands-on experiments that they can take back to the classroom.

In addition, the ANS publishes an information letter created explicitly for teachers, distributed free of charge to more than 7,000 teachers and librarians. Other materials available include information booklets on nuclear-related careers, potential salaries, and financial aid sources. The ANS Audio Visual Lending Library now offers more than 70 film/video, slide, cassette, software, and curriculum guide resources for members and educators to use.

Thousands of other teachers are reached through ANS exhibits at professional educator meetings, and many students have the opportunity to see a nuclear exhibit while on a field trip to their local science museum through an ANS exhibit loan program.

Children need to be exposed to science and scientific toys. The ANS is working with teachers' groups in distributing nuclear energy coloring books aimed at children in Kindergarten to Grade 3. At the other end of the spectrum, ANS has recently developed and published materials to supplement a high school social studies curriculum.

Future plans include more involvement in teacher workshops, production of videos for use in the classroom and local communities, and development of curriculum materials for lower elementary grade levels.

The Women of the American Nuclear Society

Of the 16,462 members of the American Nuclear Society, 813 members, or - 4.9% - are women. Reflecting the comparatively recent emergence of women in the field, 74% of these ANS women are under 40 years old. Only 41% of men ANS members are under 40 years of age, 68% are under age 50.

The Emergence of Japanese Women as Antinuclear Activists

Echoing the Western experience, some Japanese women have found a new role, as grassroots leaders and participants in Japan's growing movement against nuclear power. This revived national movement was largely triggered by their anxiety about the contamination of imported food by the fallout from the Chernobyl accident and their role as providers of food for their children. Lectures and books by Jinzaburo Tadagi, a strong antinuclear scientist; Takashi Hirose, a nonfiction writer; and Taeko Kansha, the mother of two, have been instrumental in feeding these antinuclear sentiments.

In August and September of 1987, the Prime Minister's office polled 3,000 Japanese adult men and women. The nationwide survey found that 85.9% felt uneasy about nuclear power plants. The high disapproval rate apparently reflected the increased concern following the 1986 Chernobyl accident, since a 1980 survey showed that 55.6% of Japanese were apprehensive about nuclear power generation. In explaining the marked increase in concern in 1987, the officials conducting the survey pointed to the fact that 92.9% of those surveyed knew about the accident at Chernobyl.

In April 1988, about 20,000 people, many of them housewives with children, participated in the nation's biggest rally yet held against nuclear power generation. In an article titled "***Nuclear Power Loses Popularity in Japan***" in February 9, 1989 issue of ***Nature*** magazine, "The number of antinuclear protest meetings has reached an all-time high in Japan, according to National Police Agency figures released (earlier this year), and has more than doubled since 1987." "...Now surveys show supporters of nuclear construction are outnumbered two to one, with opposition particularly strong in areas near proposed construction sites."

As in the West, many in the nuclear industry believe that the public is being manipulated with inflammatory and scientifically unsound assertions. According to the ***Christian Science Monitor***, July 19, 1988 article, "***Foes of Nuclear Power Make Gains in Japan***", the Japanese government and the power industry have poured extra funds into pronuclear publicity campaigns stressing the safety of Japan's nuclear plants and the environmental pollution caused by coal and oil fired plants. "The companies are even finding it necessary to run an educational campaign for their own employees." It may be useful to run a similar campaign for the employees' wives and children.

There is a general sense that broader participation by women in science and engineering, especially in the nuclear field where the percentage of women is extremely low, will lead to their increased acceptance of nuclear energy. Whether or not this theory is valid for the United States - and whether or not it is applicable to other countries - only time and experience will tell. But the evidence accumulated thus far suggests that the concept has merit.

In the United States, until now, the role of minorities, people with disabilities, and women in science and engineering has been widely seen only as an equity issue rather than as the key to future national strength in science and technology. In the United States at least, these groups must be incorporated into our scientific and engineering infrastructure so that we may retain our industrial and technical capacity.

A Formula for the Future

To meet our future needs, we must cultivate scientific and engineering personnel. We need better, high quality science education programs. In the United States at least, industry leaders need to become more aware of the immediate and long-term risks created by the shortfall in scientists and engineers and of the importance - to their own organizations as well as the national interest - of recruiting and sustaining women in these fields.

Many companies have become sufficiently concerned about scientific education to make substantial financial donations to efforts to enhance school programs. In addition, corporations have begun to donate personnel by providing release time and other incentives to encourage individual scientists or engineers, both men and women, to work with schools, museums, scout troops, and other youth groups.

However, the scientific, engineering and industrial community also needs visible role models and mentors to make young girls aware of the range of opportunities open to them and to promote a more hospitable environment for women students and professionals. This same community also needs to assume a strong leadership role in enhancing the visibility of accomplished women scientists and engineers. Qualified women often are not considered for public recognition in the form of deserved authorship on scientific papers, awards, and invitations to speak at conferences or serve on editorial boards and technical committees, recognition essential to career advancement.

And last, we need a heightened consciousness on the part of all in our community, as well as the general public, to do away with discrimination, bigotry, and inappropriate treatment that can seriously interfere with women's self-esteem and productivity. For example, it is professionally inappropriate to emphasize the scholar as a woman first and a scholar second. These difficulties, often encountered in the labor force, are especially formidable in the male-dominated science and engineering professions.

A recent report by the Government-University-Industry-Research Roundtable summarizes the situation very well. They concluded that "the advance of science and technology is essential to the health of the nation-essential to quality of life, to economic stability and national security". They went onto state that "human resources are key to advancing science and technology".

We in science and engineering, particularly the nuclear field, can no longer afford to ignore almost fifty percent of our human resource. Women must be encouraged to not only study science and engineering, but to become full partners in the hi-tech community of tomorrow. If we fail to ensure an adequate supply of scientists and engineers, then we jeopardize the very future of civilization as we know it which is now critically dependent on our application of science and technology. Further, if we fail to impart scientific literacy to both the men and women of tomorrow, we will have a citizenry incapable of making the scientific choices required for the very survival of our planet.

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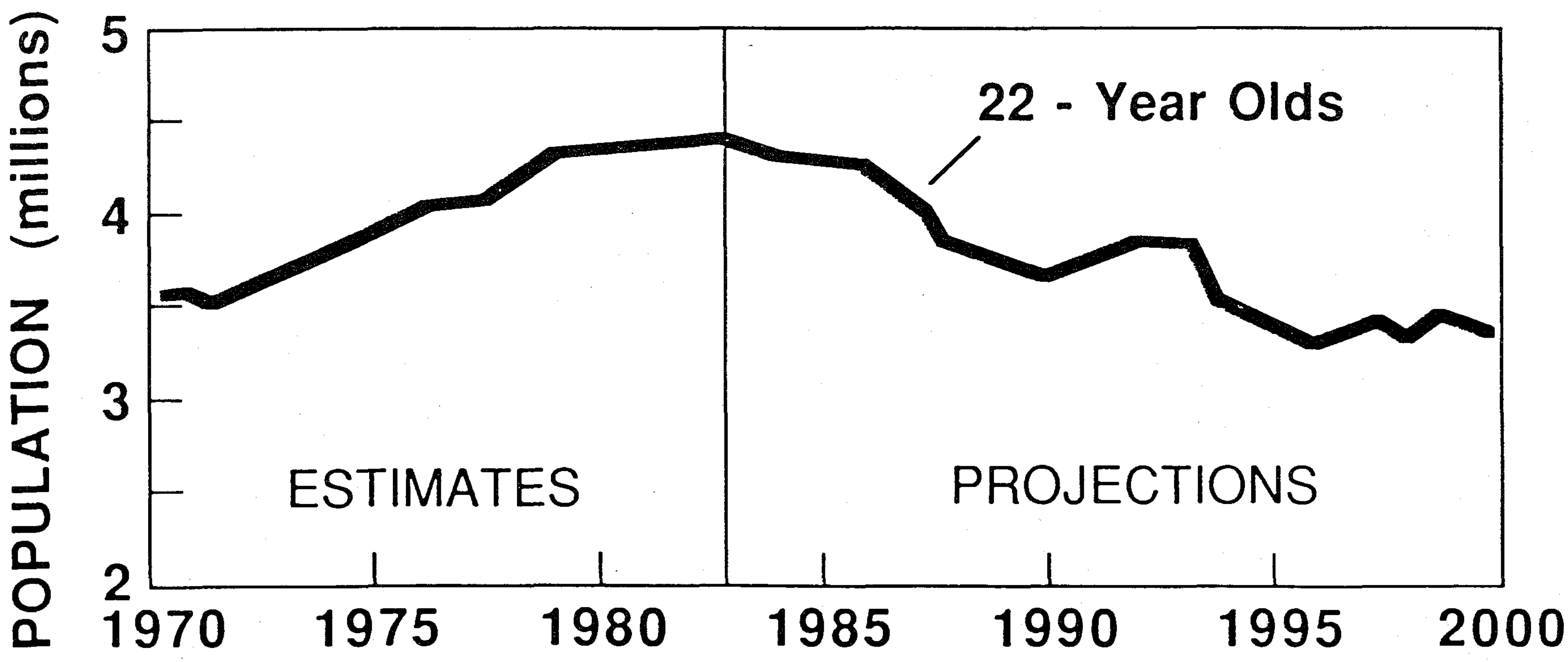
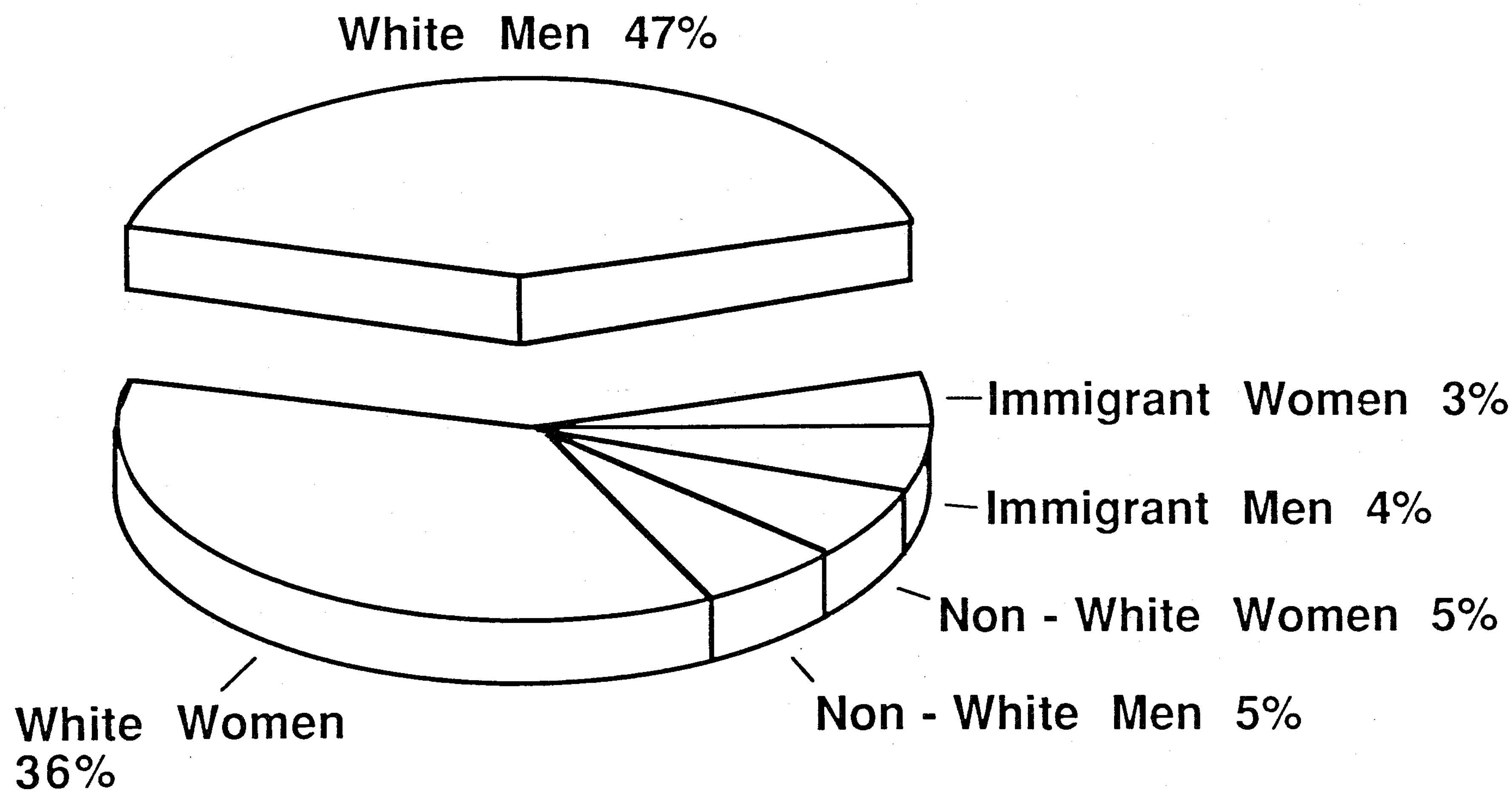
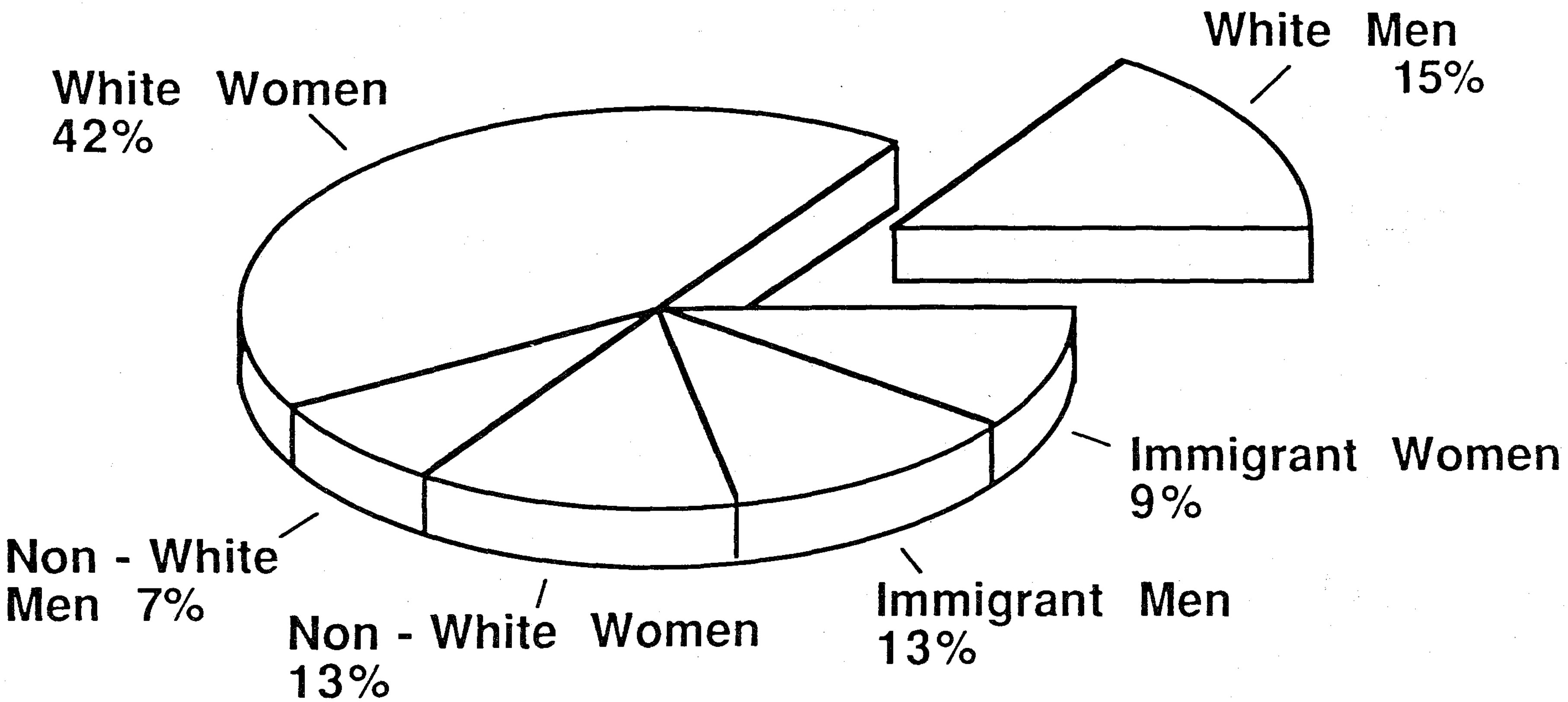
ESTIMATES OF 22 -YEAR OLDS IN THE U.S. POPULATION





1985 LABOR FORCE

115,461,000



NET NEW WORKERS 1985 - 2000

25,000,000

WOMEN IN THE WORKFORCE

1987 45% WOMEN

2000 47% WOMEN

63% OF NEW ENTRIES WILL BE WOMEN

1987 67% OF WOMEN 18 - 64

75% OF WOMEN 35 - 44

70% OF WOMEN < 4 YRS. HIGH SCHOOL

82% OF WOMEN ≥ 4 YRS. COLLEGE

AVG. FEMALE WORKER IS AS WELL EDUCATED AS AVG. MALE WORKER - 12.8 YRS.

WOMEN IN THE WORKFORCE

60% OF WOMEN WHO WORK DO SO FOR ECONOMIC SURVIVAL:

25%	SINGLE
12%	DIVORCED
4%	WIDOWED
4%	SEPARATED
15%	HUSBANDS EARN < $15K

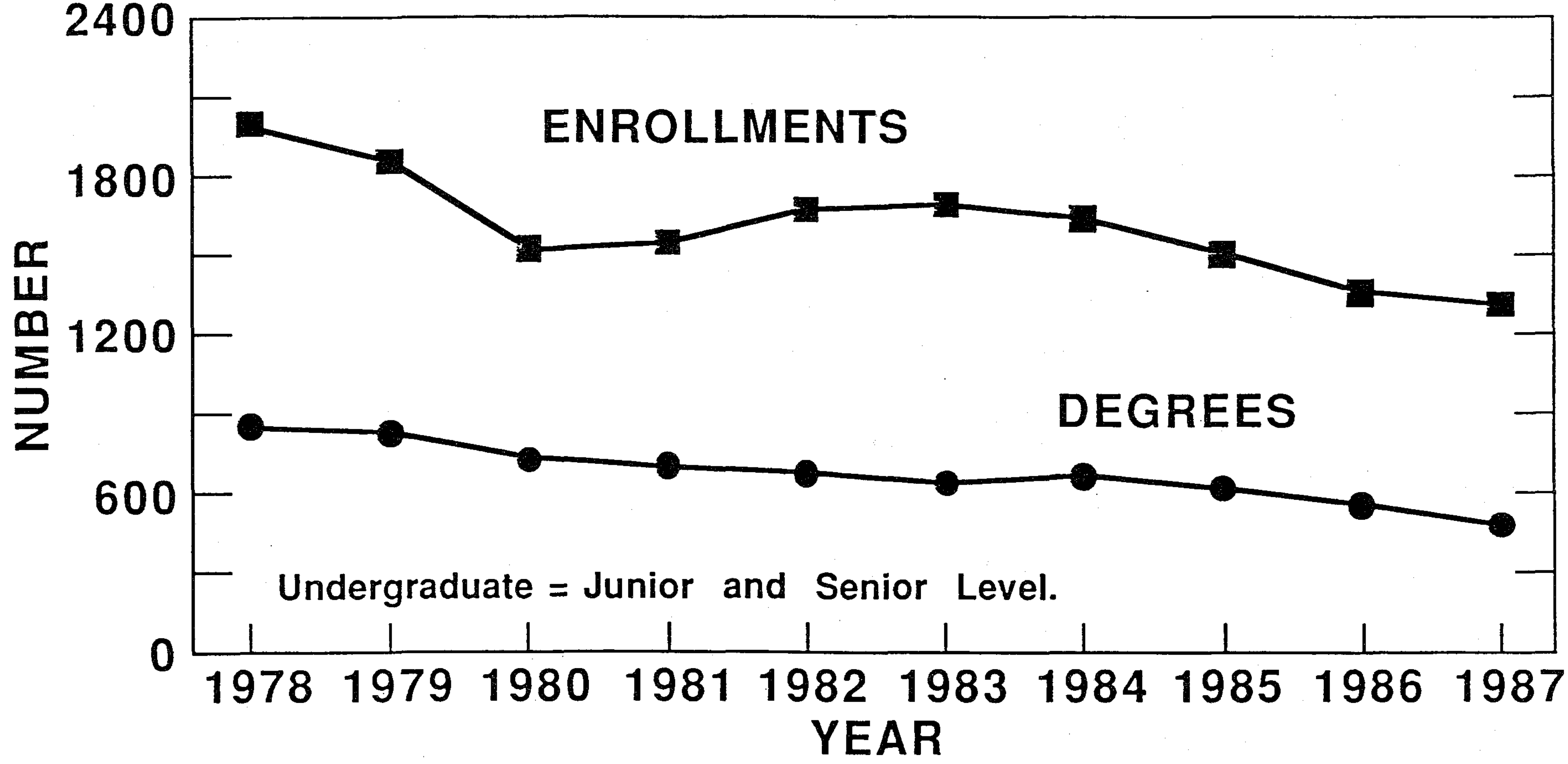
WOMEN EARN 65 ¢ / $ EARNED BY MEN.

WOMEN IN THE WORKFORCE

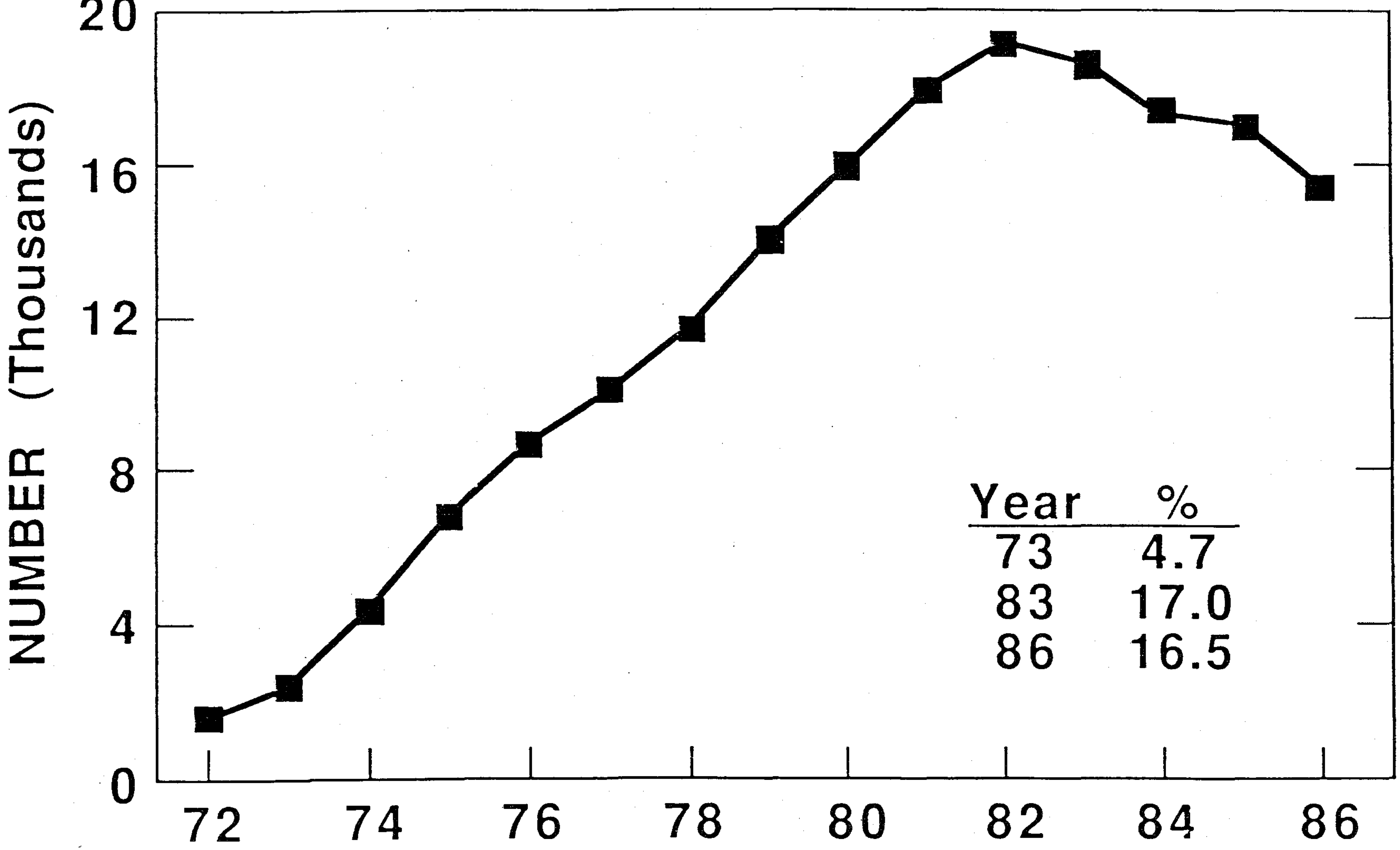
73% OF WORKING WOMEN ARE OF CHILD - BEARING AGE:

	1960	1984
WOMEN WITH CHILDREN	28%	61%
WOMEN WITH CHILDREN < 6	11%	52%

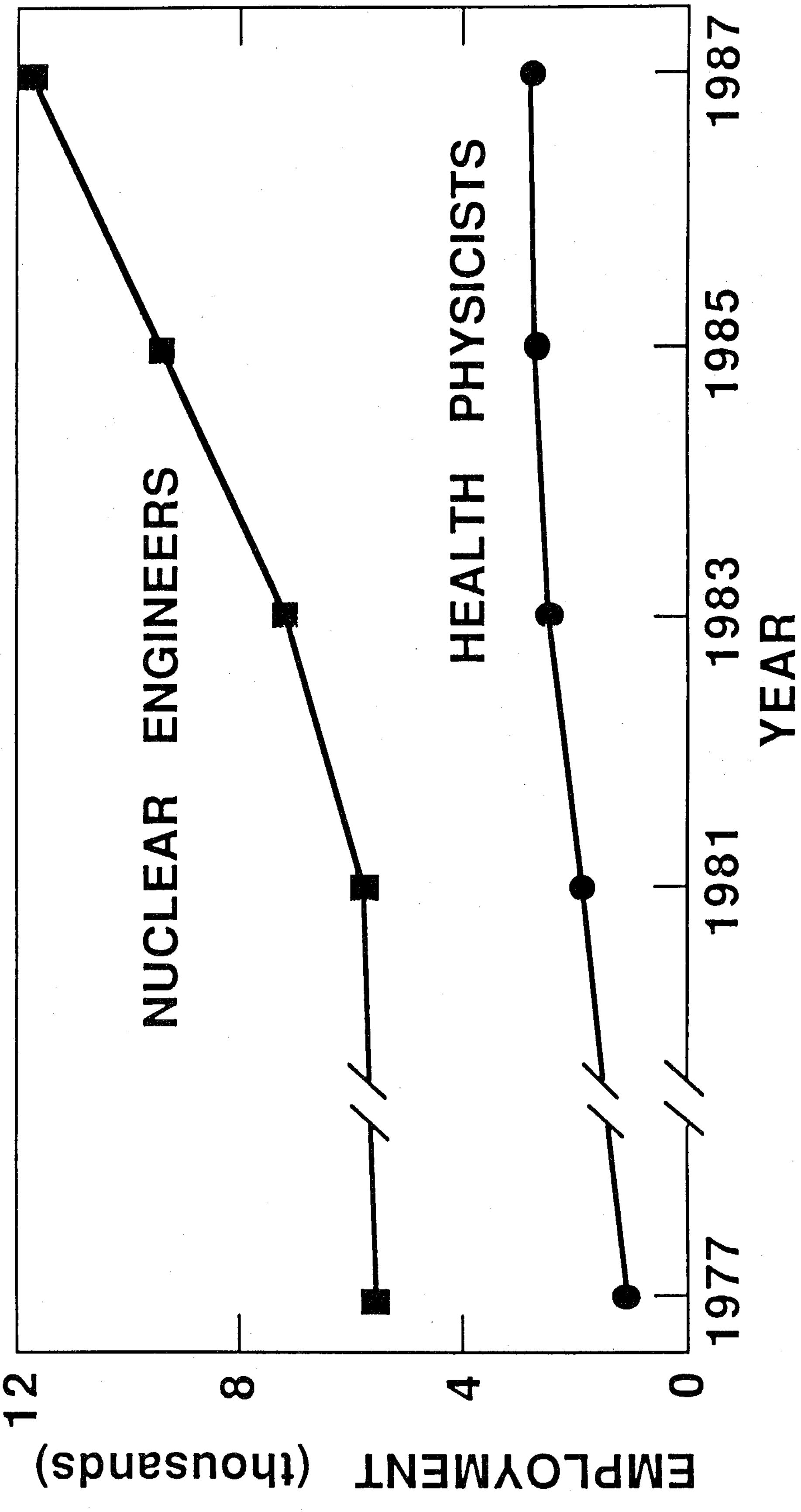
NUCLEAR ENGINEERING UNDERGRADUATE ENROLLMENTS AND DEGREES 1978 - 1987



FRESHMAN WOMEN IN ENGINEERING (1972 - 1986)

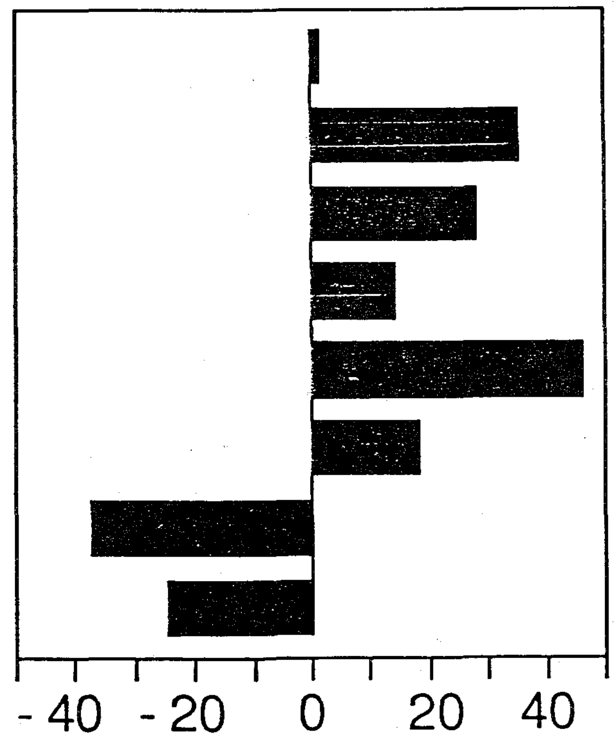


U.S. NUCLEAR - RELATED EMPLOYMENT:
NUCLEAR ENGINEERS AND HEALTH PHYSICISTS
1977 - 1987



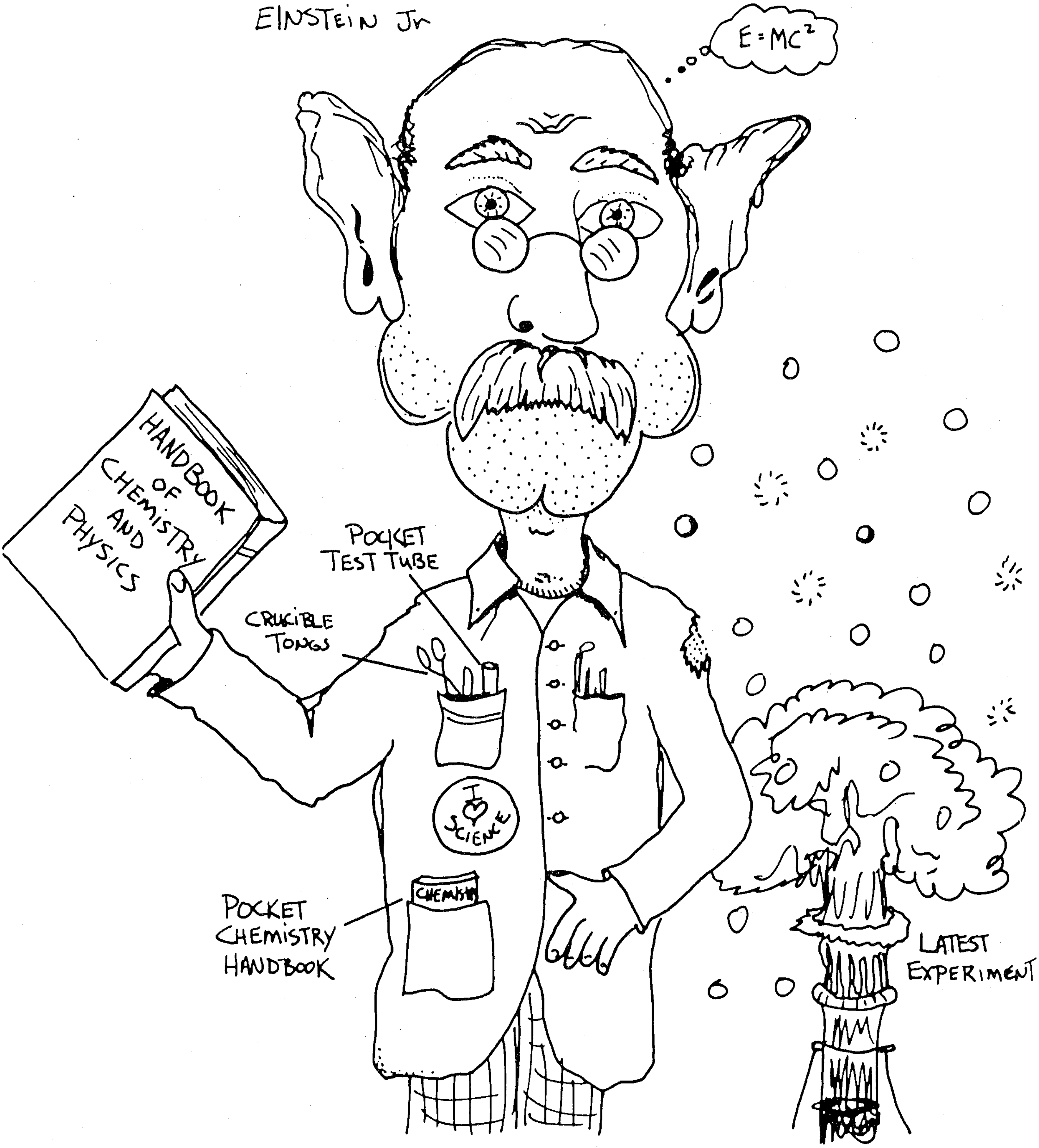
NUCLEAR - RELATED EMPLOYMENT BY OCCUPATIONAL GROUP 1981 - 1987

	1981	1987
Total Employment	281,300	285,000
Managers	20,800	28,150
Engineers	45,300	58,100
Scientists	14,650	16,650
Other Professionals	18,400	26,850
Technicians & Operators	47,150	55,800
Skilled Craft Workers	52,150	32,800
All Other Workers	82,850	66,650

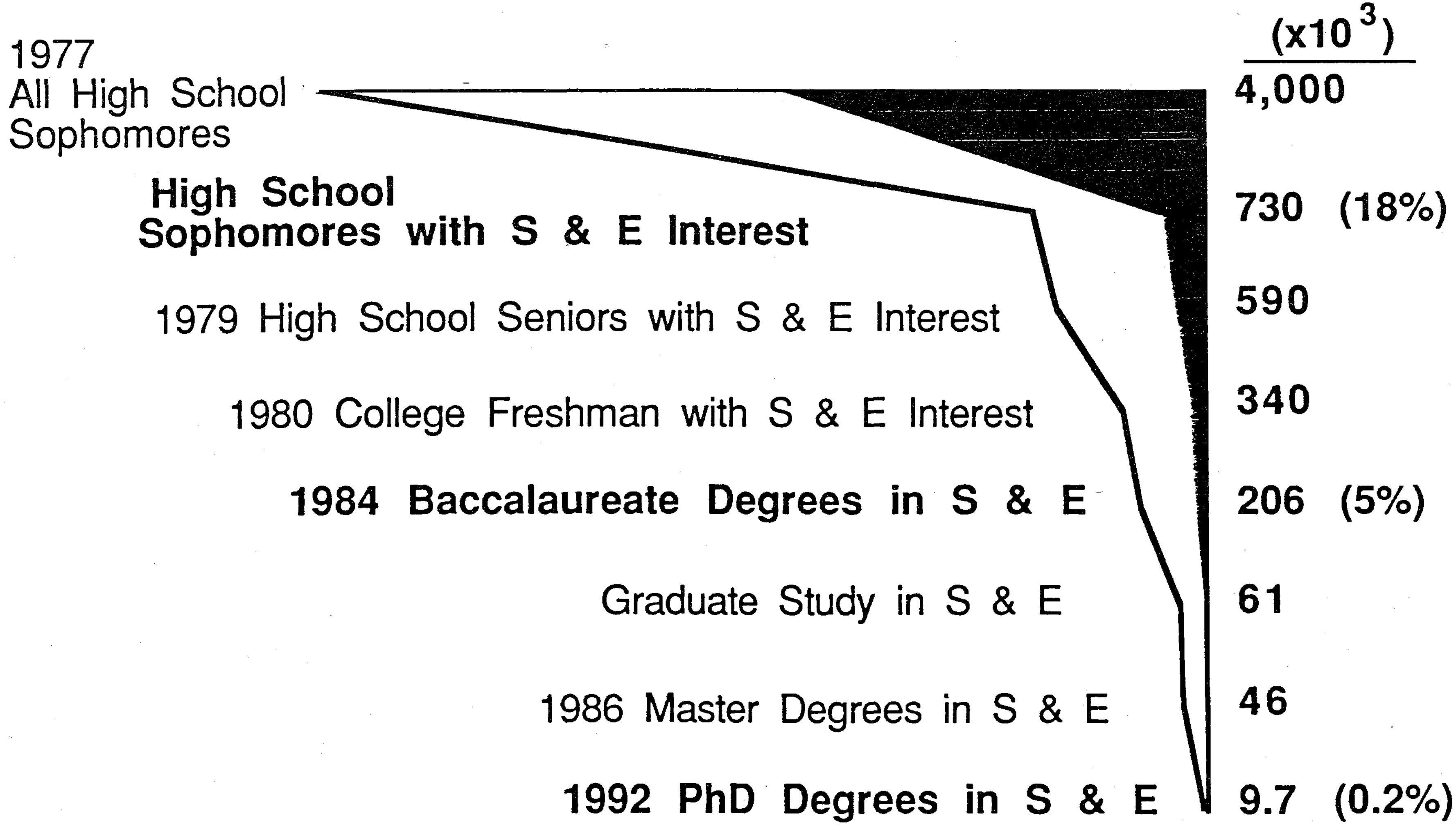


ELECTRIC UTILITIES (NUCLEAR)

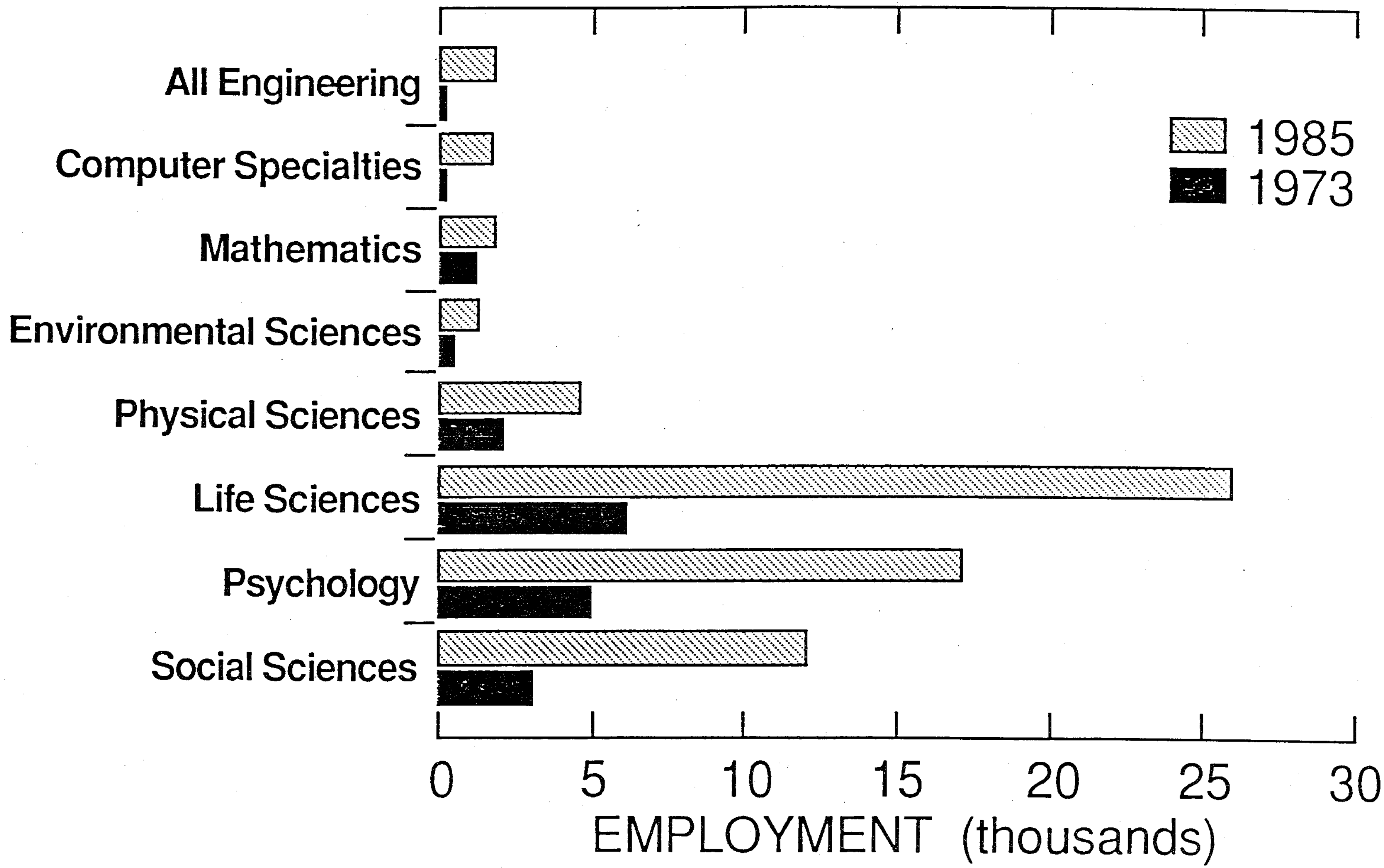
1987	71,000	MANAGEMENT, TECHNICAL, PROFESSIONAL
	21,000	OTHER
	92,000	TOTAL NUCLEAR - RELATED
1997	1,700	(2.3% GROWTH)
	28,200	(REPLACEMENT)
	3,700	(VACANCIES)
	33,600	


EINSTEIN Jr
E=MC²
HANDBOOK OF CHEMISTRY AND PHYSICS
POCKET TEST TUBE
CRUCIBLE TONGS
I ♡ SCIENCE
POCKET CHEMISTRY HANDBOOK
CHEMISTRY
LATEST EXPERIMENT

SCIENCE & ENGINEERING PIPELINE HIGH SCHOOL THROUGH PH.D. DEGREE



WOMEN DOCTORATES IN SCIENCE AND ENGINEERING JOBS BY FIELD: 1973 AND 1985



"We should concern ourselves with the issue of future public support for science on the part of groups who perceive that they have been excluded from full participation in the scientific enterprise. The years ahead may be troublesome for the support of science, and the image of science as a community accessible to all will be important to maintain public support."

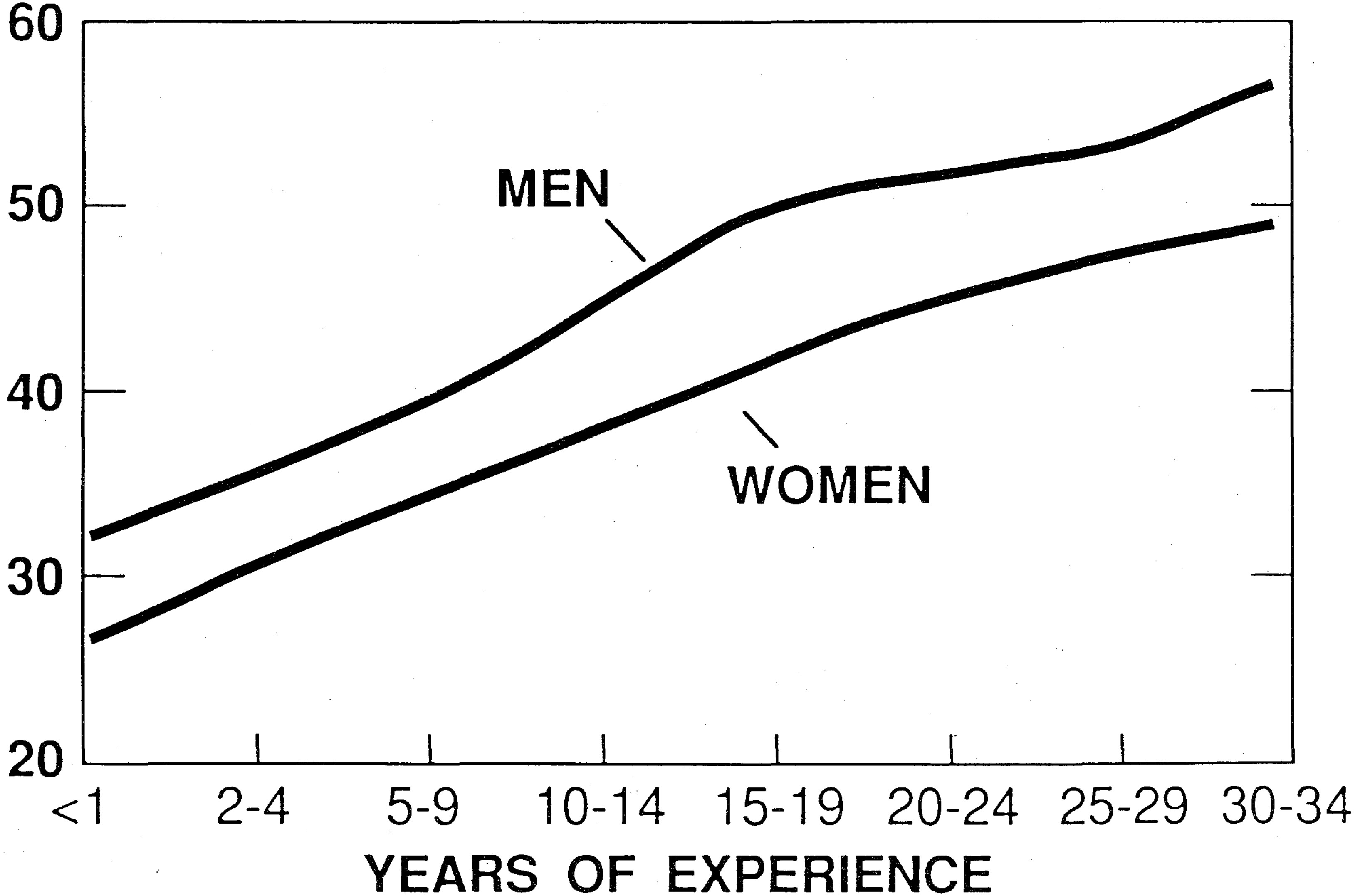
BARRIERS

- ENGINEERING PERCEIVED AS A HIGHLY COMPETITIVE FIELD
- ENGINEERING PERCEIVED AS A "MALE PROFESSION"
- MOST STUDENTS DON'T KNOW ANY WOMEN ENGINEERS
- WOMEN ARE NOT PERCEIVED AS BEING AS GOOD AS MEN IN MATH & SCIENCE
- THERE IS SEX DISCRIMINATION IN THE PROFESSION

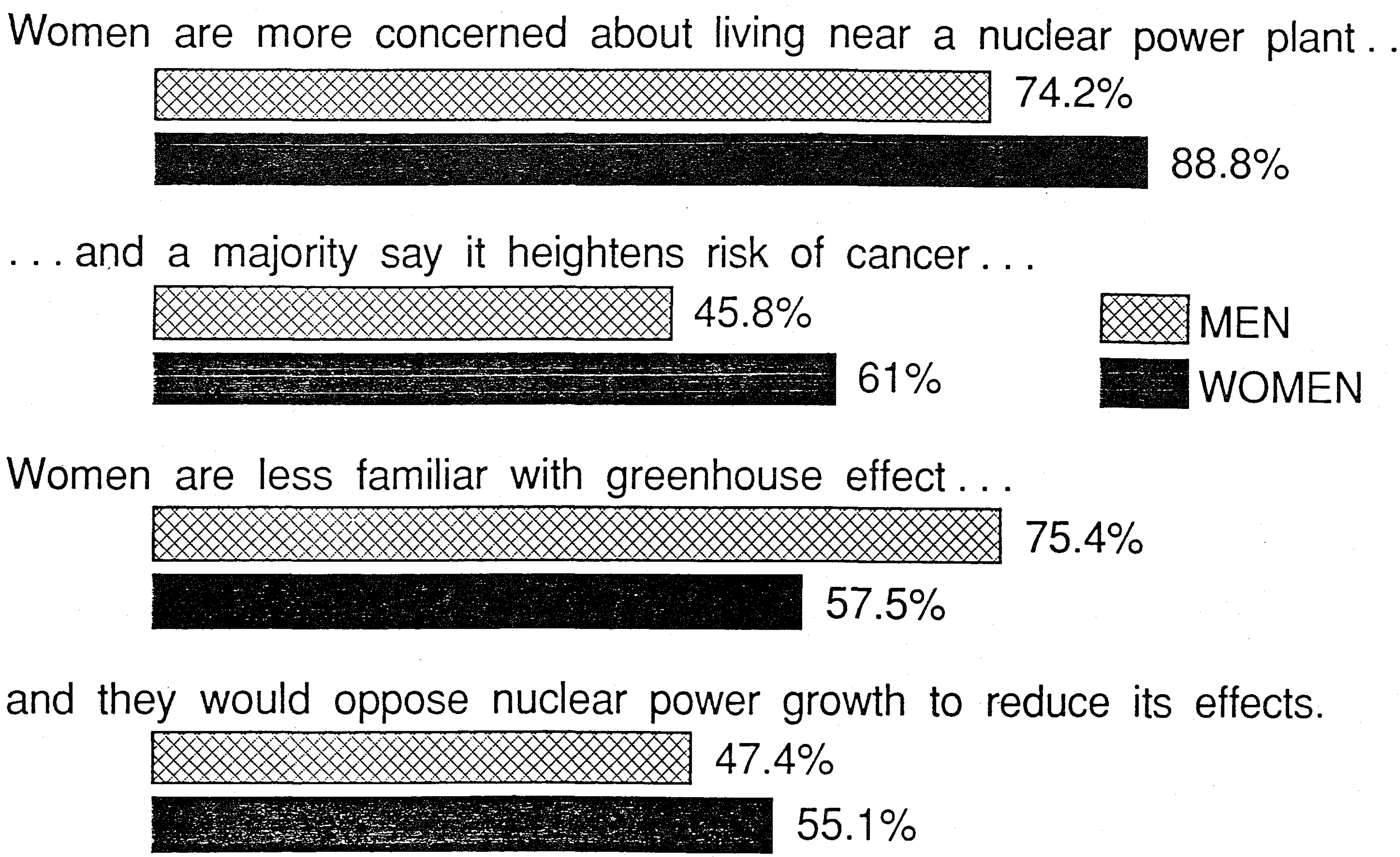
WOMEN AND MINORITIES FACE THE FOLLOWING OBSTACLES IN THEIR EFFORTS TO ADVANCE TO UPPER MANAGEMENT:

- The 'comfort' factor as white, male bosses tend to promote people like themselves
- Absence of performance feedback
- Lack of mentoring
- Little formal career guidance
- Exclusion from country clubs and other social settings
- Stereotyping
- Harassment
- Erroneous assumptions about assignments they will accept

SALARIES ($1000) OF DOCTORAL SCIENTISTS AND ENGINEERS 1985



WOMEN WORRY MORE ABOUT NUCLEAR POWER RISKS



"Until now, the role of minorities, women, and people with disabilities in science and engineering has been widely seen only as an equity issue, rather than as the key to future national strength in science and technology."

"The advance of science and technology is essential to the health of the nation, essential to quality of life, to economic stability, and national security.
Human resources are key to advancing science and technology . . . ."

JAIF 1989

PRESENTATION BY DR W L WILKINSON,
British Nuclear Fuels plc

Introduction to Video

Mr Chairman, ~~Ladies~~ I would first like to say how honoured I am to be invited to [illegible] In Europe the Japanese Atomic Industrial Forum is regarded as a very important event in the nuclear energy calendar

BNFL has always put great importance on the need for technical innovation to support its nuclear fuel cycle activities. The Company is perhaps best known in Japan for its activities at the back-end of the fuel cycle; that is for irradiated fuel transport, storage, reprocessing and waste management. However, BNFL's operations extend over the whole nuclear fuel cycle. The video you are about to see, whilst reviewing briefly all the areas of the Company's application of advanced technology, concentrates on two areas at the front-end of the fuel cycle.

The two areas are the use of advanced centrifuge technology for the enrichment of uranium and the integrated dry route (IDR) for the conversion of enriched uranium hexafluoride to ceramic grade uranium dioxide powder.

After a brief introduction to all the fuel cycle services offered by BNFL

you are about to see

The video first reviews the development of enrichment technology in the UK starting with the Diffusion Plants built in the 1950s, the establishment of the Urenco organisation to develop and exploit the centrifuge process, to the development of the laser isotope enrichment process.

The video then describes the single step integrated dry route (IDR) to convert enriched uranium hexafluoride into ceramic grade uranium dioxide powder and highlights the advantages this process has over the alternative multi-stage wet route, both in the process itself and in the quality of the product produced.

VIDEO PRESENTATION HERE

Summary

The video you have just seen provided you with an insight into two important areas of the fuel cycle which benefit from advanced technology.

In the case of the IDR process BNFL has successfully developed an innovation of the early 1970s and customers in 10 countries ~~use~~ are benefitting from the process and recognise its reliability and versatility.

BNFL has nearly 20 years experience in the production of IDR powder on a commercial scale and has refined the process to a high degree.

Since the Springfields plant began operations in the early 1970s it has produced more than 6000 te U of which more than two-thirds has been exported. The remaining one-third was used to meet requirements of British AGR reactors and over 1500 te U of this fuel has used uranium recovered from the reprocessing of Magnox fuel. The IDR process therefore already has an impressive record in dealing with reprocessed uranium.

The important advantages of the process are:-

(i) it carries out the conversion process in one step;

(ii) the exceptionally pure and consistent uranium dioxide powder can be used to meet the specific pellet requirements of the many fuel types required by different nuclear reactor systems;

(iii) the IDR process produces minimal effluents;

(iv) it is the ideal technology for use in the fabrication of fuel from recycled uranium and is better suited to this than the traditional wet routes.

In the field of enrichment, major advances have been made possible because of the considerable R&D effort committed by the Urenco partners to the centrifuge project. This has been a great success, not only in technical terms but also in the field of international collaboration. The result is a low cost, flexible and efficient process. It has the important added advantage of being able to handle recycled uranium.

Further development of the centrifuge is planned and a machine will be available by the mid-1990s which will have a unit output some twenty-five times that of the machines running in the early 1970s.

Whilst laser isotope separation may currently show little economic advantages over these advanced centrifuge machines, its long term potential is considerable. BNFL therefore intend to exploit this exciting and promising new technology and we are already engaged on a substantial programme of development. International collaboration, so successful in the centrifuge process, could also offer significant advantages in this complex and expensive field of work.

6 April 1989

The role of nuclear energy for energy security in Czechoslovakia

Prof. A. Krumnikl
(Minister of Fuel and Energy,
Socialist Republic of Czechoslovakia)

Abstract

The reason for Czechoslovakia to develop, improve and atttain a stable position for nuclear power is to be found in the environmental safety, economic efficiency and supply stability. At present nuclear power plants produced about 23 TWh electricity in 1988 (it accounted for 27 % of the CSSR electricity energy). Economic advantage of nuclear power over other thermal power sources are at present obious. Czechoslovakia's record of maintaining safety of nuclear power plants continues to be good. Efforts to gain public acceptance for the nuclear power have resulted in a relative smooth licensing of the new nuclear power plants in the country.

Downward revision of the projected long-term energy demand and available resources for the financing of the future nuclear power projects present a major challenge for the next nuclear development in the country.

The future development of nuclear energy in Czechoslovakia is based on the long-term outlook on energy supply and demand.

The estimated primary energy demand for 2000 (2005) is expected 110.9 (10 8) million tons in coal equivalent. In this content, the outlook for installed nuclear capacity 10,280 MW (14,000 MW).

At present about 9,280 MW in VVER-400 and VVER-1000 are in operation or under construction. It is expected the share of nuclear power generated electricity accounts for 43 % by 1995. To reach the target figures for 2000 (2005) year, it is necessary to prepare the nuclear development plans for three new sites during the next 5 years.

As far as the reactor strategy is concerned, the advanced VVER-1000 reactor systems will be the workhorses of the Czechoslovak nuclear programme. Czechoslovakia is also deeply interested in the development of easy-to operate, easy-to maintain medium and small size reactors of the so called "second nuclear era" for steam and hot water supply, electricity generation, coal gasification, chemical industry etc. Studies are conducted by national institutions on the technological and economic feasibility of such reactors.

R&D nuclear activities in CSSR are implemented within the joint technological development on an international scale within the CMEA countries.

Introduction

The reason for Czechoslovakia to develop, improve and attain a stable position for nuclear power is to be found in the following advantages features of nuclear power itself :

- environmental safety

Nuclear power is one large-scale source of energy which does not give rise to acid rain or any of the greenhouse gases. These features have a rapidly growing importance not only for Czechoslovakia but for the whole grobe.

- economic efficiency

In terms of generating cost over the entire plant life within the Czechoslovak grid, nuclear power is less affected by price fluduations, because fuel costs are only a small part of the entire cost (as compared with coal powe r).

- supply stability

Nuclear power plants can operate for one year on a single loading of fuel, it is easy to transport nuclear fuel for the nuclear power plants, uranium ore is a domestic energy resource.

- living standard of the people

Through nuclear power, the electricity production can be raised rapidly in the country. It enables to improve a living standard of the people and to introduce the advanced technologies in the whole economy system.

Current status of nuclear energy development

Nuclear power in Czechoslovakia is based on the Soviet PWR reactor system on a 440 MW power level (VVER 440-water-water type reactor).

The nuclear power projects are implemented mainly by the Czechoslovak companies. They cover about 85 % of the whole delivery contract value, including start-up activities.

There are at present two commercial nuclear power plants with eight VVER-440 reactor units. Total net capacity is 3,207 MWe, total operating experience (to 30 September 1988) accounts for about 42 years [1].

Total electricity generation by the Czechoslovak power industry was about 87.5 billion kWh in 1988 and the share of nuclear power rose to 27 %.

Moreover, the nuclear power plant in Jalovske Bohunice started to deliver the heat for the town Trnava (about 1.48 PJ of low-temperature heat for community - public consumption).

The operation of the Czechoslovak VVER-440 nuclear power plants (NPPs) is analyzed using the following indicators mainly :

- load factor
- time utilization factor

The mean value of the load factor of all VVER-440 units by the end of 1988 equals to 76%.

Accordingly, the time utilization factor is about 82 %

These figures prove a good level of the reliability of the Czechoslovak VVER-440 NPPs [2].

The load factors are highly affected by planned outages for periodic inspections and potential repairs, which are performed simultaneously with refuelling opreations. Standardized time requirements for activities performed during planned periodic inspections (each year) and extended periodic inspections (each fourth year) are 49 days and 84 days respectively. There is an effort to reduce this figures to 39 days and 70 days by 1990. Czechoslovakia's record of maintaining safety of nuclear power plants covers the following :

- the results of the nuclear power plants operation in Czechoslovakia are confirming the safety of the Czechoslovak VVER-440 units. There has been no accident in which radioactive substances have affected people in the vicinity of a nuclear power plant ;

- the scram frequency for Czechoslovak nuclear reactors has decreased to about two per reactor year ;

- the radiation exposure of the operational personnel is very low and can be compared with that of the best NPPs worldwide. This statement can be supported by the analysis of the indicator "mean collective dose equivalent of the personnel related to the produced energy ". The value of this indicator annualy varies between 0.25 - 1 mSV per GWh. ;

- efforts to maintain the possible lowest level of radioactive substances emitted from nuclear power plants during normal operation have held such emissions to levels well below those permitted by the regulation.

For instance, in the site of Jaslovske Bohunice, the real emissions of radioactive noble gases are about 5 % and emissions of radioactive aerosols between 0.02 - 1.3 % of the authorized limits. The total radioactive release into the hydrosphere is under 20 % of the limits 〔3〕.

Czechoslovakia shares its operational and safety experience internationally participating actively in the following IAEA systems : PRIS (Power Reactor Information System).

To evaluate the economy of power sources, three methods are usually used in Czechoslovakia :

- the initial year cost
- the leveled cost method
- the system cost method

Using the system cost method, the present economic composition of the Czechoslovak grid can be assessed as follows 〔4〕.

- nuclear generating cost (base load)	212.1 Cs crowns/MWh
- coal generating costs (base load)	297.6 Cs crowns/MWh
- system costs	352.0 Cs crowns/MWh

The cost of nuclear power dose not include reprocessing cost. The reason is that under present condition the spent fuel is transported back to the USSR on cost-free basic. Also decommissioning costs are not included due to the lack of realiable cost estimates.

Referring to these figures, the economic superiority of nuclear power in Czechoslovakia is obvious. We estimate that this superiority will last even in the case the cost of nuclear power includes both reprocessing and decommissioning costs.

The effort has started to confirm these results within the joint IAEA-OECD report on electricity generation costs. Here the generating costs are analyzed using the UNIPEDE methodology.

In the nuclear fuel cycle Czechoslovakia closely cooperates with the USSR.

Enrichment services and fuel fabrication are provided by the Soviet organizations. The spent fuel is transported back to the USSR. Efforts to gain public acceptance for the nuclear power have resulted in a relatively smooth licensing process of the new nuclear power plants in the country. The next development of Czechoslovak nuclear power is challenged by the following:

- projected long-term energy demand outlook revised downward ;
- the resources for the financing of the nuclear power projects are shrinking due to the two main reasons : the rising investment costs of nuclear power plants and the changing overall investment policy (as a result of the intention to change the overall structure of a national economy system).

Long-term energy outlook

The primary energy forecast estimates that the total energy demand in terms of coal equivalent (CE) will increase to 113 MTCE by 1995 and then will level off (108 MTCE in 2005).

The actual energy supply in 1985 was 106.6 MTCE. This forecast is attributed to the expected radical conversion of the industrial structure of Czechoslovakia which will mean reduced importance of heavy energy consuming industries (fuel industry, iron and steel industry, heavy engineering and chemical industries) and that energy - saving measures will be increased [5] .

The industry is expected to have zero growth (till 1995) and then will level off, the consumer consumption will grow for the whole period.

By power source, the most dynamic one is natural gas. Its composition rate in the primary energy structure will increase from the actual figure 15 % in 1985 by 20.4 % in 2000. Following this strategy natural gas will become very important power source by the end of the century.

The percentage of electricity is estimated to rise from 10.4 % in 1986 to 17.9 % by 2000.

Depending on the nuclear power development, raising of import of a natural gas and shrinking resources for the financing of the future coal industry development, the supply of coal will decrease (both for thermal power generation and for metallurgical coal) corresponding composition rates are 56 % (in 1985) and 43.9 % (in 2000). The demand for oil also will decrease from the actual figure of 19.1 % in 1985 to 16.1 % in 2000.

Long-term electricity supply-demand outlook

Total electricity demand, estimated in consideration of changes in the economic situation. Population increase and other factors is projected to grow to 107 billion kWh in 1995 and 117 billion kWh in 2000 from the factual figure 85 kWh in 1985 (this 1985 figure covers 4 billion kWh imported to Czechoslovakia through the CMEA international grid).

The average annual growth rate of power demand will be 2.3 % until 1995 and 1.8 % between 1995-2000. These rates are higher than the estimated growth rate of total energy demand.

This will mean a shift toward electricity consumption in end-uses energy consumption structure, the electrification rate in this structure is expected to reach 10 % by 2000.

Clasified by the users, electricity demand from large-lot electric power consumers will level off, because racionalization programme will be intensified in industries consuming large quantities of electric power begining with the iron and steel industry, fuel industry, chemical industry and heavey-engineering industry, elctricity demands from the other sectors of economy are expected to grow.

As regards maximum power demand, this is expected to grow higher rate than growth rate of power consumption, because the percentage of daytime power demand from the consuming public will grow, reflecting the raised living standards of the people and progress in urbanization, although energy-saving equipments are more widespread.

As a result, maximum power demand will rise to 16,000 MW by 2000 from 12, 700 MW in 1985. The annual load factor is expected to continue its downward trend.

In consideration of the characteristics of different electric-power sources and taking into account above mentioned long-term electricity demand, our outlook regards nuclear power, which is ecologically acceptable, excellent in economic efficiency and stable in fuel supply, as the main power supply source to meet base demand.

It is followed by coal fired power generation, excellent in load following and power output adjustment functions, and pumped-up and pool types of hydropower as power sources to meet peak demand.

Taking these points into consideration, and in view of progress in the other aspects of various power supply sources, the target capacity of installed power generation at the end of 1995, 2000, 2010 are shown in tables 1 and 2.

Non-public utility power generation and consumption is estimated to be down on a long-term view from the existing 2,800 MW (10 billion kWh) to 2,240 MW (8~9 billion kWh) in 2000 and 1,850 MW (5 billion kWh) in 2010.

According to these tables, the installed nuclear capacity will be increased from 1,700 MW at the end of 1985 (composition rate 16.8 %) to 7,300 MW (31.9 %) at the end of 1995 and 10,300 MW (41.2 %) at the end of 2000.

Further, nuclear electricity generation will reach 61.8 billion kWh in 2000, accounting for 69.7 % of total power generation by public utilities.

By contrast, coal-fired thermal power generation will gradually go down in importance declining to 32.8 % in 2000 from 77.2 % in 1985.

Referring to power development and tasks for different power sources, it is desirable that nuclear power should be developed positively as the basic power supply sources.

Future tasks are the assurance of public acceptance, sophistication of light water reactors (VVER 1000), the sound nuclear fuel cycle management in Czechoslovak conditions, establishment of methods of radioactive waste treatement and disposal, and measures for reactor decommissioning.

<u>Power resources development plans</u>

The amount of power resources to be developed between 1985-2000 will be 10,000 MW of which nuclear power will account for 8,600 MW (86 %) and 1,400 MW (14 %) for hydropower generation (table 3).

If these plans are carried out to schedule, nuclear power (10,300 MW) will exceed in 2000 coal-fired installed capacity (10,000 MW) and takes the largest share (59.7 %) in electicity generation.

This basic strategy does not imply "too" fast coal-fired power plants decommissioning plan. These power plants will be retroffited or backfitted for cogeneration within the large district heating systems.

So far as nuclear power development is concerned, plants at two other sites are scheduled to come into operation :

- 1. site : Mochovce, four VVER-440 MW reactor units, between 1990-1994

- 2. site : Temelin, four VVER-1100 MW reactor units, between 1992-1998.

To reach the target figures for 2000 (2010) year it is neccessary to prepare the nuclear power development plans for additional three new sites during the next 5 years.

As far as the reactor strategy is concerned, the advanced VVER-1000 reactor systems will be the workhorses of the Czechoslovak nuclear programme. It is expected the advanced VVER-1000 can reduce the exposure doses of operational personnel and the quantity of low-level wastes, save the uranium ore, improve the availability factor and reduce kWh cost.

As far as the nuclear fuel cycle strategy is concerned, the front-end part (uranium resources, conversation, enrichment, reconversion, fabrication) is implemented together with the USSR organizations.

At present no major changes are envisaged. In the back-end strategy, the effort has started to store the spent fuel in dry and in high density inside the country. There is no intention to develop domestic reprocessing capability.

Czechoslovakia is also deeply interested in the development of easy-to operate, easy-to maintain medium and small size reactors of the so called "second nuclear era" for steam and hot water supply, electricity generation, coal gasification, chemical and iron & steel industries.

Special attention attracts a modular high temperature gas-cooled reactor (MHTGR). The MHTGR can solve the problems in improving the economy and broadening the field of utilizing nuclear energy while maintaining safety, due to its specific characteristics of high temperature heat, inherent safety, and high burn-up. Considering the importance to use nuclear energy in non-electric fields in the future, studies are being conducted by national institutions on the technological and economic feasibility of the HTGR perspective in the coal gasification and chemical industry.

<u>Technical development</u>

The present good safety record and economic efficiency of nuclear power in Czechoslovakia is based in past technological development within the long-term CMEA-Research and Development Programme. Efforts continue to improve both the reliability and economic efficiency of the existing VVERs. Advanced VVER-1000 are under development and will come into operation in the mid-1990s.

New reactor systems of the so called "second nuclear era" are under development (the next version of VVER in the power range between 500-1000 MW, reactor systems for district heating, high-temperature gas-cooled reactors etc...).

Through its active participation in the above-mentioned CMEA-Nuclear R&D programme Czechoslovakia is trying to make its contribution to maintaining the good safety record and the economic advantage of nuclear power in the future.

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TABLE 1: Installed Capacity Target (public utilities)

Year	1985		1995		2000		2010	
Type	Capacity (MW)	Ratio (%)	Capacity (MW)	Ratio (%)	Capacity (MW)	Ratio (%)	Capacity (MW)	Ratio (%)
Nuclear	1700	10.0	7300	31.9	10 300	40.1	17 300	51.8
Coal	12 300	72.4	11 500	50.2	10 000	38.9	8600	25.7
Hydro	3000	17.6	4100	17.9	5400	21.0	7500	22.5
Total	17 000	100.0	22 900	100.0	25 700	100.0	33 400	100.0

TABLE 2: Power Generation Target (public utilities)

Quantity of Power Generation (billion kWh)								
Year	1985		1995		2000		2010	
Type	Capacity (MW)	Ratio (%)	Capacity (MW)	Ratio (%)	Capacity (MW)	Ratio (%)	Capacity (MW)	Ratio (%)
Nuclear	11.8	16.8	43.4	47.4	61.8	59.7	94.8	72.0
Coal	54.1	77.2	40.8	44.5	34.0	32.8	25.1	19.1
Hydro	4.2	6.0	7.4	8.1	7.8	7.5	11.7	8.9
Total	70.1	100.0	91.6	100.0	103.6	100.0	131.6	100.0

TABLE 3: Electric Power Resources Development Program of Public Utilities

Years	1990 - 1995		1996 - 2000		2001 - 2010	
Type	Capacity (MW)	Ratio (%)	Capacity (MW)	Ratio (%)	Capacity (MW)	Ratio (%)
HYDRO	1140	27.5	1300	30.2	2100	23.1
general	490	11.8	300	7.0	500	5.5
pumped	650	15.7	1000	23.2	1600	17.6
NUCLEAR	3000	72.5	3000	69.8	7000	76.9
TOTAL	4140	100.0	4300	100.0	9100	100.0

原子力開発の今日的意義

〔原子力は人間社会に貢献できるか〕

電気事業連合会会長　那　須　　翔

那須でございます。

このたび、日本原子力産業会議の年次大会におきまして、わが国の電気事業者を代表して私の所信を述べさせていただく機会を与えられましたことを、関係各位に深く感謝申し上げます。

皆様ご承知のように、本年は一九三九年オットー・ハーン博士達がウランの核分裂を発見してから丁度五十年目にあたっておりますが、顧みますと、人類がそれまで全く未知の世界であった原子核の世界に、足を踏み入れてからわずか半世紀という極めて短い時間で、原子核反応を人が制御できるような科学技術を造りあげてきたことは、誠に驚くべきことであります。

そしてそれを可能にしたもの、すなわち原子力技術の発達を促したものは、一つは、科学技術自体に内在する本質的な自己発展性であると思いますが、もう一つは原子力エネルギーの利用によって、人類の生存と発展のための基本要素の一つであるエネルギー資源の量に限度があるといった制約条件を取り払うことができること、ひいてはそれによってこれまで資源を求めて繰り返し起こってきた国際紛争をなくすことができるであろう、といった大きな夢と期待があった、と考えられるのであります。

一般的にいって科学技術は、私達の日常生活の質的な向上を実現さ

せるものといえるかと思いますが、それはすなわち、科学技術が発達すればするほど、そのメリットや影響が日常生活に身近に入り込み、社会に密着して切り離すことができなくなってくるということであります。

さて、原子力エネルギーという科学技術と人間社会との関わり方の過程において、核分裂の発見が第二次世界大戦の間近にありましたことから、原子力の人間社会との最初の出会いが戦時兵器としての原子爆弾であったことは、その誕生は不幸であった、といえるかと思います。

しかし戦後、私達は「平和利用」という形で原子力と再会いたしました。原子力という科学技術は、再び本来の使命に戻って、人類の平和と福祉に貢献する道を歩み始めましたが、その不幸な誕生は、現在に至ってもなお、社会文明との関わりにおいて歪みを残しております。その歪みが、何らかのきっかけでしばしば軋みを生じ、原子力開発に携わる私達への戒めとなり、警告を与えてくれているように思えてなりません。

本年は、一九五三年の国連総会におけるアメリカのアイゼンハウアー大統領による「原子力平和利用演説」から数えて三六年目に当たります。この機会をお借りして、演題に掲げました「原子力開発の今日的な意義」につきまして、原子力と人間、および原子力と人間社会の関わり合いの面から、私なりの考えを申し上げてみたいと思います。

〔人類とエネルギー〕

われわれ人間は、本能的に向上への欲望を持っております。いうなれば、精神的な向上、すなわち充実感ある心と、物質的な向上すなわち快適な生活の追求、ということであるといってもよいと思います。そしてまさにこのことこそが、人間が人間として存在する一つの証しであります。

人間社会はエネルギーによって、発展成長してきました。すなわち、社会の発展を支えるのはエネルギー資源と、エネルギーを創造し使用する技術である、ともいえようかと思います。

そしてこの資源と技術とは、深い関係を保ちつつ相互に作用しあい社会の成長発展に寄与してきました。

先進諸国に例をとれば、

- 産業革命期においては、それ以前の木炭・薪等の原始的な利用から、石炭とそれを利用できる蒸気機関の発達を促しました。
- そして第二次大戦前後の石油時代においては、石炭から石油への利用資源の転換と、それを利用できる自動車や重化学工業を発達させました。
- さらに現代社会においては、多様な化石燃料資源と、それを利用する各種のエネルギー技術、ウラン・プルトニウム資源とそれを利用した原子力技術、さらには自然エネルギーを利用した新エネルギー技術等が相補いあう複合エネルギー時代へと進んできております。

この場合、省エネルギーや省資源技術についても、現代における重要な資源利用技術であることはいうまでもありません。

〔エネルギーと環境〕

自然界から得たエネルギー資源を利用すれば、その結果として受けるメリットと同時に、資源の枯渇とか廃棄物などによる環境への影響などのデメリットも発生いたします。

したがって、資源を利用するエネルギー技術の目標が、「資源からエネルギーというメリットをできうるかぎり多く取り出し、利用し終わったあとの、自然環境や生活環境へのデメリットをできうるかぎり少なくする」ことにあることは当然といえば当然のことであります。

過去のある時期、わが国におきましても、また他の国におきましても、メリットの獲得のみに精を出したあまりに、適正な容量を超えた廃棄物の環境への放出によって、あるいは自然界に存在しなかった新たな物質の環境への放出によって、自然環境、さらには生活環境までをも悪化させてしまい、いわゆる公害問題を発生させましたことは、記憶にあらたなところでありますが、これは決して過去のこととして忘れ去ることはできないものであります。

もし人間に油断や気の緩みがあったならば、こういった問題はいつなんどきでも起こりうるものである、ということを私達は肝に命じて行動しなければならないわけであります。

人間の生存は環境に依存します。その一方で、人間の存在と文明の

発展それ自体が環境を改変し、悪化させるという自己矛盾性を持っております。そしてその最大の原因は、社会生活に必要なエネルギー使用にある、といっても過言ではないわけでありますが、そういたしますと、私達には、自らの生存・発展のため、自らの知恵によって環境条件が悪化していくことを食い止めなければならない、大きな責任があると考えるのであります。

〔科学技術と環境〕

現在、科学技術と環境という面から社会の状況をみてみますと、二つの大きな問題が次第に深刻化しつつあるように思えます。

その一つは、現在世界的に大きな課題となっております炭酸ガスによる温室効果問題をはじめ地球規模の自然環境悪化の傾向であります。

もう一つは、途上国における農村を中心とする自然環境破壊と、人口急増に伴う社会環境悪化の問題であります。

こうした傾向に対し、もしも何らの策をも講じないならば、やがては人類の生存そのものを脅かす危険性をはらむものと認識すべきであると思います。

こうした問題の起こってきた背景には、いろいろの要因が複合し、作用しているのでありましょうが、その一つに、世界の人口の僅か1／4に過ぎない先進諸国において、世界のエネルギーの3／4をも消費し、かつその恩恵に浴しているという豊かさが途上国へのしわよせとして現れつつある、といっても過言ではないと考えられます。

もちろん、これまで先進諸国が科学技術を発展させて、社会の成長

の牽引者となってきたことは事実であり、大きな功績であることは間違いのないところであります。しかし一方で、科学技術の恩恵を享受できる国とそうでない国との格差がますます広がりつつあること、すなわちその科学技術がエネルギーなどの資源を多く消費することによって、光の部分はますます光り、それに対して影の部分はますますかげる、そして今や、それがますます加速されつつあるようにみえるのではないでしょうか。

とすれば、環境の悪化傾向を食い止めるため、先進諸国の自覚と献身による、人間社会と自然環境とを調和するための科学技術の開発が、いまこそ求められているときはないと思うのであります。

そのため一つは、先進諸国が自ら率先してエネルギー多消費・資源多消費型のライフスタイルを改革してゆくとともに、途上国の経済・社会問題に充分配慮をしながら、地球規模での環境問題に対しても、牽引車として積極的に、真剣にとりくむべきであります。

もう一つは、先進諸国の生み出した科学技術、とりわけエネルギーの創造と利用に関する技術の開発と普及こそ、その最も有力な方途であります。

〔科学技術と人間〕

ただいま申し述べた点を考えていくための前提として、ここで人間社会が新しい科学技術に対してどのように反応してきたかをみてみますと、その導入の初期には、次の二つのパターンをみることができようかと思います。

一つのパターンは、メリットへの期待が大きいことから、デメリットへの認識が低いままに、摩擦なく、あるいは歓迎されて受入れられたケースであります。

これに対して、もう一つのパターンは、デメリットへの不安が大きいことから、メリットへの期待は感じつつも拒否反応の大きかったケースであります。

第一のケースといたしましては、極めて便利で有用だった化学製品のＤＤＴやＰＣＢなどにこれをみることができますが、これらはその後に有害性が判明して消え去り、それに代わるものが現れました。もちろん、有害性が発見されたのも代替物が開発されたのも、ともに科学技術によってであります。

一方、第二のケースといたしましては、電気や蒸気機関車、航空機などが考えられますが、それが登場したときの不安が技術の発展によって薄められる一方、身近に体験できる利便性によって克服され、ついには社会に次第に受入れられていきました。

この場合、どうして「不安感」という当初に存在した感性に関わる問題が解消していったかをよく見究めておく必要があると思いますが、それは人の心がメリットを大きく感じ、デメリットはあまり感じないようになってきたとき、すなわち「不安感」が「信頼感」に変わって、新しいものの受入れを歓迎する「安心感」として拡大のサイクルに乗ったときに、初めて広く社会全体に定着していったといえるのではないでしょうか。

人間は理性と感性とを合わせ持っております。割り切った言い方を

いたしますと、理性の部分は「論理」すなわちメリット・デメリットで判断し、感性の部分は「情緒」すなわち「好き・嫌い」が選択の決め手となる、といっても過言ではないと思います。新たな科学技術の登場に対する反応は人ひとりひとりとしても、あるいはまた社会全体としても「理性」のまさった時代と「感性」がまさった時代との間を揺れ動いてきた、ともいえるのではないでしょうか。

ある一定の科学技術レベルが定着した社会にとって、新たに出現してくる科学技術、とりわけその時代の社会の意識レベルを超えた複雑な技術あるいは巨大技術は、往々にして導入の初期段階に拒否反応が多いのは当然であります。それを進める側は人間の「理性」の部分に訴え、一方受け手の側は「感性」の部分で受けるという、基本的に異なるコミュニケーションの構造になっていることに加えて、その間を埋める「信頼感」が未成熟であるからではないでしょうか。そして、それらが成熟していくために相当な時間と技術が必要であり、またより秀れたものにしていくための不断の努力が不可欠であることは、経験からよく知られているところであります。

〔原子力と環境〕

さて、以上のような観点に立ってみたとき、巨大技術、先進技術といわれる原子力については、どのように位置付けられるのでしょうか。

軍事利用からスタートした原子力は、当然のこととして、平和利用としてのスタートが、「その利用によって、万が一にも残滓である放射性物質が環境を決して悪化させない」ということを第一義とし、そ

れが可能であるという確信と、それを実現させるという強い決意で始まったということは当然であります。

さらにまた、技術的手段によってこれを実現するために、いかに完璧を期した技術であるといえども、機械には故障があり、それを誤りなく扱っていこうとする人間も時にはミスをおかすものであることを前提として、それでもなお周辺環境の安全を保証するという安全思想を徹底させることによって、放射性物質の持つ危険性の封じ込めに万全を期しているのであります。

その一例として、原子力発電については、運転に伴う環境への影響の有無を事前に的確に予測し、また実情を迅速・確実に把握するため、その開発の当初から、

① 事故時や通常運転時の放出放射性物質による環境を予め計算・評価して定量的に確認する事前評価方式、とか、

② 通常運転時に気体や液体の形で環境に排出される廃棄物に含まれる放射性物質の排出総量管理と環境サイドに立っての放射能監視

など、それまでの産業には必ずしも一般的ではなかった考え方を導入して、環境の保全には細心の注意を払ってきているのであります。

また、化石燃料エネルギーのような資源依存・資源消費型エネルギーに比べて、原子力が、基本的に異なるのは、技術によって資源利用を拡大し、廃棄物を制御・管理してゆく技術依存型エネルギーであるということであります。現在、原子力の廃棄物処理問題について必ずしも世界的に完全な合意が得られていないという現状は認めるとい

たしましても、このような基本的な認識を心して今後の技術開発に取り組んでいく必要があると考えるものであります。すなわち、もともと多くのエネルギーを得るのに必要なウランの量が少くて済むことから、廃棄物の量は一般産業や生活廃棄物に比べて比較的少なく、その殆どを固体に固めて安定化して取り扱うことができるうえ、ステンレス鋼やガラス、コンクリートなどの人工の障壁と何層もの地層などの天然の障壁によって人間社会から遠ざけることが可能でありますし、また将来、技術が進めば、これらの廃棄物の一部消滅処理や有用物質のリサイクル利用をも期待しうるのであります。

さらに加えて、原子力の持つ技術エネルギーという特性はまた、資源量や資源価格の影響を受けにくい経済的な側面として、人間社会が必要とする経済財としてのはかりしれないメリットを有しているということを付言しておきたいと思います。

〔科学技術と先進諸国の責務〕

このように考えるとき、原子力を利用できる技術を持つ先進諸国のとるべき道はおのずから明らかであります。自らの生存・発展のためのエネルギーを原子力を柱とする技術エネルギーに適度に多く委ねることによって、途上国からの資源の吸い上げを軽減し、また途上国の発展のために使いやすい化石エネルギー資源に依存できるよう、資源を残すと同時に、資源の有効利用のための技術を途上国に普及していくことが肝要であると考えます。

こうしたことを通じて、途上国における生活環境の向上に強力に手

を貸すことが先進諸国のこれからの大きな責務ではないでしょうか。

そして、先進諸国のこうした行動は、必ずや地球規模の環境問題の解決に向けての糸口にもなるものと確信するものであります。

このために先進諸国は、経済・社会情勢に左右されることなく、科学技術の発展、とくに新たな、より環境に調和しうるエネルギー技術の研究開発に、着実に、計画的に、かつ不断に邁進していかなければならないものと考えます。

世界的な規模でのエネルギー問題の解決と環境問題の緩和には、地域、国、人それぞれの事情に応じた資源と技術が利用されていく中で、より良い技術が多様にとりそろえられ、多様に使われることが必要でありますが、そのためには、先進諸国の技術開発こそその重要な決め手になるからであります。

〔原子力と人間社会〕

最後に、私達の社会、私達の生活にとって原子力とは何かという命題について、私の思うところをお話し、私達原子力開発に携わる者のなすべき課題を考えてみたいと思います。

ここで再び先ほど申し述べました新たな科学技術が、当初社会にどのように受入れられるかといったテーマに戻るようで恐縮ですが、原子力という科学技術が人間社会に導入されたときの人間の反応はどうだったのでしょうか。

その誕生の歴史はさておき、三六年前の平和利用開始の頃は、いろいろな論議があったにせよ、莫大なエネルギーを生産するというメ

リットを期待する大きな夢をもって迎えられ、この流れに乗って、実用化されていったことはまぎれもない事実であります。原子力平和利用という言葉が未来の明るさの象徴であったことを思い出します。しかしながらそれが商業用に本格的に使われ始めると、不安感を主とする強い拒否反応が現れてきました。すなわちデメリットへの不安が大きくて、導入の初期に拒否反応が強かったパターンの典型であります。その後今日に至るまで、拒否反応は社会の様々な状況を背景に繰り返し現れ、一つの社会現象化しつつあるといえるのではないでしょうか。

原子力の場合、その必要性の訴えかけが、人間の心の中にベースとして存在する不安感という「感性」に対して、例えば石油危機後の代替エネルギーとしての必要性、および近年は炭酸ガスによる温室効果に対する効果、あるいは、発電所の立地地域においては過疎からの脱却や地域振興の柱といった「理性」で考えれば理解しやすいことであります。にもかかわらず、それが「感性」と融和し、妥協する時間的な余裕もなしに、しかも実質的にはともかく形のうえで肯定を強制されるような形で現れてくると、人の心の中に「理性」と「感性」の間の歪みを残して推移することになり、そのときどきの社会現象に振り回されて思わぬときに表面化するのではないでしょうか。

石油危機後、重要な代替エネルギーとして認識された「理性」的理解を逆撫でするように、TMI事故やチェルノブイル事故が「不安」につながる「感性」をかき立て、それまで心の中に落ち着きをもって納まっていた「理性」がいとも容易に後退していってしまったのであります。

こうした意味で、とくに原子力という科学技術については、人間の「理性」と「感性」とが引き裂かれたり、あるいは対立する傾向が著しいものがあります。そしてこれは、個人の中にも、また社会集団としての推進側と受け手との間にもある、とみられるのであります。

この対立を解消し、原子力への理解を浸透してゆくための手だては果たして何でしょうか。

最近の世界の中における原子力開発に対する各国間の背景の違いや日本国内における原子力反対運動のかつてない高まりの様相をみるにつけ、ここで改めて受け入れ側の気持に立った原子力理解のための諸活動とは何かを抜本的に点検し、見直してみる必要があるように思われます。

私達が原子力開発に取り組んでいくうえで、心すべきこの重要なテーマについては、本年次大会のセッション２「社会のなかの原子力」において取り上げられている課題でもありますので細かくは触れませんが、何といっても私達がこれから考えていくべきことは、今こそ、推進側が「理性」に訴えるプロダクト・アウトの発想から受け手の「感性」にも共感を呼ぶようなマーケット・インの発想に切替えて、原子力への夢と信頼を回復しなければならないということかと存じます。

そして、「理性」と「感性」とをつなぐ架け橋は「知識」であり、「信頼」であり、それにもとづく「安心感」であります。

このためには、なによりも原子力発電の安全・安定運転の実績を積み上げていくことがもっとも大切であるのは論をまちませんが、同時

に大切なものは、これらに携わる原子力関係者自体のオープンな姿勢であり、また、これらを通じての原子力に携わる者への一般の方々の信頼感の回復であり、再構築であります。また、原子力に携わる者の誠実で、誠意溢れる理解活動がなによりも大切であることはいうまでもないことです。

そしてこれは、原子力エネルギーの開発利用が既存のエネルギーと異なって長期的な視野を必要とするように、あせらず長い歳月をかけて何としても実現していかなければならない私達エネルギーの開発利用にあたる者の基本的責務であると存じます。

私の話を終わるにあたりまして、東京電力の社長といたしまして、本年一月に発生致しました福島第二原子力発電所の再循環ポンプの損傷事故につきまして心からお詫び申し上げます。私どもは一九六六年の初号機の建設開始以来、二三年の長きにわたり、安全には細心の注意と万全の対策をとってまいりましたが、それによって培われてきた地元の信頼感と安心感が今回の事故によってゆらぎを生じ、原子力反対運動に拍車をかける結果となりましたことは誠に申し訳ないことであります。我々の子孫の為に必要なエネルギーとしての原子力の再評価構築のために、初心にかえって努力をする所存であります。何卒よろしくお願い申し上げます。

御静聴有り難うございました。

以　上

ASSURANCE OF ENERGY SOURCES AND THE ROLE OF NUCLEAR POWER FOR XXIst CENTURY

J.D. LEVI , Director-General for Energy and Raw Materials, Ministry of Industry, FRANCE

The supply of energy is a strategic issue. I won't go back to the prehistoric era since I have no time to give you a detailed descripton of the invention of fire in old Europe. I will just go back to year 1973.

Energy has always been a specific field. In France, the energy policy is a mix of public and private policy, involving both the administration and companies.

Till 1973, our main problem was to secure the supply. Energy policy was mostly regarded as a problem of allocation of resources. The priority was to match the demand.

With the oil shock of 1973, things have changed. That year opened a new era of high prices due to both economic factors - a scarce resource and a too high level of consumption - and political factors. An economist would qualify those political factors as non rational since they make the model much less simple to handle. But actually they have been dominant in the 1973 crisis.

Confronted to a vital risk of shortage or high prices, we had to react in the form of a policy which could influence both consumption behaviours and supplies. France, like Japan, is a country rather poor in primary energy sources. There is a tradition in that country of high energy prices. So we were rather well prepared to elaborate a policy with the different aspects needed to meet the crisis.

These aspects are rather classical : the new policy emphasized the supply dimension of the problem with the diversification of our resources. This led to the setting of a strong nuclear program. We also focused the attention on an ambitious conservation and energy saving policy. On one hand our policy is achieved through a small number of big producers ; on the other hand it depends on the responsibility of almost everybody.

This two-fold policy upon producers and consumers, which has been adhered to by all the successive governments, has been very efficient :

- In 1989, more than 70% of electricy come from nuclear power plants ; fossil fuels have become of little importance in our electricity production system.

- We have diversified our sources of supply as much as possible, with natural gas for instance.

- We save each year some 17% of our energy consumption, the equivalent of 34 TOE.

So, our dependency on energy imports has decreased from 78% in 1973 to 52% last year.

We went the right way as regards to our initial goals but we must still go on.

What are the new determinants of an energy policy for the next years in a developped country such as France ? Do these determinants validate or modify the main lines we have followed without discontinuity for 15 years ? In the present debate on energy, we have to consider two important issues that might influence our judgement on our policy : the environmental debate and the opening of the European-market within the next three years.

The European Challenge

In 1985, the 10 countries of the European Economic Community - they are now 12 - have decided to make a decisive step in the building of Europe. It was the so-called "Acte Unique" (Single Act) and the decision of the full opening of the market at the end of year 1992.

Energy which was considered so far as apart from the free market, will at that time be considered as other products.

The free market of 1993 is a major issue for our sector. We can now expect that we will be able to use at their best the resources of each country. The new market organization and the increasing flow of exchanges will allow to reduce the cost for energy production, and thus to improve the competitiveness of the economy. As energy is a key of economic development, this will result in a better efficiency and a higher level of employment.

If we consider in its diversity the European Community, there are oil and gas producing countries, countries which rely on nuclear power and other countries that rely on coal. There is a need for a better allocation of these resources, in order to avoid a misuse of energy due to too separate national policies.

We estimate at about 10 billions $ the cost of the overequipment due to the addition of national autarcic policies.

The single market of energy will lead each country to rely on its partners' capacities for programming its own equipments. This will evidently result both in investment and operating cost savings.

The positive effects expected from the single energy market are specially clear for the electricity system. We, in France, are in the case where nuclear power is the cheapest source for electricy production as far as nuclear plants are used on a full time basis. Of course coal or oil made electricy is cheaper for the peak periods.

Our challenge in the new European market of 1993 will be to optimize the uses of the different kinds of primary energies. Each country will be offered an opportunity for importing the cheapest energy for its needs.

This optimization of the overall European production system would undoubtedly save much money, around 5 billions dollars each year according to our estimate.

What is the case for France in this new deal ? France has become in few years a big energy producer although the country remains quite poor in fossil energy sources. Thanks to a huge investment effort in a nuclear progam which has become a reference in the world, we have ~~political~~ potential capacities of exporting nuclear electriciy. Of course, exportation implies the opening of closed markets and there are many obstacles to free trade. The main obstacles are protectionist attitudes in countries that are organized to protect their national coal production.

This new European deal reinforces our previous choices : we can match the big challenge of the opening of the european market.

Environmental issues

The debate on environmental issues is more and more acute. The green-house effect and the risk of a global climatic change rather reinforces both our nuclear orientation and our will of reducing our overall consumption, and especially our consumption of fossil fuels.

All these targets are not shared by all the countries of the European Community. Nevertheless there is unanimity to recommend a strong incentive in energy saving.

For France a continuous energy consumption management has been followed for the last 15 years, with specific measures adapted to each sector :

- in the housing sector we have reached a high level of building standards. For instance the new standard introduced at the beginning of this year, leads to a consumption of energy for heating lower by 25% .Further efforts are being made to reduce home appliances consumptions.

- in industrial processes we emphasize efficient uses of electricy.

- in the transportation sector, energy savings come mainly from low consumption engines.

To achieve these targets, the Government has set a broad range of incentives, most of them are managed by the French Energy Management Agency which has proved to be a very efficient agency.

This policy combined with the development of nuclear plants resulted in a quite significant reduction of emissions of SO2, NOx and CO2. This means a sigificant contribution to the solution of the problems of acid rains and green-house effect. For instance, for CO_2 emissions, the figures are rather impressive. In 1987, 360 Million tons (Mt) of CO_2 have been produced in France ; 600 Mt would have been produced with no nuclear power and more than 700 Mt with no nuclear and no energy saving programs. The figures for the reduction of air pollution by acids are similar.

But of course, speaking of nuclear power, we must carefully consider its acceptability. How do people match their anxiety on the risk of global climatic change, and the risk of nuclear power ?

We have to consider those factors which may not be always rational.

Towards the XXIst century

We believe in France that we have given the proper answer to our problems through our present policy. There is no reason to change it substantially.

We are aware anyway that this policy cannot be a universal answer. In any given country, one actually has to meet a certain number of conditions for its success. Among these conditions are the industrial and technical capabilities of the country. Nuclear power needs a very high level of technology and a high standard of quality insurance. Operating and maintaining nuclear plants require a qualified manpower. Other conditions are the financial resources of the country necessary for such a huge investment, also the acceptability of nuclear power for public opinion.

Then we might hope that the current debates on environmental issues would lead to a rehabilitation of nuclear power among people whose hostility is not always rational. This supposes a permanent efforts in nuclear safety, a permanent dialogue with the public at local and national levels.

ОСНОВНЫЕ НАПРАВЛЕНИЯ И ТЕХНИЧЕСКИЕ КОНЦЕПЦИИ АЭС С РЕАКТОРАМИ ВВЭР-1000

ОСНОВНЫЕ НАПРАВЛЕНИЯ И ТЕХНИЧЕСКИЕ КОНЦЕПЦИИ АЭС С РЕАКТОРАМИ ВВЭР-1000

I. Введение

Проблема обеспечения безопасности АЭС в настоящее время приобретает особую актуальность. Отсутствие практической альтернативы широкому развитию ядерной энергетики заставляет качественно по новому взглянуть на проблему обеспечения безопасности, особенно учитывая последствия аварий на АЭС "Три Майл Айленд" и Чернобыльской АЭС.

В отношении АЭС типа ВВЭР, получивших широкое распространение в мире и которые должны стать основными по крайней мере до 2000 года, в последнее время проведено много анализов безопасности, показавших в целом, что эти АЭС с одной стороны обладают технологическими свойствами, позволяющими считать приемлемым достигнутый уровень безопасности; с другой стороны существуют реальные пути повышения их надежности и безопасности.

После аварии на "Три Майл Айленд" в различных странах были проведены особенно тщательные анализы безопасности АЭС с ВВЭР. Факт аварии привлек внимание международной общественности и послужил толчком для расширения научно-технического поиска путей совершенствования решений по безопасности.

В этом направлении были достигнуты соответствующие результаты, часть которых уже сегодня внедрена на АЭС в виде тех или иных технических решений и тем самым достигнута более высокая ступень уровня безопасности современных АЭС.

ОСНОВНЫЕ НАПРАВЛЕНИЯ И ТЕХНИЧЕСКИЕ МЕРОПРИЯТИЯ ПО ПОВЫШЕНИЮ БЕЗОПАСНОСТИ АЭС С РЕАКТОРАМИ ВВЭР-1000

СОДЕРЖАНИЕ

СТР.

ОСНОВНЫЕ НАПРАВЛЕНИЯ И ТЕХНИЧЕСКИЕ МЕРОПРИЯТИЯ ПО ПОВЫШЕНИЮ БЕЗОПАСНОСТИ АЭС С РЕАКТОРАМИ ВВЭР-1000

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Результатом этого научно-технического поиска явилось также и выявление путей дальнейшего повышения безопасности.

В Советском Союзе имеется три поколения ядерных энергетических реакторов типа ВВЭР:

- опытно-промышленные;
- первые серийные реакторы (типа ВВЭР-440);
- современные серийные (типа ВВЭР-1000).

Серийные АЭС с реакторами ВВЭР-440 первого поколения (типа В-230) разработаны до введения в широкую международную практику специальных нормативов по АЭС и по этой причине формально их уровень безопасности не соответствует современным требованиям. В настоящее время мы рассматриваем пути возможной реконструкции таких АЭС с учетом всех конкретных обстоятельств и особенностей.

Анализ безопасности серийных АЭС с реакторами ВВЭР-440 второго поколения и ВВЭР-1000 показал, что их безопасность соответствует международным требованиям. В некоторых случаях поверочный анализ по принятым решениям давал даже более оптимистичные результаты чем те, которые были заложены при разработке проектов в качестве критериев. Так выполненный аналитической группой специалистов министерства энергетики США (группа ДОЕ) анализ советских проектов реакторов типа ВВЭР показывает, например что строительные конструкции защитной оболочки, спроектированные исходя из аварии с разрывом Ду 850 не разрушаются и в случае окружного разрыва корпуса реактора в районе активной зоны и др.

Несмотря на то, что достигнутый уровень безопасности современных АЭС с ВВЭР может считаться удовлетворительным, мы приняли решение о поиске путей дальнейшего совершенствования с целью обеспечить максимальное снижение риска, как от действующих, так и строящихся АЭС. Направления по совершенствованию безопасности будут проиллюстрированы на примере ВВЭР-1000,

современное состояние которого охарактеризовано ниже.

2. Краткие сведения о ВВЭР-I000

Тепловая схема АЭС с ВВЭР-I000 имеет 2 контура, реактор с водой под давлением корпусного типа, четырехпетлевой, парогенераторы горизонтальные.

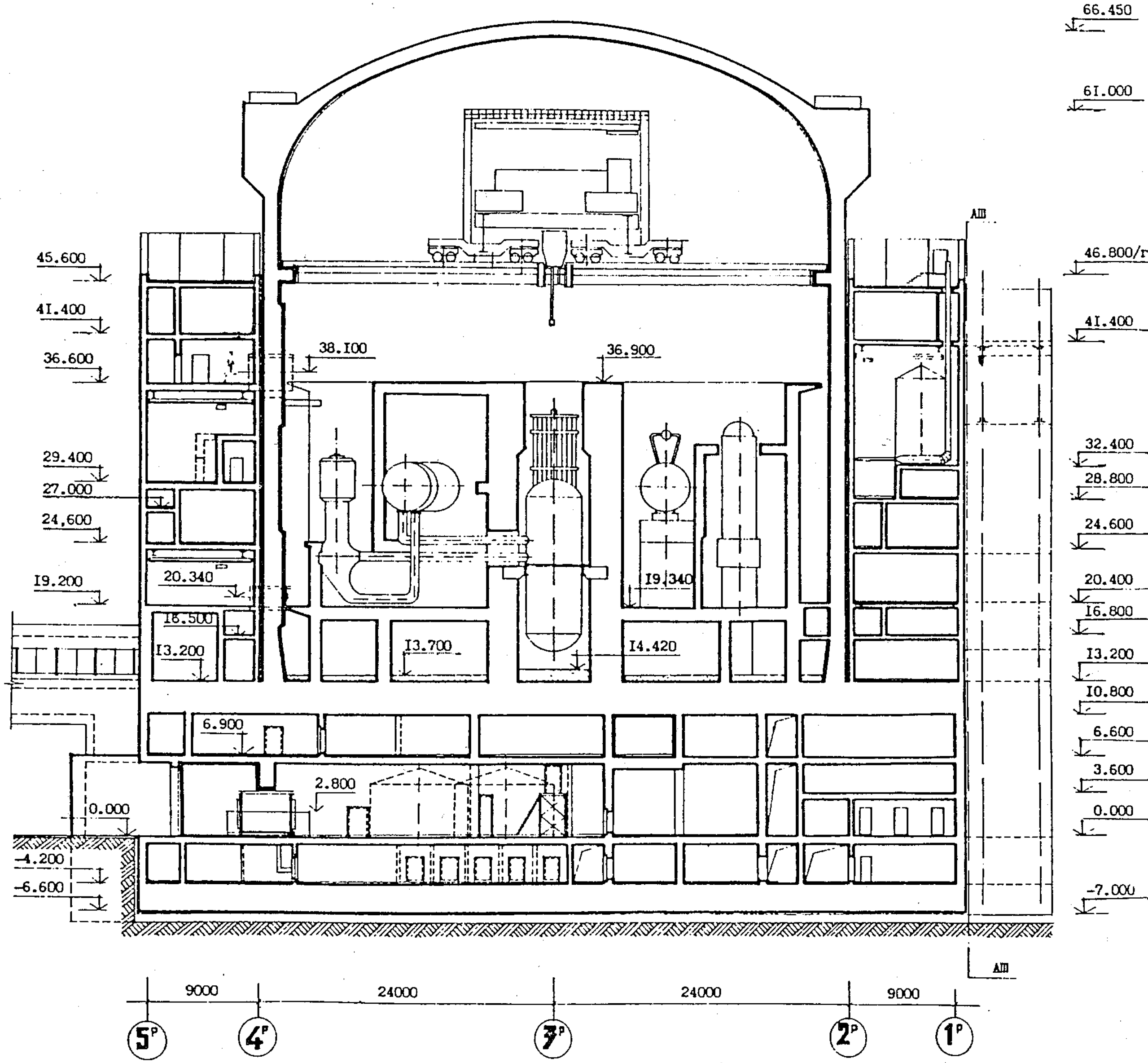
Основные технологические решения имеют традиционный характер.

Защитная оболочка полного давления (5 ата) - цилиндрическая, одинарная из предварительно-напряженного железобетона, имеющая герметичную стальную облицовку. Здание реакторного отделения АЭС размером в плане 66х66 м и высотой 66,6 метров отнесено к первой категории сейсмостойкости как сооружение, в котором размещены системы, обеспечивающие безопасность АЭС. Для улучшения динамических характеристик здания реакторного отделения и сведения к минимуму разности деформаций его различных по массам частей при сейсмических воздействиях, оно запроектировано как симметричное местное сооружение, при этом оболочка, обстройка и реакторная установка размещены на единой фундаментной коробчатой железобетонной конструкции, наиболее тяжелое оборудование и баковое хозяйство - на самых низких отметках. Такое решение позволило повысить устойчивость сооружения, упростить решение проблемы взаимодействия грунта с конструкцией фундамента, снизить влияние сейсмических воздействий на строительные конструкции и оборудование.

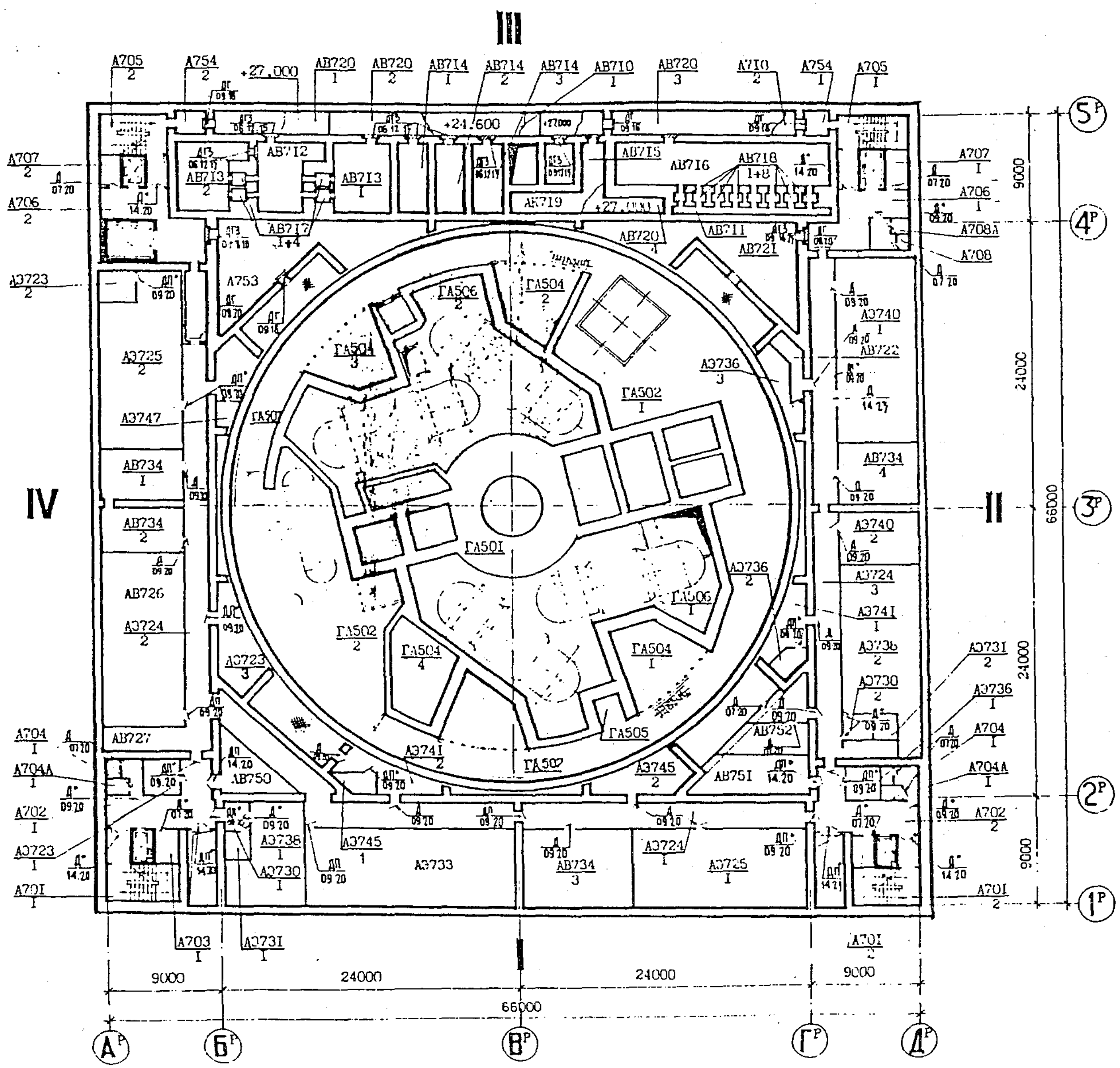
Система технического водоснабжения реакторного отделения осуществляется по оборотной системе с использованием брызгальных бассейнов.

Реакторное отделение унифицированного блока ВВЭР-1000. Разрез 1-1.

I – I



Реакторное отделение унифицированного блока. План на отметке 24,60.



ПЛАН
ОТМ. 24,60

Реакторное отделение унифицированного блока ВВЭР-1000

I. Гидроемкость САОЗ

2. Насос аварийного расхолаживания

3. Насос аварийного впрыска бора

4. Спринклерный насос

5. Насос техводоснабжения

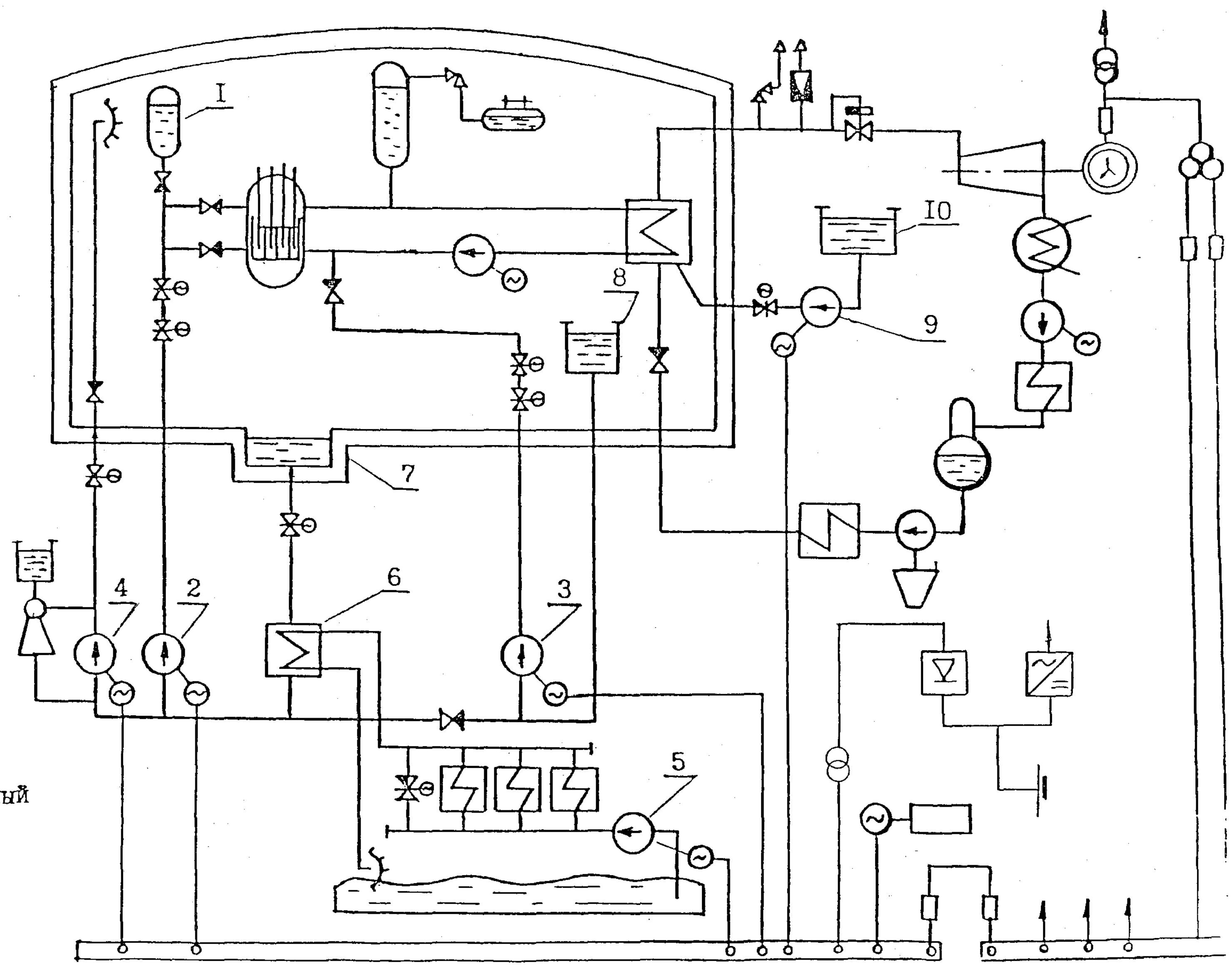
6. Теплообменник САОЗ

7. Приямок-бак

8. Бак запаса концентрированного раствора бора

9. Аварийный питательный насос

10. Бак запаса дистиллата



Принципиальная схема канала системы безопасности энергоблоков АЭС ВВЭР-1000

Энергоблоки АЭС с реакторами ВВЭР-1000 рассчитаны на преодоление последствий различных аварий, в том числе максимальной проектной аварии - мгновенный поперечный разрыв главного циркуляционного трубопровода диаметром 850 мм контура охлаждения реактора с двухсторонним истечением теплоносителя в условиях обесточивания и при наличии сейсмических воздействий.

АЭС с ВВЭР-1000 имеют системы безопасности, построенные по принципу трех полностью независимых систем, или каналов, каждый из которых способен полностью выполнить функции защиты, (т.е. используется структура 3х100%). Каналы системы безопасности имеют независимые источники энергоснабжения - дизельгенераторы мощностью по 5600 кВт и независимые источники охлаждающей воды - брызгальные бассейны-производительностью, обеспечивающей длительный отвод остаточных тепловыделений реактора.

Технические решения по системе безопасности энергоблока с реактором ВВЭР-1000 направлены на обеспечение высокой функциональной надежности. Так при возникновении любой аварийной ситуации, вызывающей срабатывание систем безопасности, автоматически налагается запрет на дистанционное управление ее механизмами для исключения ошибочных действий операторов. Запрет на дистанционное управление автоматически снимается после выполнения данным механизмом своей функции, например: запрет на дистанционное отключение спринклерного насоса автоматически снимается после снижения давления в защитной оболочке.

С целью обеспечения высокой надежности системы безопасности в проекте АЭС с ВВЭР-1000 реализована единая программа нагружения аварийных дизель-генераторов независимо от вида и масштаба аварии.

Такое решение позволяет сделать наиболее простой и надежной программу ступенчатого пуска аварийных дизель-генераторов; управление подачей воды в I-й или П-й контур достигается автоматическим воздействием на соответствующую арматуру в зависимости от конкретного развития аварийного процесса. Например, при аварии с течью паропроводов вне пределов защитной оболочки задвижки на напоре спринклерных насосов не откроются, т.е. не будет роста давления в защитной оболочке, хотя спринклерные насосы будут автоматически запущены и работать на линию рециркуляции.

Системы безопасности АЭС с ВВЭР-1000 имеют резервный щит управления, с которого возможен контроль и поддержание реактора и энергоблока в целом в безопасном состоянии даже в случае выхода из строя основного щита управления АЭС.

Основные решения по безопасности на энергоблоках АЭС с реакторами ВВЭР-1000 соответствуют или подобны аналогичным решениям принятым, например, в ФРГ, США, Франции, Японии.

Опыт эксплуатации АЭС типа ВВЭР-1000 с реактором В-320 показал их надежную и экономичную работу.

Основные характеристики ВВЭР-1000

Мощность электрическая/тепловая	1000/3000 МВТ
Давление I контура (рабочее)	16,0 МПа
Температура на выходе из реактора	322°С
Давление П контура (рабочее)	6,4 МПа пар насыщенный
Число петель	4
Тип парогенератора	горизонтальный

Способы воздействия на реактивность	– механическая система (до температуры 250 °C) – жидкостная система (во всем диапазоне температур)
Кампания топлива	3 года
Глубина выгорания	40000 $\frac{\text{МВт сутки}}{\text{т}}$
Обогащение ^{235}U	4,4%
Тип контаймента	одинарная оболочка полного давления
Расчетное аварийное давление контаймента	0,5 МПа
Расчетная сейсмичность реакторного отделения и систем безопасности	до 7 баллов по MSK
Источники надежного энергоснабжения	независимые дизель-генераторы
Источники надежного техводоснабжения	независимые брызгальные бассейны

Основные характеристики реакторной установки ВВЭР-1000.

Таблица 1

щность электрическая/тепловая	1000/3000МВт
вление 1 контура (рабочее)	16,0МПа
мпература на выходе из реактора	322°С
вление 2 контура (рабочее)	6,4 МПа пар насыщенный
сло петель	4
п парогенератора	горизонтальный
особы воздействия на реактивность	-механическая система (до температуры 250°С) -жидкостная система (во всём диапазоне температур)
мпания топлива	3 года
убина выгорания	40000 $\frac{МВт\ сутки}{т}$
огащение ^{235}U	4,4%

Тип контаймента	одинарная оболочка полного давления
Расчётное аварийное давление контаймента	0,5 МПа
Расчётная сейсмичность реакторного отделения и систем безопасности	до 7 баллов по MSK
Структура систем безопасности	3×100%
Источники надёжного техводоснабжения	независимые брызгальные бассейны
Источники надёжного энергоснабжения	независимые дизельгенераторы
Производительность очистки теплоносителя	высокотемпературная $4\times125 м^3$/час низкотемпературная до $60 м^3$/час

3. Основные направления по повышению надежности и безопасности АЭС с ВВЭР-1000

Советский Союз наряду со странами-участниками МАГАТЭ считает, что основными путями по дальнейшему снижению риска от АЭС являются сформулированные в отчете Международной консультативной группы по ядерной безопасности "Основные принципы безопасности атомных электростанций" (INSAG -3)

следующие основные направления:

- глубоко эшелонированная защита;
- анализ и контроль управления тяжелыми авариями;
- паритетность функций профилактики и защиты;
- культура безопасности и др.

Реализация полного комплекса указанных направлений связана с проведением большого количества НИОКР, экспериментов и по нашей оценке продлится по крайней мере до 2000 г. В этих условиях в нашей стране большое значение придается тем техническим и организационным мероприятиям, которые уже в настоящее время могут внести существенный вклад в снижение риска от АЭС как по направлению предотвращения тяжелых аварий, так и по средствам аварийной защиты и локализации.

В целях разработки наиболее эффективных мероприятий для внедрения в ближайшее время были проанализированы основные пути, приводящие к серьезному повреждению топлива, а именно:

- непроектное протекание проектных аварий;
- масштаб аварии, превышающий максимальную проектную аварию;

- сочетание указанных выше причин.

В результате анализа выявлены наиболее вероятные пути, приводящие к тяжелым авариям, например:

- исчезновение на длительное время всех источников энергоснабжения (как в сочетании с течью, так и при ее отсутствии);

- отказ отдельных групп органов регулирования СУЗ;

- значительная течь из I контура во II, приводящая к потере среды охлаждения активной зоны и др.

Таким образом, определились пути повышения безопасности АЭС с ВВЭР-1000 и практические мероприятия. (см. таблицу 2).

Основные направления по повышению надежности и безопасности АЭС с ВВЭР-1000

Цели безопасности	Пути повышения безопасности АЭС	Практические мероприятия по повышению безопасности АЭС с ВВЭР-1000
Предотвращение аварий	Повышение внутренней безопасности реактора	Улучшение ядерно-физических свойств реактора, его модернизации: - 121 СУЗ - более надежные привода СУЗ
	Повышение надежности систем и оборудования	- диагностика состояния металла и оборудования - доработка оборудования
	Совершенствование АСУ ТП и информационного обеспечения	- совершенствование внутриреакторного контроля, - системы поддержки оператора в переходных и нештатных режимах
Глубокая защита барьеров	Совершенствование локализующих барьеров	- локализация течи из I контура во II-й - система сжигания водорода; - система сброса давления и очистки аварийных выбросов
	Использование СБ, основанных на пассивных принципах для защиты барьеров	- СПОТ - СБВБ
	Совершенствование АСУ СБ и информационного обеспечения	- система готовности СБ

Таблица 2

Основные направления по повышению надёжности и безопасности АЭС с ВВЭР-1000

Цели безопасности	Пути повышения безопасности АЭС	Практические мероприятия по повышению безопасности АЭС с ВВЭР-1000
Предотвращение аварий	Повышение внутренней безопасности реактора	Улучшение ядерно-физических свойств реактора, его модернизация -121 СУЗ -более надёжные привода СУЗ
	Повышение надёжности систем и оборудования	-диагностика состояния металла и оборудования -доработка оборудования
	Совершенствование АСУТП и информационного обеспечения	-совершенствование внутриреакторного контроля -системы поддержки оператора в переходных и нештатных режимах
Глубокая защита барьеров	Совершенствование локализующих барьеров	-локализация течи I контура во второй -система сжигания водорода -система сброса давления и очистки аварийных выбросов из защитной оболочки
	Использование систем безопасности, основанных на пассивных принципах для защиты барьеров	-система пассивного отвода тепла -система быстрого ввода бора
	Совершенствование АСУСБ и информационного обеспечения	-система готовности СБ

4. Практические мероприятия по повышению безопасности АЭС с ВВЭР-1000

4.1. Модернизация реактора

Модернизация реактора предусматривает улучшение ядерно-эксплуатационных характеристик, усовершенствование конструкций реактора и др. с целью повышения ядерной безопасности АЭС. Для реализации поставленной цели в модернизированном реакторе предусматривается следующее:

4.1.1. Увеличение эффективности механической системы воздействия на реактивность путем увеличения количества органов регулирования СУЗ с 61 до 121 для обеспечения перевода реактора в подкритическое состояние при температуре до 100°С без дополнительного ввода жидкого поглотителя; следует отметить, что в соответствии с требованиями к системам воздействия на реактивность на советском реакторе имеется две системы: быстродействующая механическая система, эффективная в зоне рабочих температур и жидкостная, эффективная во всем диапазоне температур. Необходимость обязательного использования жидкостной системы воздействия на реактивность определяет требования к системам ввода бора и усложняет системы безопасности. С целью повышения надежности и безопасности требования к механической системе воздействия на реактивность расширены на весь температурный диапазон.

Таким образом, исключен ядерноопасный режим при нештатных ситуациях, связанных с изменением температуры теплоносителя.

4.1.2. С целью достижения глубоких отрицательных обратных связей по всем параметрам относительно реактивности, а также в конечном счете для уменьшения повреждения топлива в широком спектре режимов проведено совершенствование активной зоны реактора;

- уменьшена неравномерность энерговыделения активной зоны за счет увеличения числа органов регулирования СУЗ и стержней СВП;

- усовершенствована система внутриреакторного контроля - применены вновь разработанные сборки каналов ВРК, обеспечивающие при эксплуатации реактора непрерывный контроль нейтронного потока по объему активной зоны и температуры теплоносителя на входе и выходе и ТВС;

- изменена конструкция патрубков верхнего блока для улучшения его обслуживания в процессе эксплуатации - патрубки СУЗ совмещены с чехлами приводов, тем самым исключены фланцевые соединения по патрубкам;

патрубки выводов сборок каналов ВРК размещены на периферии крышки, что упрощает их обслуживание и контроль;

- в конструкцию реактора введен новый узел - элементы крепления шахты при ее обрыве, предназначенные для исключения бокового смещения активной зоны и выхода головок кассет из зацепления с нижней плиты БЗТ. Таким образом, новые элементы конструкции обеспечивают возможность надежного охлаждения активной зоны и сброс органов регулирования СУЗ при аварии с обрывом шахты по любому поперечному сечению.

4.2. Система пассивного отвода тепла (СПОТ) при полной потере источников энергоснабжения

Система пассивного отвода тепла (СПОТ) предназначена для длительного отвода остаточных тепловыделений от реактора при полной потере энергоснабжения, включая аварийные источники, при герметичном первом и втором контурах РУ и представляет собой замкнутую систему с естественной циркуляцией по I и II контурам. Отвод тепла осуществляется непосредственно наружным воздухом, имеющем температуру в диапазоне $\pm 50^{\circ}C$; теплообменники системы располагаются в надстраиваемых помещениях выше отметки 45,6.

Система состоит из четырех полностью независимых контуров, каждый из которых подключается к соответствующему парогенератору и соответствующей петле главного циркуляционного контура реакторной установки.

Конструкция реакторной установки может обеспечить отвод остаточных тепловыделений естественной циркуляцией на уровне 10% номинальной мощности реактора. Контур естественной циркуляции со стороны II контура спроектирован исходя из необходимости отвода 80 МВт остаточного тепла на 3-х петлях ($\sim$2,7% номинальной мощности) при рабочих параметрах РУ.

В режиме нормальной эксплуатации система находится в прогретом состоянии, что позволяет в аварийной ситуации достаточно быстро выйти на проектную мощность отвода остаточного тепла. Эти результаты подтверждены экспериментом, причем время выхода на мощность составило менее I минуты.

I. Реактор

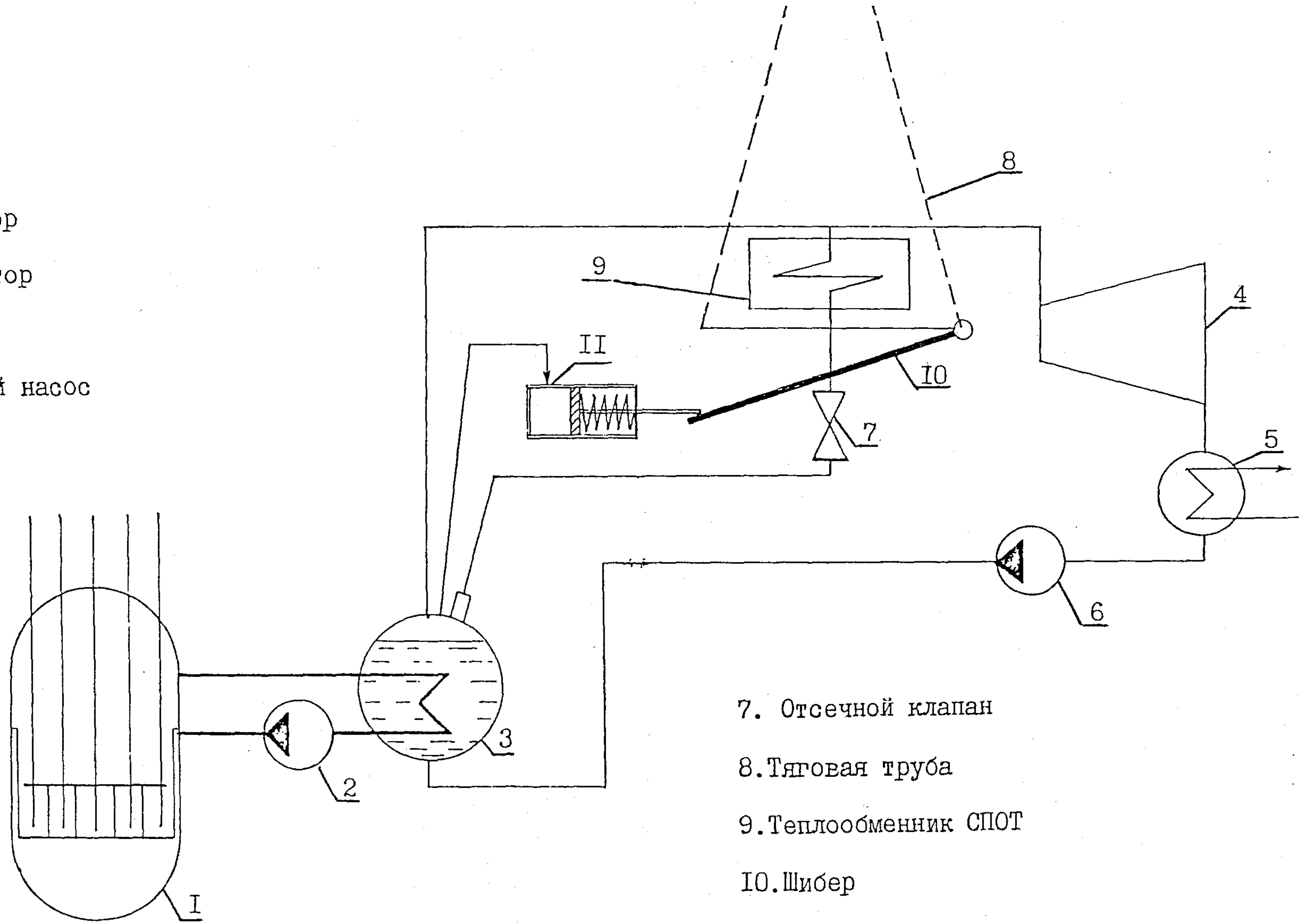
2. ГЦН

3.Парогенератор

4.Турбогенератор

5.Конденсатор

6. Питательный насос



7. Отсечной клапан

8.Тяговая труба

9.Теплообменник СПОТ

I0.Шибер

II.Гидроцилиндр-регулятор

Система отвода остаточных тепловыделений является пассивной. При ее запуске и функционировании не требуется работа каких-либо механизмов и источников электропитания. Регулирование мощностью СПОТ производится по воздушному тракту путем открытия или закрытия шибера с помощью пассивного регулятора прямого действия, работающего от давления П контура.

В парогенераторе тепло I контура передается среде П контура; полученный в результате этого пар П контура поступает в теплообменники СПОТ (тракт турбины отсечен), где при охлаждении наружным воздухом конденсируется и под давлением столба конденсат стекает в парогенератор. Для организации необходимого расхода охлаждающего воздуха предусмотрена тяговая труба, в нижней части которой расположены теплообменники системы.

Помещение теплообменников имеет шиберное устройство, регулирующее сечение для прохода воздуха. В нормальном режиме эксплуатации блока шибер закрыт. При исчезновении всех источников переменного тока на АЭС, включая аварийные, по повышению давления П контура шибер открывается на величину, достаточную для обеспечения необходимого расхода воздуха. При снижении давления в парогенераторе шибер прикрывается, таким образом обеспечивается пассивное регулирование расхода воздуха и, как следствие, расхода среды в контуре СПОТ и таким образом осуществляется регулирование мощности теплоотвода СПОТ, обслеживая отвод остаточных тепловыделений реактора.

Возможно также использование СПОТ без регулирования ее мощности, что приводит к расхолаживанию реакторной установки.

Система, предназначенная для отвода остаточных тепловыделений при плотных основных технологических контурах, имеет достаточно высокую эффективность при средних и малых течах I контура и сохраняет работоспособность при кипении в горячих нитках I контура, что имеет место при снижении уровня в корпусе реактора. При малых и средних течах, включая течь эквивалентным диаметром Ду 100, использование СПОТ позволяет значительно увеличить время осушения активной зоны.

Снижение давления I контура , и, как следствие, уменьшение расхода течи и более полное использование воды гидроемкостей, а также возврат конденсата I контура в активную зону, (что имеет место при сниженном уровне в корпусе реактора) позволяют за счет работы СПОТ более рационально использовать запасенную охлаждающую среду.

Так например, при течи эквивалентным диаметром Ду 80, сопровождающейся полной потерей всех источников энергоснабжения без использования СПОТ время достижения оболочками ТВЭЛ опасных температур (уверенный рост температуры выше 1200°С) составляет менее часа. Использование СПОТ при этой аварийной ситуации затягивает указанный процесс до 6 часов и более. Столь длительное время увеличивает возможности принятия необходимых мер для восстановления энергоснабжения и предотвращение тяжелого разрушения активной зоны.

Система пассивного отвода тепла является эффективной и высоконадежной системой, ее преимущества очевидны:
в основе действия заложены пассивные принципы, отвод тепла осуществляется непосредственно по конечному поглотителю - воздуху, высокая мощность системы позволяет осуществить ее

функцию даже при ее частичных отказах (например, отказ 2 петель).

Следует сказать, что возможности СПОТ не исчерпываются описанными выше свойствами. В настоящее время ведутся проработки технического решения об отказе от системы АПН и БРУ-А в связи с использованием СПОТ, а также возможности плановых операций расхолаживания энергоблока с помощью СПОТ. Таким образом, система пассивного отвода тепла является высокоэффективной с возможностями многофункционального использования системой.

Внедрение этой системы позволяет значительно повысить уровень безопасности АЭС.

4.3. Система быстрого ввода бора

Система быстрого ввода бора в первый контур (СБВБ), предназначена для быстрого приведения реактора в подкритичное состояние посредством подачи концентрированного раствора борной кислоты в режимах с отказом системы управления и защиты реактора (СУЗ) вплоть до полного отказа.

Система состоит из четырех независимых каналов, подключенных к "холодным" ниткам петель главного циркуляционного контура. Каждый канал состоит из гидроемкости с высококонцентрированным раствором борной кислоты, соединенной трубопроводами с напором и всасом ГЦН и арматуры на этих трубопроводах.

В настоящее время проводится оптимизация характеристик СБВБ, например, рассматриваются такие варианты:

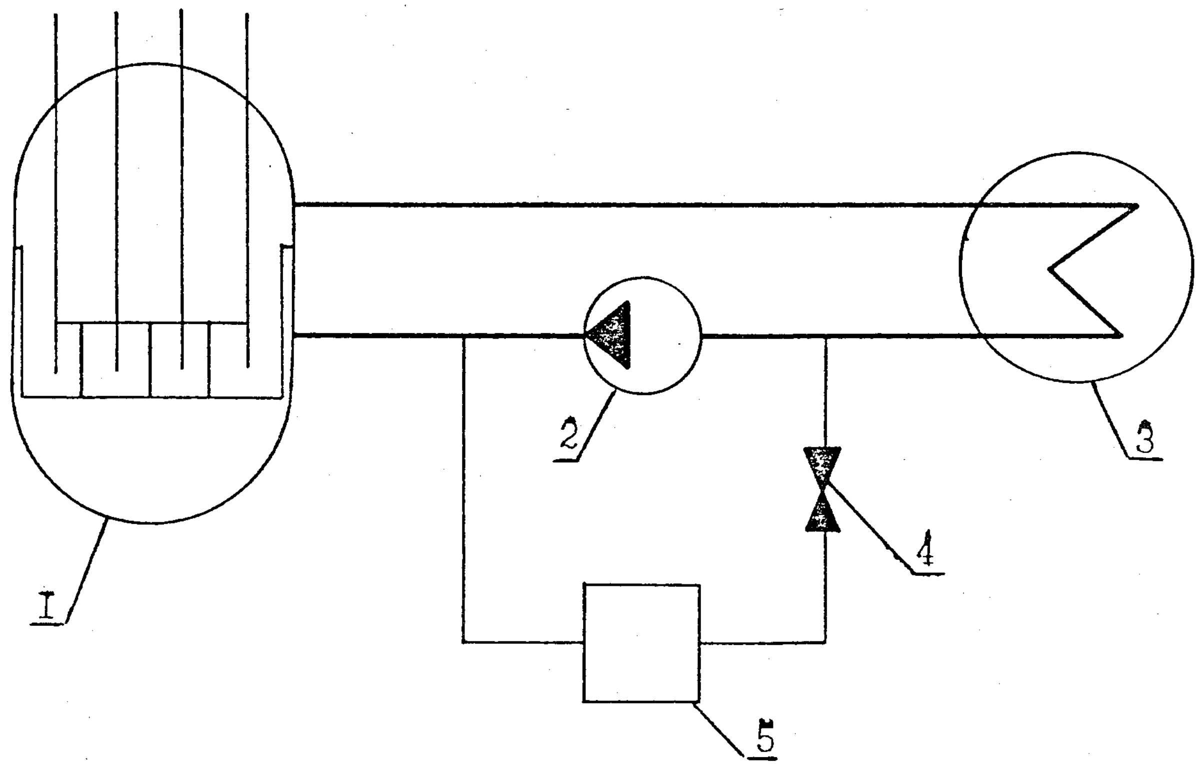
- объем емкости 2,5 м3
- концентрация борной кислоты 160 г/л
- объем емкости 8 м3
- концентрация борной кислоты 40 г/л.

Рассматриваются также различные конструкции арматуры, способы поддержания в рабочем состоянии емкости и др.

В настоящем докладе отражена, главным образом, сама идея этой системы.

Система быстрого ввода бора по быстродействию уступает механической системе воздействия на реактивность из-за невозможности сокращения времени транспорта борного раствора бора. Однако, эффективность СБВБ позволяет значительно снизить, а в большинстве случаев исключить эффекты реактивности в случае полного отказа СУЗ на требование работы.

Принципиальная схема системы быстрого ввода бора.



I Реактор

2.ГЦН

3.Парогенератор

4.Отсечная задвижка

5.Ёмкость высококонцентрированного раствора бора

Сигнал на срабатывание системы поступает при сочетании двух сигналов:

- сигнал АЗ

- отсутствие снижения нейтронного потока через 2 секунды после сигнала АЗ.

Команда на запуск системы осуществляется открытием быстродействующей арматуры на байпасе ГЦН.

За время выбега ГЦН высококонцентрированный раствор борной кислоты поступает в контур, тем самым осуществляется введение жидкого поглотителя.

Таким образом, действие самой системы основано на пассивном принципе (используется энергия инерции при выбеге ГЦН). Электропитание необходимо лишь для сигнала на запуск системы.

Следует отметить, также, что эффективность СБВБ такова, что при ее использовании на действующих АЭС можно отказаться от замены верхнего блока реактора, т.е. наличие регулирования СУЗ в сочетании с этой системой позволяют исключить ядерноопасный режим при нештатных ситуациях, связанных с изменением температуры теплоносителя.

4.4. Система контроля готовности систем безопасности (КГСБ)

Система контроля готовности систем безопасности предназначена для непрерывного контроля дискретного положения элементов систем безопасности с выводом обобщенного сигнала на БЩУ.

Каналы системы безопасности в режиме нормальной эксплуатации блока мощности могут находиться:

- в режиме ожидания,
- в режиме опробования,
- в ремонте (не более 2 смен, затем блок должен быть остановлен).

При выводе канала СБ в ремонт два других канала должны быть опробованы с целью выявления скрытых отказов.

Система контроля готовности СБ реализуется с помощью УВС и работает по двум программам:

для режима ожидания и режима опробования. В случае нештатного положения элемента СБ поиск этого элемента осуществляется машиной, выявляется причина неготовности и принимаются соответствующие меры к ее устранению.

Использование системы контроля готовности систем безопасности позволяет:

- свести к минимуму случайные ошибки персонала,
- иметь на БЩУ непрерывную информацию по готовности каждого из трех каналов СБ в целом к выполнению своих функций,
- контролировать и своевременно устранять неготовность элементов СБ.

Таким образом, внедрение системы контроля готовности СБ вносит значительный вклад в снижение вероятности нештатного протекания аварийных ситуаций.

4.5. Система сброса давления и очистки аварийных выбросов

Система сброса давления и очистки аварийных выбросов из защитной оболочки предназначена для предотвращения повышения избыточного давления сверх допустимого, которое может возникнуть при сверхнормативных авариях и привести к потере оболочкой функциональных свойств.

В качестве расчетной нагрузки на фильтр приняты предельные значения активности, соответствующие расплаву активной зоны.

Конструкция фильтра принята аналогичной фильтру производства фирмы ABB (Швеция).

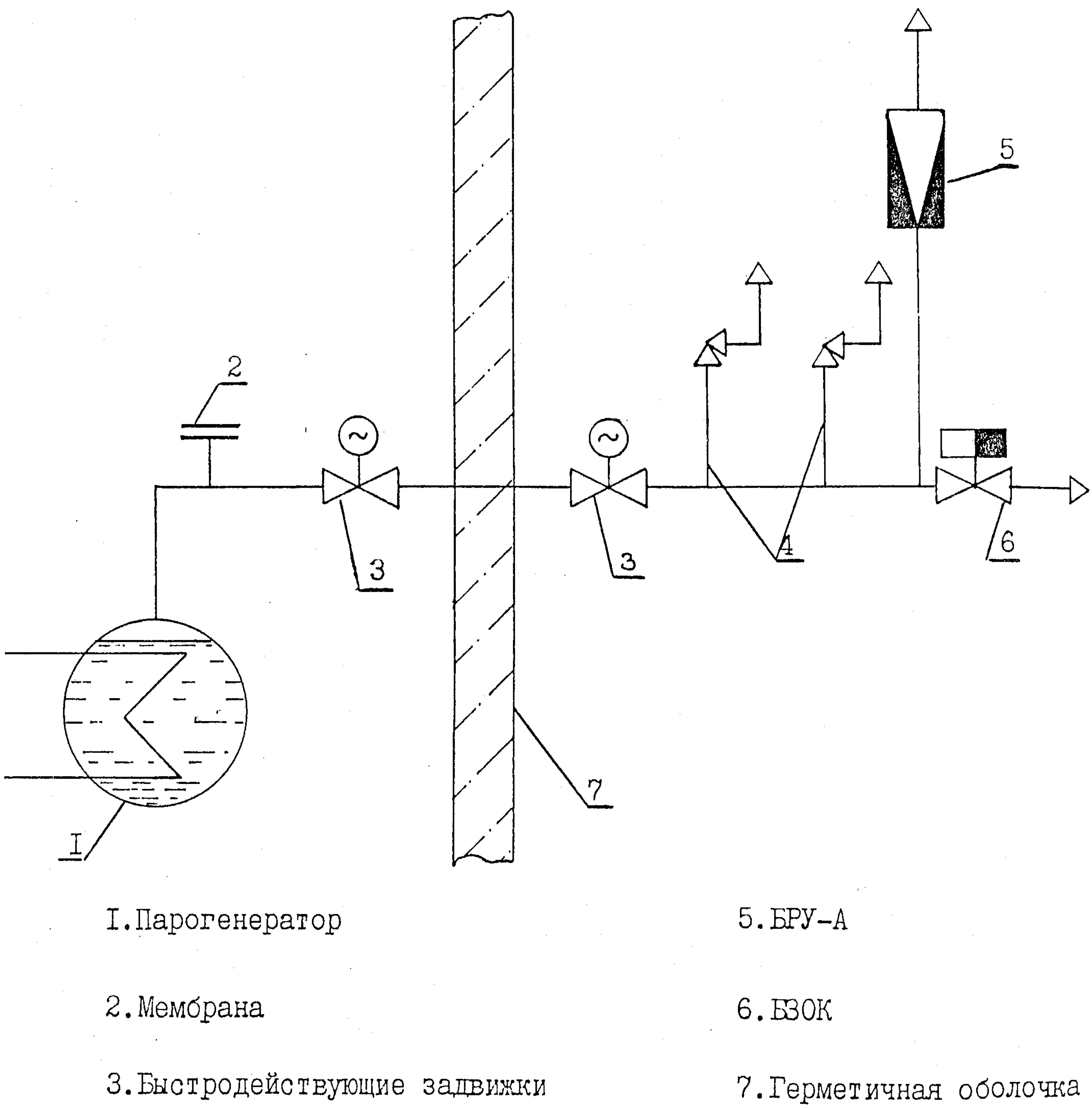
Фильтр устанавливается на площадке АЭС у оси 5Р обстройки реакторного отделения.

4.6. Система локализации течи из I контура во П-й (в парогенераторах)

Система предназначена для исключения выброса активной среды в атмосферу при разрыве теплообменной трубки или разуплотнении коллектора парогенератора по I контуру значительным сечением.

В случае, если идентифицирована значительная течь из I контура во П, то происходит срабатывание системы и возврат активной среды в защитную оболочку.

Принципиальная схема локализации при течи из I контура во $2^{ой}$.



I.Парогенератор

2.Мембрана

3.Быстродействующие задвижки

4.Импульсно-предохранительные устройства

5.БРУ-А

6.БЗОК

7.Герметичная оболочка

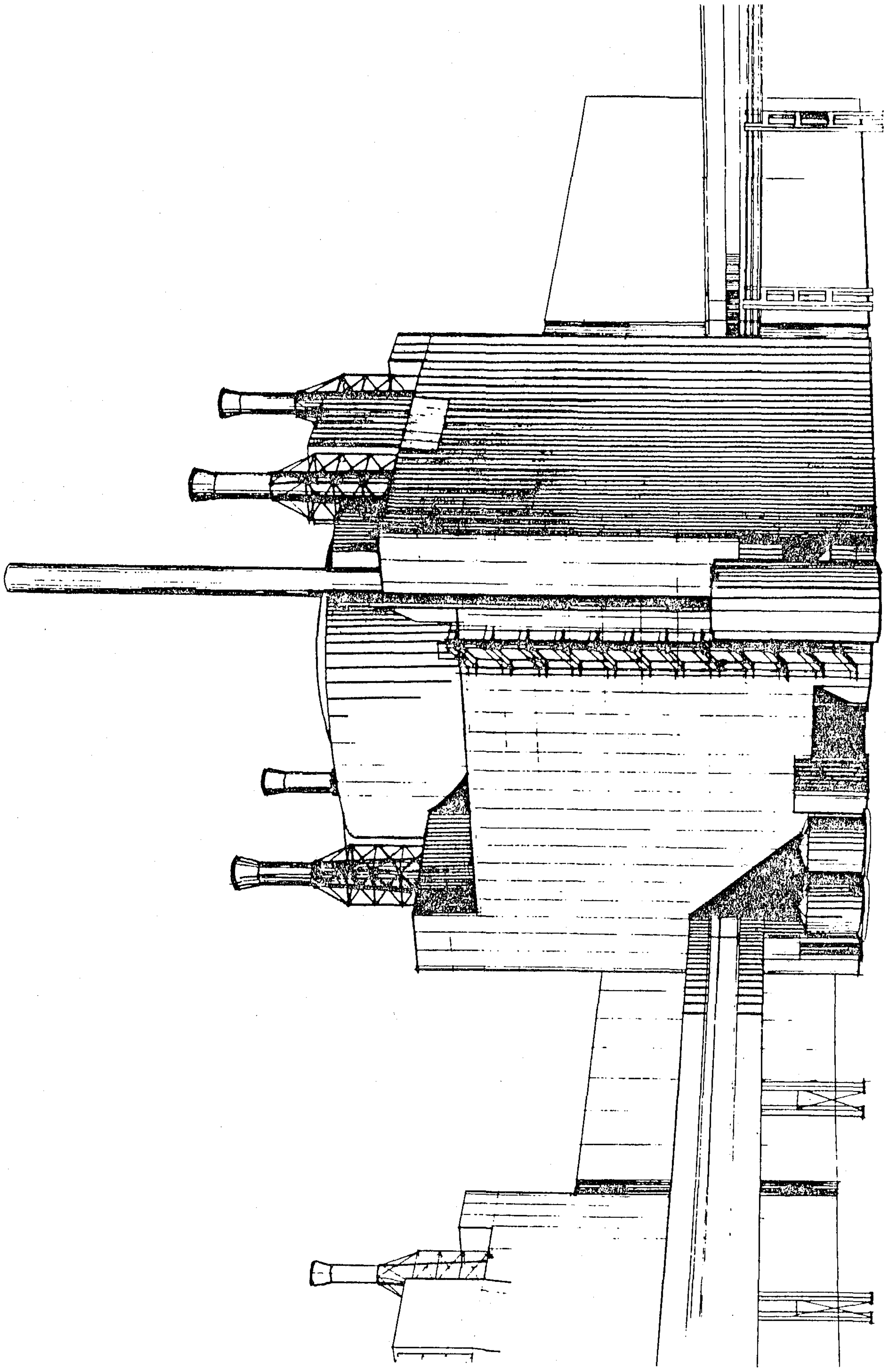
4.7. Система улавливания и охлаждения расплавленной активной зоны за пределами корпуса реактора ("ловушка")

В соответствии с рядом научно-технических задач в Советском Союзе рассматриваются возможности улавливания расплава, за пределами корпуса реактора, несмотря на малую вероятность к выходу расплавленной активной зоны из корпуса реактора. В настоящее время в нашей стране, как и большинстве стран, развивающих ядерную энергетику, изучаются устройства и пути улавливания расплавленной активной зоны, а также сопутствующие этому вопросу проблемы. На сегодняшний день эти работы не завершены и поэтому ни одна из существующих конструкций ловушки не может быть уверенно рекомендована к внедрению.

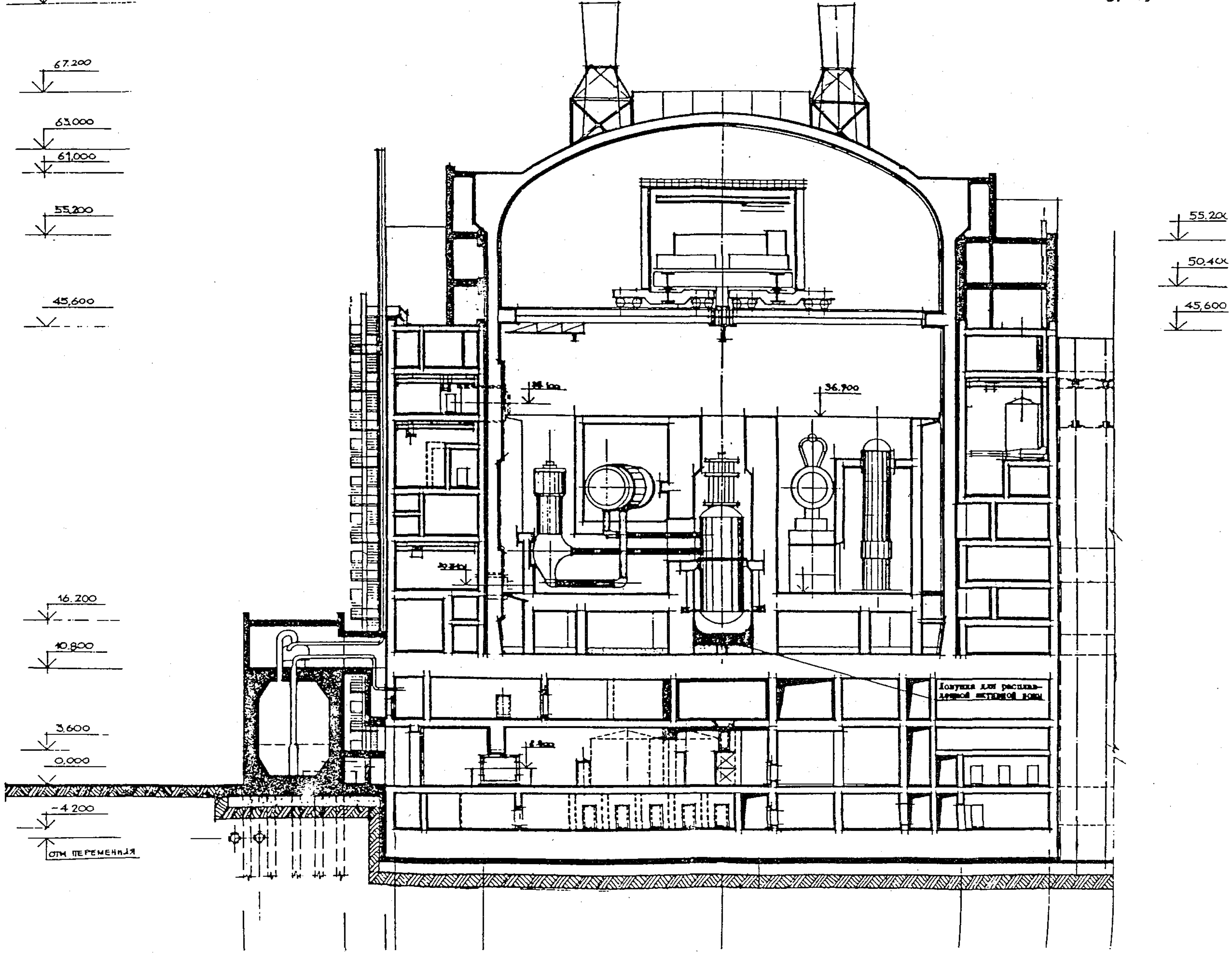
По результатам ряда анализов система улавливания расплавленной активной зоны малоэффективна по вкладу в повышение уровня безопасности. Однако, усовершенствование системы локализации, проектные основы которой включали бы в себя локализацию аварий с расплавлением активной зоны и выходом ее за пределы корпуса реактора, является весьма заманчивым.

Создание такой системы локализации позволило бы предотвратить выход радиоактивных продуктов в окружающую среду при предельном состоянии топлива и, таким образом, обеспечить предельную безопасность атомной электростанции несмотря на чрезвычайно малую вероятность такой аварии. Поэтому наша страна продолжает изучать эту проблему, принимает участие в международных программах, посвященных этой теме (н-р, программа АСЕ).

После завершения необходимых НИОКР в случае положительного результата, т.е. достаточно обоснованного и инженерно-приемлемого решения, система улавливания расплавленной активной зоны за пределами корпуса реактора будет внедрена на последующих стадиях совершенствования энергоблоков АЭС.



... Разрез 1-1.



67.200
63.000
61.000
55.200
45.600
16.200
10.800
3.600
0.000
-4.200
отм перемения
55.200
50.400
45.600
36.900
Ловушка для расплавленной активной зоны

5. Заключение

С целью определения эффективности от внедрения предлагаемых систем был выполнен вероятностный анализ безопасности унифицированного проекта ВВЭР-1000 без дополнительных мероприятий и с их учетом.

В качестве вероятностных показателей были выбраны вероятности (частоты) плавления активной зоны и вероятности (частоты) превышения индивидуальной дозы, нормируемой СП АЭС-79 на границе зоны радиусом 25 км.

При определении вероятностных показателей безопасности АЭС исходные данные по частотам исходных событий и интенсивности отказов оборудования принимались на основе имеющихся статистических данных, а также данных приведенных в технической документации на оборудование (ТУ).

Следует отметить, что принятые таким образом исходные данные достаточно консервативны и запас по абсолютной величине вероятности может быть значительным.

Однако на относительную величину повышения уровня безопасности это обстоятельство влияния не отказывает.

Оценка влияния различных исходных событий на вероятностные показатели безопасности выявила группу критических исходных событий, вклад которых в вероятность плавления активной зоны и частоту превышения нормируемой дозы составляет 98-99%.

К их числу относятся:

- нарушение теплоотвода по II контуру,
- обесточение,
- течь из I во II-й,
- малые и средние течи

Оценка влияния принятых в настоящих предложениях дополнительных мероприятий по безопасности на критическую группу исходных событий и, как следствие, вероятностные показатели безопасности АЭС в целом показывает следующее:

5.I. По показателю вероятности плавления активной зоны повышение уровня безопасности составляет до 40 раз .

5.2. По показателю вероятности превышение индивидуальной дозы, нормируемой п.3.I7 СПАЭС на границе зоны радиусом 25 км повышение уровня безопасности составляет до I00 раз.

5.3. Вышеуказанные результаты оценки повышения уровня безопасности носят предварительный характер и подлежат уточнению на стадии разработки проекта. В то же время, данные результаты позволяют оценить эффективность дополнительных систем и наметить пути дальнейшего повышения безопасности АЭС, в частности, вероятностные оценки критических исходных событий показали, что для дальнейшего повышения уровня безопасности (вплоть до уровня ниже, тем 10^{-6} в год) необходима доработка оборудования (например, повышение надежности паросбросных устройств на закрытие, уплотнений ГЦН), а также разработка специальной диагностики (н-р, коллектора ПГ).

Таким образом, методами вероятностного анализа безопасности подтверждена высокая эффективность от внедрения указанных мероприятий.

При этом основной вклад в повышение безопасности вносят такие мероприятия как:

- модернизация реактора,
- система пассивного отвода тепла
- система локализации течи из I контура во П и др.

Следует отметить, что рассматриваемые технические решения являются универсальными для внедрения как на вновь строящихся, так и на действующих АЭС. Таким образом, внедрение указанных мероприятий позволит значительно повысить общий уровень безопасности атомной энергетики в целом.

В заключение хотелось бы сказать несколько слов о перспективах развития атомной энергетики. В последнее время вопросы безопасности этого способа энергопроизводства широко обсуждаются мировой общественностью. При этом, профессиональные научно-технические проблемы дальнейшего развития атомной энергетики предполагают проведение глубоких расчетно-теоретических и экспериментальных исследований, проведение большого объема опытно-конструкторских работ, а также освоение нового оборудования промышленностью и др.

Учитывая, высокие материальные и временные затраты для решения указанных проблем, наиболее оптимальным выходом является, видимо, широкая кооперация, сотрудничество и обмен опытом на взаимовыгодной основе.

В связи с этим Советский Союз с интересом встретит предложение по сотрудничеству в различных областях для совместного решения указанных проблем.

BASIC DESIGNS TO IMPROVE VVER-1000 NUCLEAR POWER PLANTS

CONTENTS

BASIC DESIGNS TO IMPROVE VVER-1000 NUCLEAR POWER PLANTS

1. Introduction

The problem of ensuring the safety of nuclear power stations is nowadays acquiring special importance. The absence of any practical alternative to large-scale development of nuclear power engineering adds an entirely new dimension to the problem of safety, particularly in view of the grave consequences of the disasters at the Three Mile Island and Chernobyl Nuclear Power Statios.

VVER-1000 nuclear power plants (NPP) which are currently used worldwide and will continue to be the basic model till the year 2000, have been subjected lately to a large number of safety tests. The tests, essentially, have shown that these power plants possess characteristics indicating that the present level of safety is adequate; on the other hand, there are ways to improve the reliability and safety of nuclear power plants.

Unusually thorough safety tests of VVER-1000 nuclear power plants were launched in various countries, following the Three Mile Island accident. The accident alerted the international community and triggered a wider search for scientific and technical means to improve the existing safety designs.

Although the present level of safety of modern VVER-type NPPs may be considered satisfactory, we have chosen to search for new ways of further safety improvement with a view to minimizing the hazard posed by nuclear power stations, both existing and those under construction. VVER-1000 model, whose state-of-the-art is discussed below, will be used to illustrate ways of safety improvement.

2. Brief Information on VVER-1000

A heat generation-and-distribution arrangement of a nuclear power station using a VVER-1000 reactor installation has a primary and secondary systems, a 4-loop shell-type reactor with water under pressure, horizontal steam generators.

Basic designs incorporated in the model are traditional.

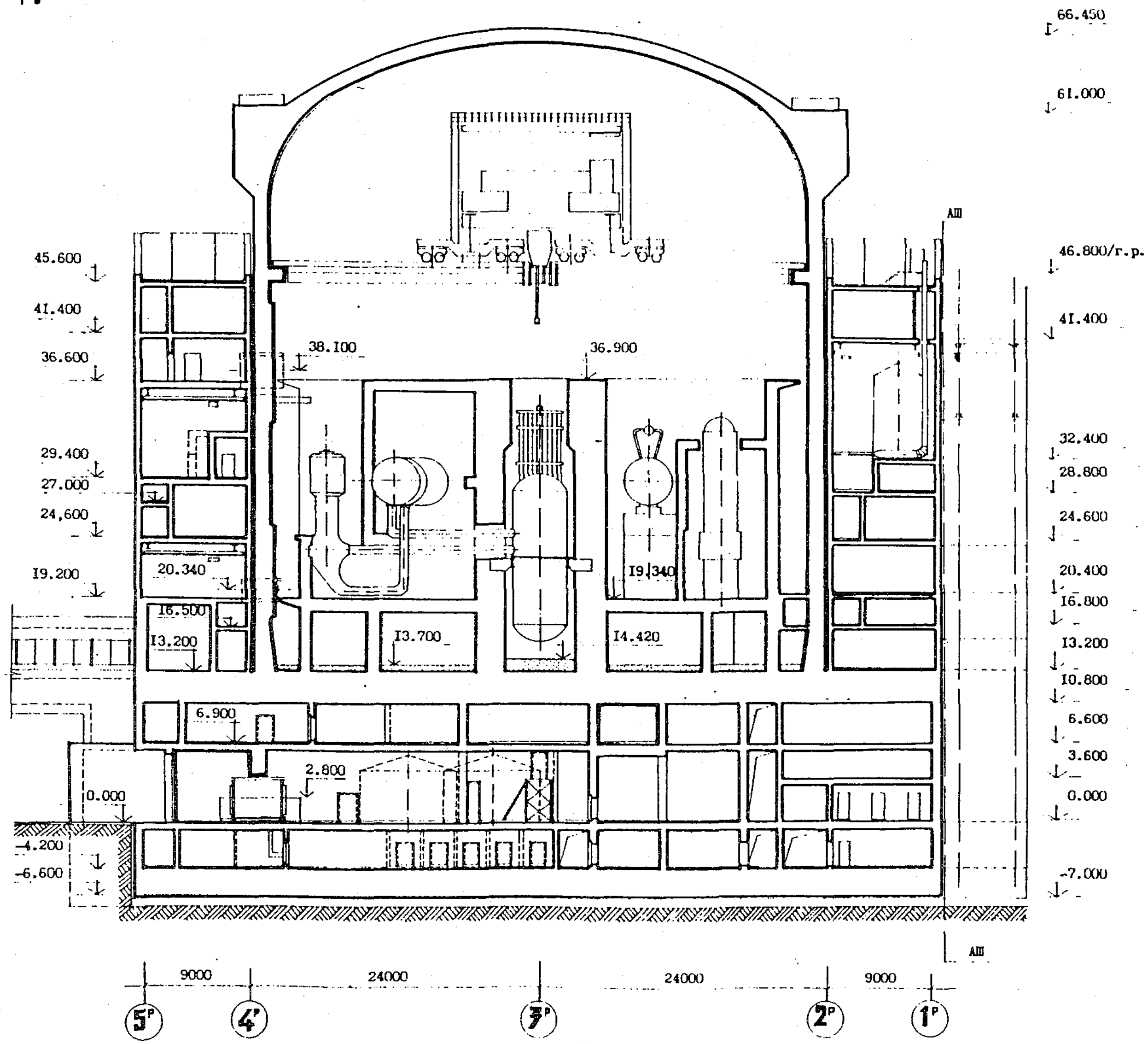
A full-pressure containment (5 kgf/cm^2) is single, of a cylindrical shape, made of pre-stressed reinforced concrete, and is provided with a leaktight steel facing. The reactor hall building of the nuclear power station is 66 x 66 m (plan view) and 66.6 m high. The building comes under the 1st category of seismic stability, being a structure , housing the systems intended to ensure the safety of the nuclear power station. To improve the dynamic characteristics of the reactor hall building and even out the deformations of its component parts differing by mass, when these are subjected to seismic impacts, the building is designed as a local symmetrical structure, the containment, ancillary structures and reactor installation being erected on a single-piece box-type foundation made of reinforced concrete. The heaviest items of equipment and the tanks are positioned at the lowermost elevations. Such a design has imparted a greater stability to the building and reduced the effect of seismic impacts on structures and equipment.

VVER-1000 nuclear power plants are designed to withstand accidents of all descriptions, including a maximum design failure, viz. an instantaneous cross-wise rupture of the dia 850 mm main circulation pipeline of the reactor cooling system , with a double-side coolant release, under the conditions where the

Реакторное отделение унифицированного блока ВВЭР-1000. Разрез 1-1

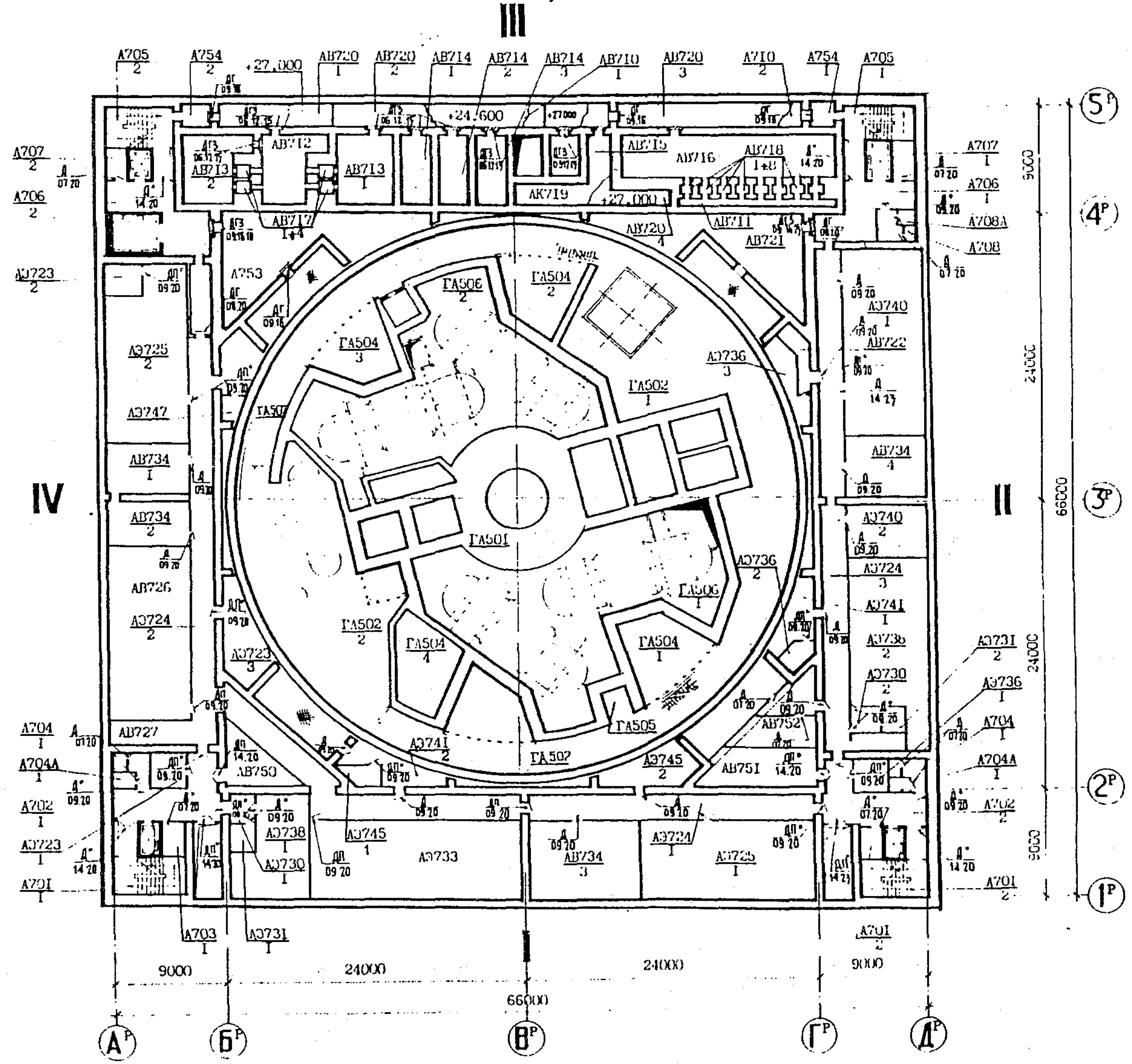
Reactor hall of VVER-1000 standard nuclear power plant. Section 1-1.

1-1



Реакторное отделение унифицированного блока. План по отметке 24,60

Standard NPP reactor hall. Plan on elevation 24,60.



ПЛАН
отм. 24,60

Reactor hall of standard VVER-1000 nuclear power plant

Principal scheme of VVER-1000 NPP safety system channel

Гидроемкость САОЗ
ECCS accumulator

Насос аварийного расхолаживания
Emergency cool down pump

Насос аварийного впрыска бора
Boric acid injection pump

Спринклерный насос
Spray pump

Насос техводоснабжения
Service water supply pump

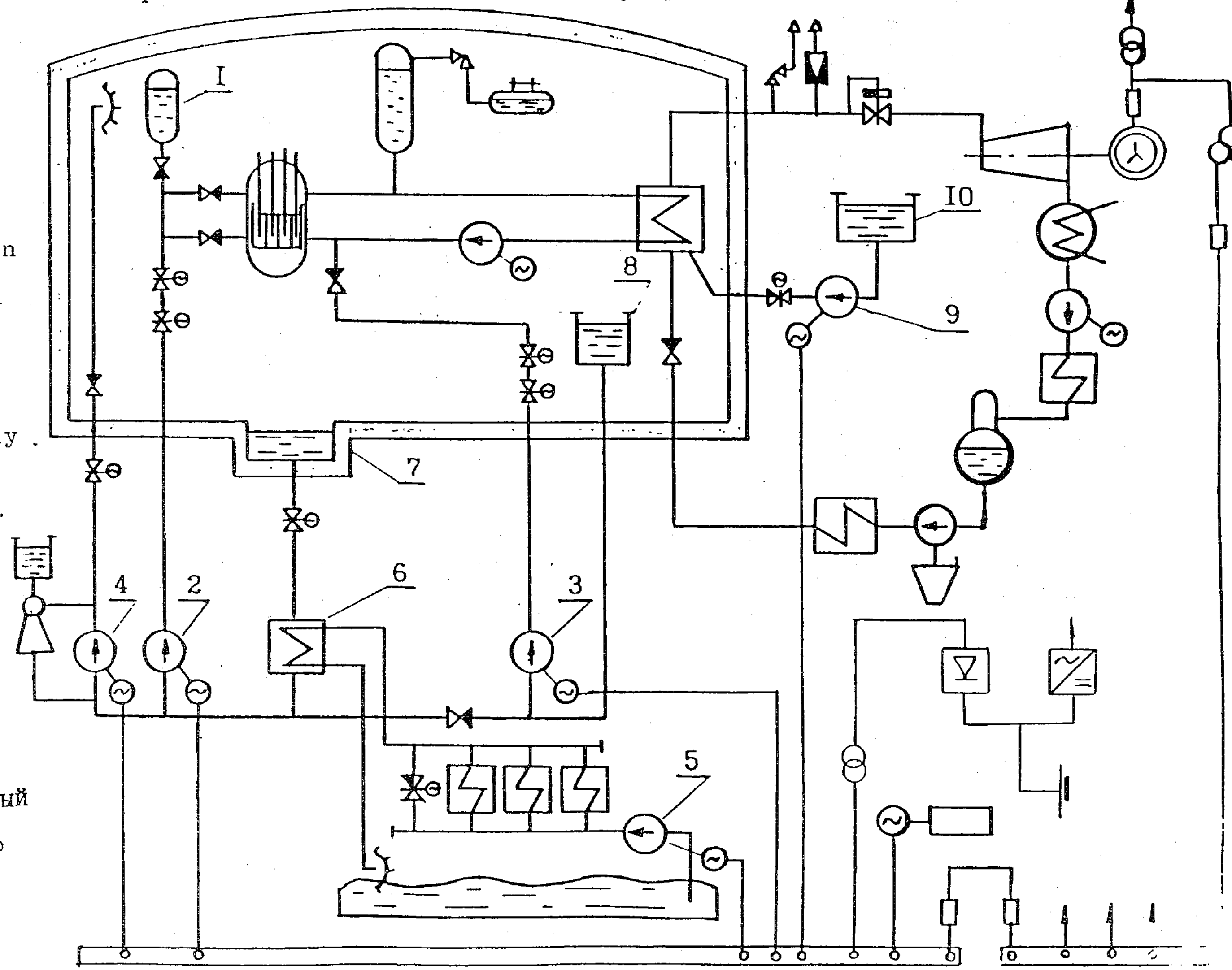
Теплообменник САОЗ
ECCS heat exchanger

Приямок-бак
Sump tank

Бак запаса концентрированного раствора бора
Boric acid storage tank

Аварийный питательный насос
Emergency feed pump

Бак запаса дистиллата
Distillate storage tank



Принципиальная схема канала системы безопасности энергоблоков АЭС ВВЭР-1000 plant is de-energized and the effects of seismic activity are tangible.

VVER-1000 nuclear power plants feature safety systems based on a principle of three absolutely independent systems, or safety channels, each capable of performing fully the functions of protection (i.e. a 3x100% structure is used).. The safety system channels have independent sources of power supply: 5,600 kW diesel generators, as well as independent sources of cooling water: spray ponds, whose capacity ensures a continuous removal of residual heat release by the reactor.

Safety systems designs of a VVER-1000 nuclear power plant are intended to provide for a high functional reliability. For example, in any emergency, actuating the safety systems, remote control of the mechanisms is automatically inhibited to rule out the operator's mistakes. The inhibition of remote control is automatically cancelled after a particular mechanism has performed its function, e.g. inhibition of a spray pump cut-off by remote control is automatically released when the pressure in the containment goes down.

To guarantee a high reliability of the safety system, the VVER-1000 nuclear power plant project incorporates a standard programme of loading emergency diesel generators, regardless of the kind and the scale of the accident.

A design like this facilitates and enhances the reliability of phased selection of power of emergency diesel generators; control of water feed to the primary of secondary system by automatically actuating the appropriate piece of hardware, depending on the progress of the accident. For example, should an accident

Основные характеристики реакторной установки ВВЭР-1000.
VVER-1000 Reaktor installation basik data

ощность электрическая/тепловая. Elektrical/thermal capacity	1000/3000МВт MW
авление I контура(рабочее) ?rimary system operating pressure	16,0МПа MPa
эмпература на выходе из реактора Reactor outlet temperature	322°С
авление 2 контура(рабочее) econdary system operating pressure	6,4 МПа. MPa пар насыщенный saturated steam
сло петель lumber of loops	4
п парогенератора team generator tupe	горизонтальный horizontal
особы воздействия на реактивность eactivity control methods	-механическая система (до температуры 250°С) mechanical system (to t° 250°C) -жидкостная система (во всём диапазоне температур) fluid system (within the whole temperature range)
пания топлива el residence time	3 года 3 years
бина выгорания urn-up	40000 МВт сутки/т MW day/т
гащение ^{235}U 235 enrichment	4,4%

Тип контаймента Containment type	одинарная оболочка полного давления Full pressure single containment
Расчётное аварийное давление контаймента Design basis assident containment pressure	0,5 МПа MPa
Расчётная сейсмичность реакторного отделения и систем безопасности Aseismic design of reactor hall and safety system	до 7 баллов по MSK up to magnitude 7 MSK
Структура систем безопасности Safety system structure	3×100%
Источники надёжного техводоснабжения Service water supply sources	независимые брызгальные бассейны independent spray ponds
Источники надёжного энергоснабжения Emergency power supply	независимые дизельгенераторы independent diesel generators
Производительность очистки теплоносителя Coolant decontamination capacity	высокотемпературная 4×125 $м^3$/час High temperature низкотемпературная до 60 $м^3$/час low temperature

occur, involving a leak in the steam lines outside the containment, the spray pump gate valves will never open as there will be no increase of pressure within the containment, though the spray pumps will automatically be started to service the recirculation line.

The safety systems of VVER-1000 NPPs are provided with a standby control panel, enabling the operator to monitor the performance and maintain overall safety of the reactor and power unit, even if there is a failure in the main control board of the nuclear power station.

Fundamental designs relating to the safety of a VVER-1000 nuclear power plant are consonant with or similar to the designs adopted elsewhere, e.g. in FRG, U.S.A., France, Japan.

Operation of VVER-1000 nuclear power plants, using a B-320 reactor, proved their reliable and economical performance.

3. Fundamental Trends in VVER-1000 NPP Reliability and Safety Improvement

In a bid to develop most efficient measures for early adoption, major causes of serious fuel damage were analysed, namely:

(a) unscheduled progress of failures;

(b) scale of failure exceeding that of a maximum design failure;

(c) combination of above-stated causes.

The analysis has made it possible to identify most grave emergencies:

(a) a protracted failure of all sources of power supply (with or without a leak);

(b) a failure of particular controls of RCPS;

Таблица 2

Основные направления по повышению надёжности и безопасности АЭС с ВВЭР-1000
Fundamental trends in VVER-1000 NPP reliability and safety improvement

Цели безопасности Safety objectives	Пути повышения безопасности АЭС NPP safety improvement methods	Практические мероприятия по повышению безопасности АЭС с ВВЭР-1000 Practical measures to improve VVER-1000 NPP safety
Предотвращение аварий Accident prevention	Повышение внутренней безопасности реактора Reactor inherent safety improvement	Улучшение ядерно-физических свойств реактора, его модернизация -121 СУЗ -более надёжные привода СУЗ Improvement of reactor nuclear physical properties, its upgrading -121 Control and protection system -more reliable RSPS drives
	Повышение надёжности систем и оборудования Systems and equipment reliability improvement	-диагностика состояния металла и оборудования -доработка оборудования -metal and equipment condition diagnostics -equipment improvement
	Совершенствование АСУТП и информационного обеспечения Automatic process control system and information system improvement	-совершенствование внутриреакторного контроля -системы поддержки оператора в переходных и нештатных режимах -in-core monitoring improvement -operator support system in transient and nonstationery conditions

Цели безопасности Safety objectives	Пути повышения безопасности АЭС NPP safety improvement methods	Практические мероприятия по повышению безопасности АЭС с ВВЭР-1000. Practical measures to improve VVER-1000 NPP safety
Глубокая защита барьеров Safety-in-depth of barriers	Совершенствование локализующих барьеров Localizing barrier improvement	-локализация течи I контура во второй -система сжигания водорода -система сброса давления и очистки аварийных выбросов из защитной оболочки -Localization of Leak from primary system within secondary system -Hydrogen ignition system -System designed for pressure suppression and accidental release venting from the containment
	Использование систем безопасности, основанных на пассивных принципах для защиты барьеров Operation of safety systems based upon passive principles of barrier protection	-система пассивного отвода тепла -система быстрого ввода бора -Passive heat removal system -Boron injection system
	Совершенствование АСУСБ и информационного обеспечения Improvement of CAD protection system and information system	-система готовности СБ -safety system availability

(c) a major leak from the primary to the secondary system, leading to the loss of the cooling medium of the fuel core.

Thus, we have been able to establish fundamental trends of improving the safety of VVER-1000 nuclear power plants and to elaborate practical measures (see Table 2).

4. Practical Measures to Improve VVER-1000 NPP Safety

4.1. Reactor Upgrading

Reactor upgrading envisages improvement of nuclear/performance characteristics, improvement of reactor designs with a view to enhancing the safety of nuclear power stations. To achieve this objective, reactor upgrading includes the following:

4.1.1. Raising the efficiency of the mechanical system of reactivity control by increasing the number of RCPS controls from 61 to 121 to ensure a shift of the reactor to a sub-critical state at a temperature of up to 100^{0}C without adding an extra amount of a liquid absorber; it is to be pointed out that in conformity with the requirements imposed on the systems of reactivity control, a USSR-made reactor has two systems: a fast-acting mechanical system effective in the operating temperature zone, and a liquid system, effective throughout the entire temperature range. The need for compulsory use of the liquid system of reactivity control imposes the requirements on the boron injection systems and makes the safety systems ever more complicated. In order to improve the reliability and safety, the requirements to the mechanical system of reactivity control have been made to encompass the entire temperature range.

This has made it possible to rule out nuclear hazard conditions associated with coolant temperature variation.

4.1.2. In order to obtain deeper negative feedbacks on all parameters relative to reactivity and, ultimately, to minimize damage caused to fuel in a wide spectre of conditions, efforts have been made to improve the reactor fuel core, namely:

- power emission by the fuel core has been made more uniform by adding more RCPS controls and more cores;

- an in-core monitoring system has been improved by using newly-developed assemblies of in-core monitoring channels, which are capable of ensuring, throughout reactor operation, a continuous monitoring of the flow of neutrons based on both the volume of the fuel core and the inlet and outlet temperature of the coolant, and

- the design of upper unit branch pipes has been modified to allow easier servicing in the course of operation: RCPS branch pipes are made to run along the drive covers, there being no need for flange connections of the branch pipes;

- the branch pipes of in-core monitoring system assembly outlets have been positioned on the periphery of the cover, facilitating service and inspection.

4.2. Passive Heat Removal System with All Power Supply Sources Cut Off

The passive heat removal system is intended for a protracted removal of residual heat released by reactor, when all, including emergency power supply sources are cut off, while the primary and secondary systems are leaktight. PHRS is a closed system with na-

Принципиальная схема пассивного отвода тепла.

Passive heat removal system

I. Реактор
Reactor

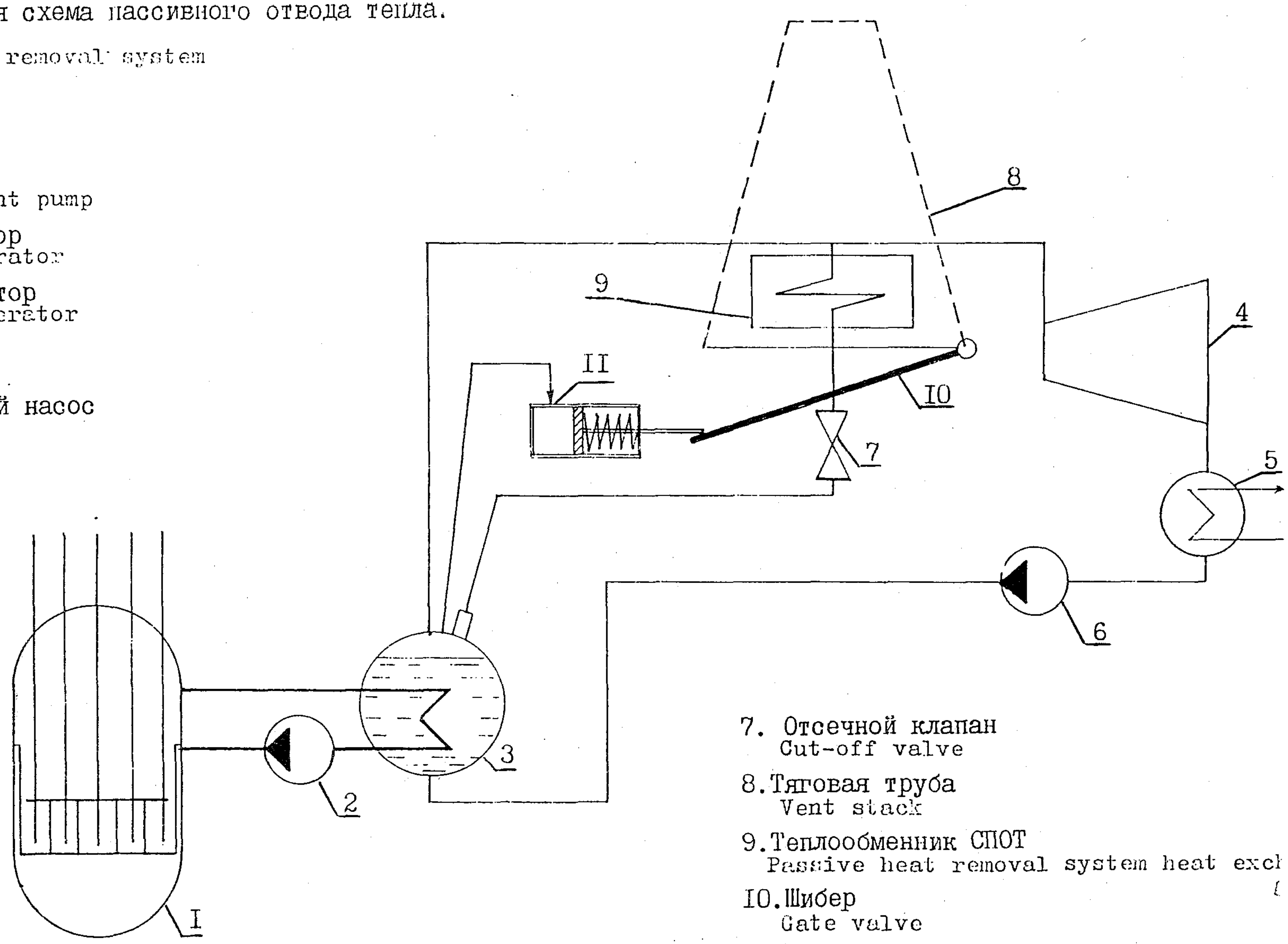
2. ГЦН
Main coolant pump

3. Парогенератор
Steam generator

4. Турбогенератор
Turbine generator

5. Конденсатор
Condenser

6. Питательный насос
Feed pump



7. Отсечной клапан
Cut-off valve

8. Тяговая труба
Vent stack

9. Теплообменник СПОТ
Passive heat removal system heat exch

IO. Шибер
Gate valve

II. Гидроцилиндр-регулятор
Hydraulic cylinder-controller

tural circulation in the primary and secondary systems. The heat is removed by ambient air, having a temperature within the ± 50°C range; the system's heat exchagers are arranged in superstructures above the elevation of 45.6.

The system comprises four absolutely independent loops, each connected to an appropriate steam generator and loop of the master recirculation system of the reactor installation.

Reactor installation design may ensure a removal of residual heat releases by natural circulation at the level of 10% of the reactor rated power. The natural circulation loop, when viewed from the side of the secondary system, has been designed to remove 80 mW of residual heat available in the three loops (arount 2.7% of rated power), using the working parameters of the reactor installation.

Under normal operating conditions, the system is warmed up, which, in an emergency, makes it possible to achieve fairly fast the design capacity of residual heat removal. These results have been confirmed experimentally: in fact it took the system less than 1 minute to gain the design capacity.

The system of residual heat removal is passive, requiring no mechanisms or sources of power supply for start-up and operation. PHRS capacity is controlled through the medium of an air tract, by opening or closing a gate with the aid of a passive direct-action regulator actuated by the pressure of the secondary system.

In a steam generator, the heat of the primary system is imparted to the medium of the secondary system; the resulting steam from the secondary system goes to PHRS heat exchangers (the turbine tract is cut off), where it is cooled by outside air, condensed, and the condensate flows by gravity to the steam generator. To ensure required input of the cooling air, a vent stack is provided, whose bottom part houses the system's heat exchangers.

The heat exchanger room is provided with a gate which controls the opening for air passage. Under normal operating conditions of the plant, the gate is closed. When all AC sources of the nuclear power station, including emergency ones, are cut off, the pressure within the secondary system increases, and the gate opens to allow required passage of air. As the pressure in the steam generator goes down, the gate closes. Thus, it makes possible to control the consumption of air and, as a consequence, of the medium in the PHRS loop; it also allows one to control PHRS capacity by monitoring the removal of reactor residual heat releases.

PHRS may also be used without regulating its capacity, which leads to the cooling of the reactor installation.

A system designed to remove residual heat releases, the major process loops being tight, PHRS is rather efficient in the case of moderate and small leaks in the primary system, remaining serviceable, when the hot lines of the primary system are boiling , which occurs when the level in the reactor shell goes down. In the case of small and moderate leaks, including equivalent to dia 100, the use of PHRS helps to reduce considerably the time required for fuel core draining.

A drop of pressure in the primary system and a resulting reduction of the leak and a better use of the water in the accumulators, plus the return of condensate of the primary system to the fuel core (which occurs at a reduced level in the reactor shell) make it possible to utilize, with the aid of PHRS, the procured cooling medium in a more rational manner.

For example, in the case of a leak equivalent to dia 80, accompanied by a cut-off of all the sources of power supply, the time of FR* containments dangerous heating (i.e. a steady rise of temperature beyond 1,200°C) is within one hour, if PHRS is not used. The use of PHRS in this kind of emergency delays the process to 6 hours and more. This length of time affords more opportunities for taking the necessary measures toward restoring power supply and preventing a heavy damage of the fuel core.

The passive heat removal system is effective and highly reliable, its advantages being obvious: it is based on passive principles, the heat is removed by an ultimate absorber, viz. ambient air, the system's high power makes it possible to rely on its functioning even in case of partial failures, e.g. failure of two loops.

It should be stressed that PHRS's capability is not confined to the properties just described. A design is being developed whereby an emergency feed pump system and a fast-acting steam dump reducing station-A will be made redundant due to the use of PHRS. The new design will also allow a scheduled NPP cooling down with the aid of PHRS. This, again, goes to prove that PHRS is a highly effective multi-functional system.

Adoption of the system makes it possible to improve the safety level of nuclear power stations considerably.

* FR - fuel rod

4.3. Boron Injection System

BIS, ensuring boron injection in the primary system, is designed to bring the reactor to a sub-critical state fast by supplying a concentrated boric acid solution under the conditions of RCPS or reactor complete failure.

BIS comprises four independent channels connected to "cold" lines of the loops in the main circulation system. Each channel consists of an accumulator containing a highly-concentrated solution of boric acid, linked by the pipelines with the main coolant plant head and suction. The pipelines are provided with all the necessary fittings.

At present, BIS characteristics are being optimized, two of the workable options given below:

- plant holding capacity - 2.5 m^3
- boric acid concentration - 160 g/l
- plant holding capacity - 8 m^3
- boric acid concentration - 40 g/l

Also under consideration are various designs of fittings, methods ensuring plant serviceability, etc.

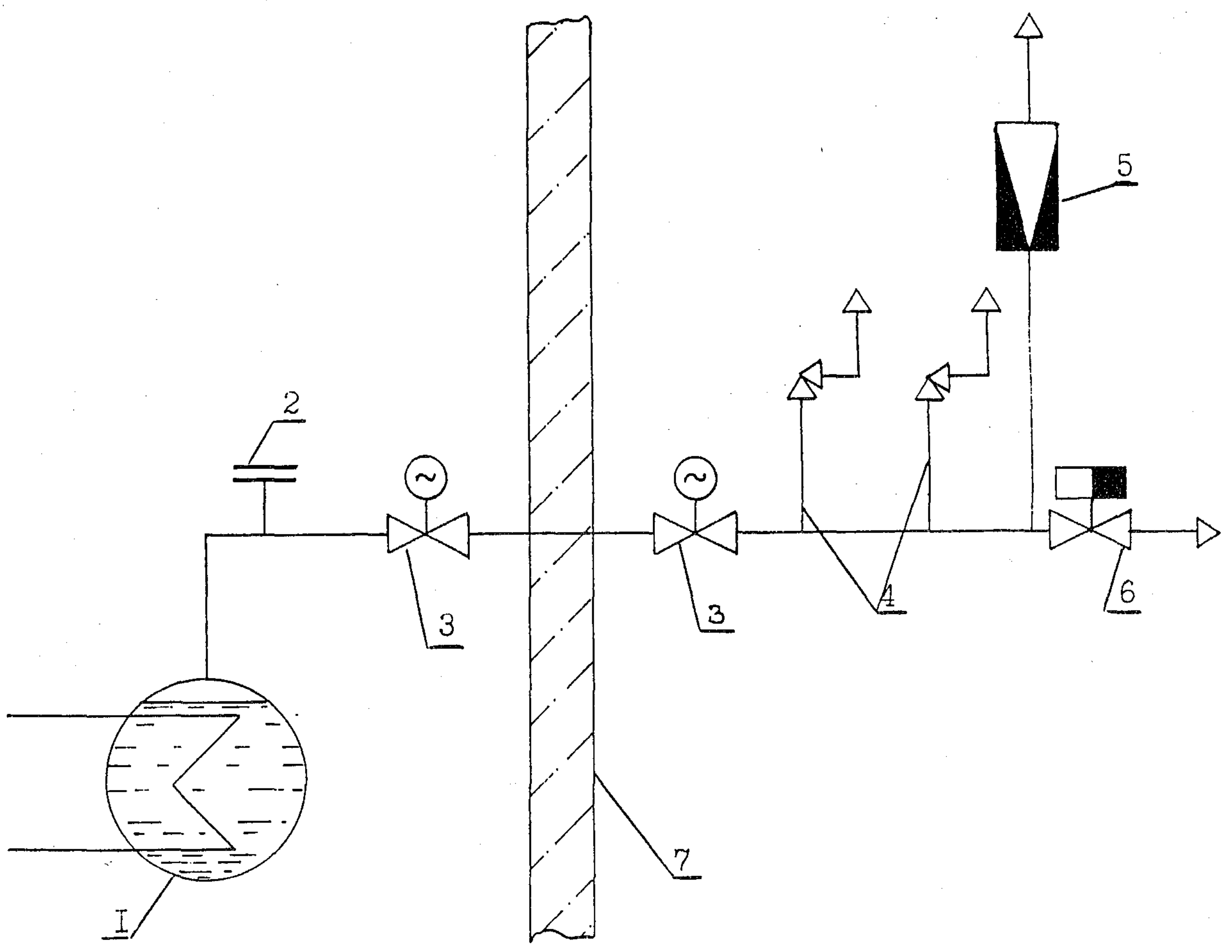
This report, essentially, dwells on the idea underlying the system.

The boron injection system is not as fast acting as the mechanical system of reactivity control as it is impossible to shorten the time of boric acid delivery. However, BIS is efficient enough to allow a considerable reduction of occurrence and eliminate most of reactivity effects in the case of a complete RCPS failure.

A system response signal is produced by a combination of

Принципиальная схема локализации при течи из I контура во 2ой.

Principal scheme of leak localization from the primary system within the secondary system



I. Парогенератор
Steam generator

2. Мембрана
Membrane

3. Быстродействующие задвижки
Fast-acting valves

4. Импульсно-предохранительные устройства
Impulse safety devices

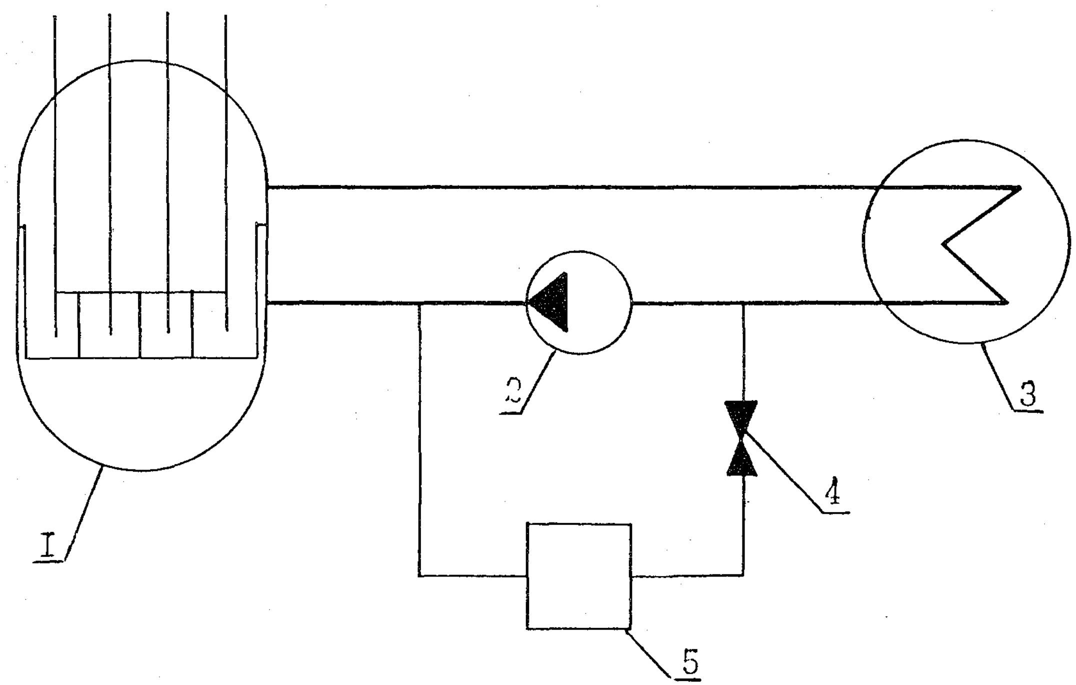
5. БРУ-А
Fast-acting steam dump reducing station-A

6. БЗОК
Fast-acting non-return stop valves

7. Герметичная оболочка
Leaktight shell

Принципиальная схема системы быстрого ввода бора.

Boron injection system



I Реактор
Reactor

2.ГЦН
Main coolant pump

3.Парогенератор
Steam generator

4.Отсечная задвижка
Cut-off valve

5.Ёмкость высококонцентрированного раствора бора
High-concentration boron solution tank

two indicators:

- A3 signal;

- no reduction in the flow of neutrons 2 seconds after A3 signal is given.

System triggering command is generated by the opening of fast-acting valves in the main coolant plant by-pass.

During the main coolant plant warm-up, boric acid solution of high concentration reaches the loop, signifying the introduction of a liquid absorber.

Thus, the action of the system proper is based on a passive principle (using the energy of inertia during the main coolant plant warm-up). Power supply is only required to produce the system triggering command.

4.4. Monitoring System for Safety System Availability

This system is intended for continuous monitoring of discrete position of safety system elements with a display of a combined signal on the control panel.

Safety system channels may be in the following modes, provided the power unit operating conditions are normal:

- standby mode;

- test-run mode;

- under repair (for 2 shifts, maximum, whereupon the unit must be cut off).

Before proceeding with safety system channel repair, test the other two channels for possible failures.

The monitoring system for safety system availability operates with the aid of CCS* in the standby and test-run modes. In the

* CCS - computer control system

case of a non-stationary position of a safety system element, the element is located by a computer, the cause of its unavailability is established and appropriate measures are taken to eliminate it.

The use of the monitoring system for safety system availability affords the following:

- minimizing random errors of personnel;

- having continuous supply of information displayed on the control panel as to the availability of each of the three safety system channels, and their ability to perform their functions;

- monitoring and timely elimination of safety system elements' unavailability.

Thus, adoption of the monitoring system for safety system availability makes a considerable contribution to reducing the probability of non-stationary conditions in emergencies.

4.5. System for Pressure Suppression and Accidental Release Venting

The system for pressure suppression and accidental release venting from the containment is designed to prevent excess pressure going beyond the permissible value which may be the case in a disastrous emergency where the containment loses its functional properties.

The filter design load is assumed to be equivalent to maximum values of activity, corresponding to the melt of the fuel core.

The filter design used is similar to that of the filter manufactured by ABB Company (Sweden).

The filter is erected at the NPP site, near the ancillary structures of the reactor installation.

4.6. Localization of Leak from Primary Sytem within Secondary System (in Steam Generators)

The localization system is designed to prevent ejection of the active medium into the atmosphere resulting from a rupture of the heat exchanger pipe or steam generator collector failure in the primary system, where a sizeable section develops.

If a considerable leak is established from the primary system within the seconadry system, then the localization system is actuated and the active medium returns to the containment.

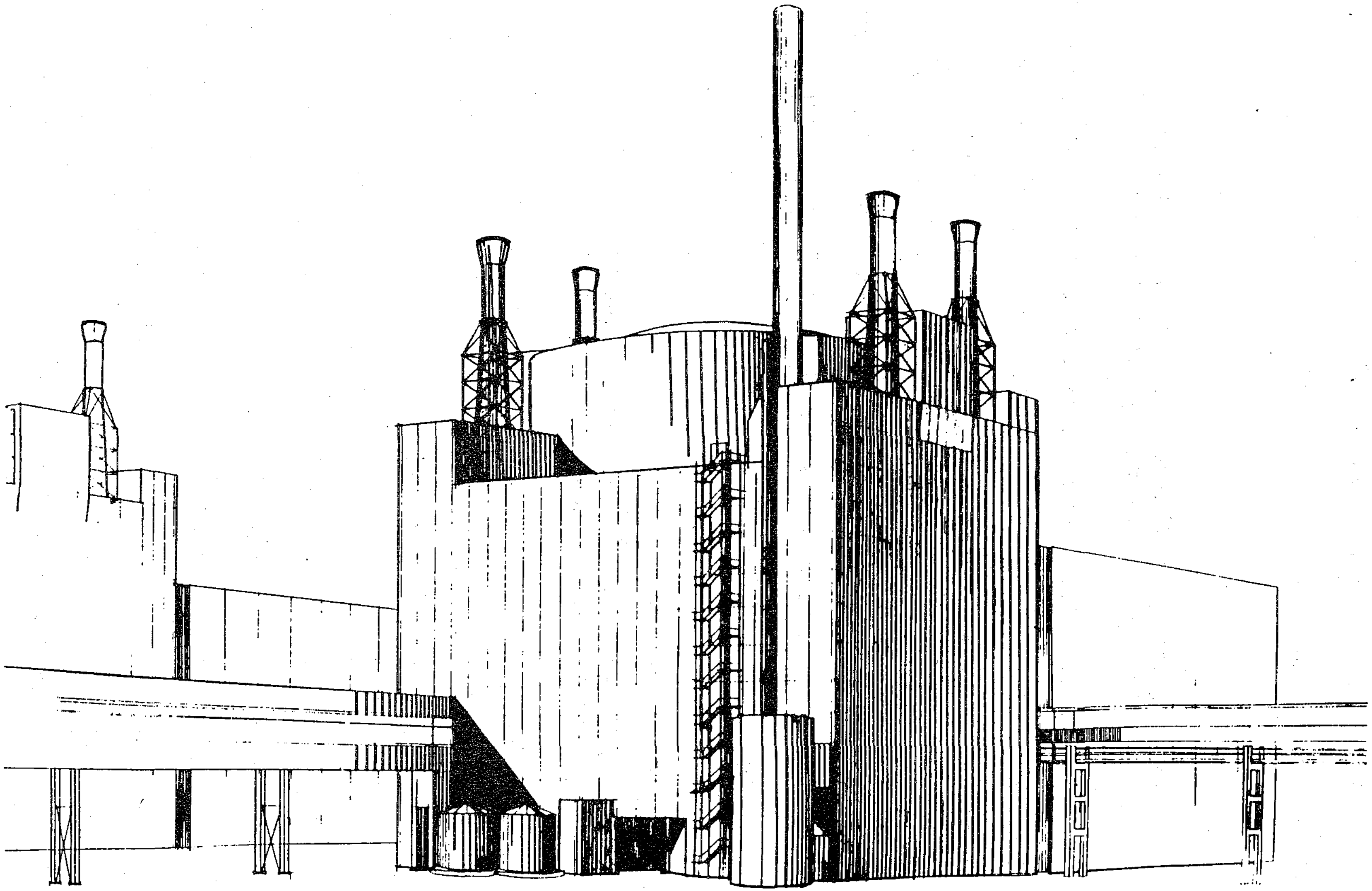
4.7. System for Recovery and Cool-Down of Molten Active Section outside Reactor Shell ("trap")

Although it is unlikely that the molten active section will ever leave the reactor shell, a number of research and technical problems currently being resolved in the Soviet Union are associated with possibilities of recovering the melt outside the reactor shell. Scholars in this country as well as in most nations developing nuclear power engineering study the devices and methods of recovering the molten active section, and examine the related problems. As of to-day, the studies have not been completed and for this reason, none of the existing designs of a "trap" can be safely recommended for commercial use.

Findings of some analyses indicate that a system for recovering the molten active section is not effective enough to en-

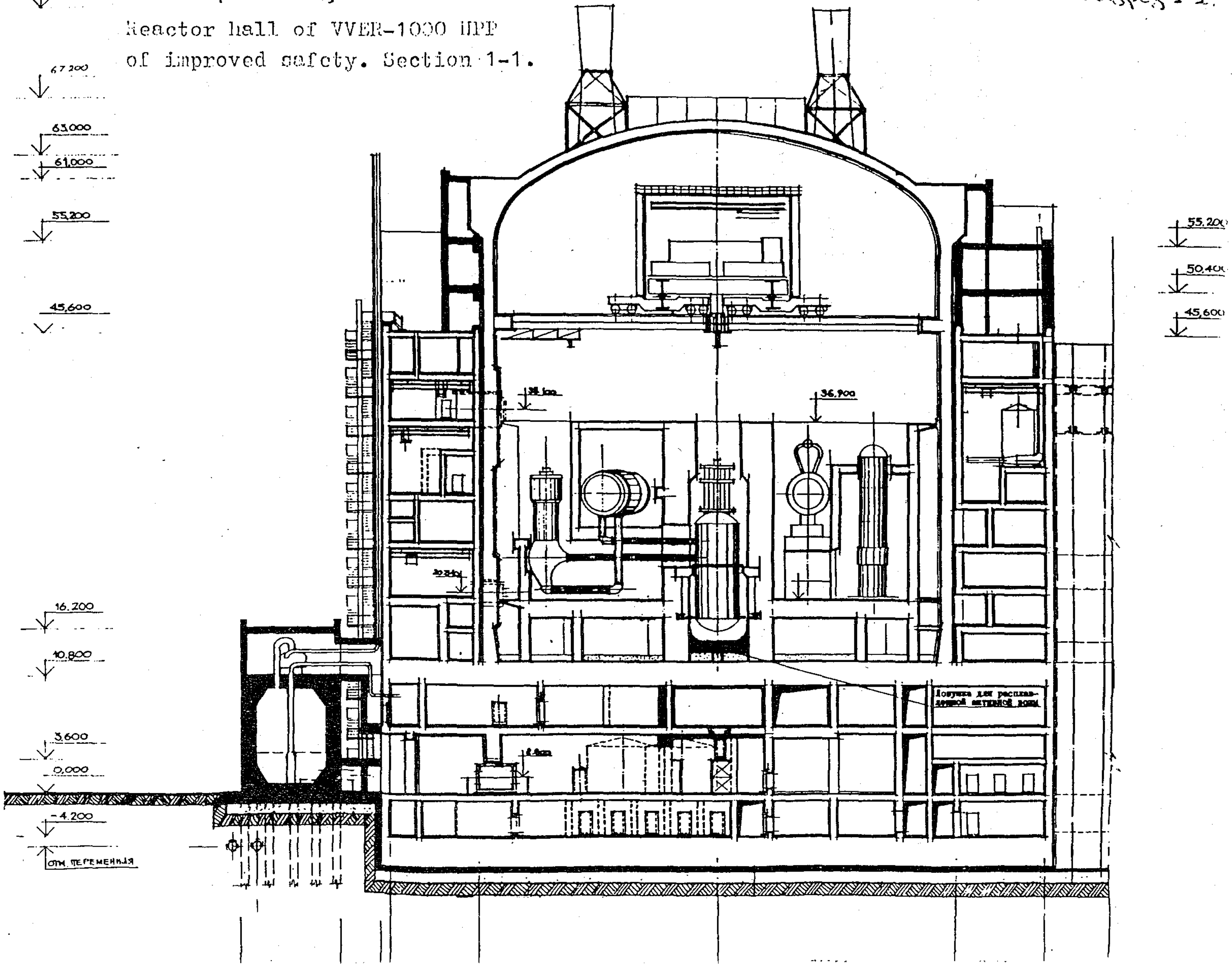
Общий вид блока повышенной безопасности с ВВЭР-1000.

General view of VVER-1000 NPP of improved safety.



Реакторное отделение блока повышенной безопасности с ВВЭР 1000 Разрез 1-1.

Reactor hall of VVER-1000 NPP
of improved safety. Section 1-1.



hance the level of safety. However, an improvement of the localization system, which would incorporate, design-wise, localization of failures involving the melting of the active section and its release outside the reactor shell, appears rather promising.

The building of a localization system, such as this, would make it possible to prevent radioactive pollution of the environment with fuel in a limit state, and thus to ensure maximum safety of a nuclear power plant even though the probability of such an accident is exceedingly small. Therefore, we continue research into this problem, taking part in international programmes devoted to this subject (e.g. ACE Programme).

After we complete the required research and development works, and if positive results are obtained, i.e. a fairly well grounded enginnering-wise acceptable solution, a system for recovering the molten active section outside the reactor shell will be adopted at subsequent stages of NPP improvement.

5. Conclusion

To determine the efficiency of adoption of proposed systems, a probabilistic analysis of the safety of a VVER-1000 standard project (with and without additional measures) was undertaken.

Used as probabilistic indicators were the probability values (frequency of occurrence) of the active section melting and of individual radiation dose excess, rated in conformity with the -79 standard on the border of affected zone of 25 km ra -

dius.

When establishing the probabilistic parameters of NPP safety, the initial data of the frequency rate of anticipated events and of equipment failure rate were based on the statistics available as well as on the technical specifications for particular items of equipment.

It must be noted that the initial data thus arrived at are fairly conservative, and the safety margin by absolute value of probability may be quite considerable.

This, however, does not affect the relative value of the safety level improvement.

Evaluation of the effect of various initial events on the probabilistic parameters of safety has revealed a set of critical initial events, whose contribution to the probability of active section melting and occurrence of rated dose exccesses amounts to 98-99%.

These events include:

- disturbance of heat removal in the secondary system;
- plant de-energizing;
- lear from primary system within the secondary system;
- minor and moderate leaks.

Evaluation of the effect of the extra safety measures (accepted in these proposals) on the critical set of initial events and, as a consequence, on the probabilistic parameters of NPP safety in general, is indicative of the following:

5.1. Based on the probability of the active section melting the safety level increases 40-fold.

5.2. Based on the probability of individual dose excess, rated by para. 3.17 of NPP SS* , measured on the border of affected zone of 25 km radius, the safety level increase 100-fold.

5.3. The above results of safety level improvement evaluation are tentative are are subject to specification at a stage of project report elaboration. This notwithstanding, the results enable one to assess the efficiency of extra safety systems and to plan further ways of NPP safety improvement. In particular, the probabilistic evaluations of critical events indicated that further enhancement of the safety level is unthinkable without improving the equipment (e.g. making steam-release devices and main coolant plant gaskets more reliable) or development of a special diagnostics procedure (e.g. for a steam generator collector).

Thus, it has become possible, using methods of probabilistic analysis of safety, to confirm the high efficiency of adopting the above measures. The safety, essentially, is improved due to the introduction of the following measures:

- reactor upgrading;
- passive heat removal system;
- system of localizing leak from primary system within the secondary system, etc.

It should be noted that designs under consideration are applicable to both the existing nuclear power stations and those being built. In our opinion, the adoption of above measures will enable us to improve considerably the general level of safety of nuclear power stations in our country, both existing and those under construction.

* NPP SS - nuclear power plant sanitory system

NUCLEAR ENERGY DEVELOPMENT IN PAKISTAN – POLICY PROSPECTS AND PROBLEMS

By: Munir Ahmad Khan,
Chairman, Pakistan Atomic Energy Commission

Introduction:

Pakistan is a developing country with a population of over 100 million people (80% of that of Japan) but with a very low annual per capita income of $ 380 (vs $ 20,000 for Japan). It is basically an agricultural country with limited resources of conventional fuels and minerals. Its merchanadise exports comprise over 80% of primary commodities and agrobased products. A literacy rate of barely 26% severely limits the optimal utilization of its considerable human resources.

Pakistan's interest in nuclear energy is essentially for accelerating its overall economic development. Pakistan is anxious to utilize nuclear technology for:-

(a) Generation of nuclear power to overcome serious energy shortages.

(b) Application of nuclear techniques to enhance agricultural production.

(c) Use of isotopes and radiation for diagnosis and therapy.

(d) Utilization of nuclear techniques and standards for improving industrial output in quality and quantity.

(e) Use of nuclear sciences and technology for raising the general scientific and technical level in the country.

Need for Nuclear Power:

Pakistan is one of the poorest countries in the availability of indigenous energy resources. Its low consumption level of about 300 KWhs per capita is just one-seventh of the world average and has retarded the process of industrialisation(Figure 1). Due to shortage of electric power, many major industrial units remain under-utilized. Over the last 10 years, the economy has been growing at an average rate of about 7% per annum, and the Planning Commission envisages an annual growth of 6% for the next ten years. Based on this projected economic growth, which implies a 9% increase in electricity generation, it is estimated that the current installed capacity of 7000 MW would increase to about 22,000 MW by the year 2000 (Figure 2).

In order to meet the estimated demand maximum emphasis is being placed on the utilization of indigenous hydro and fossil fuel resources. The maximum contribution from hydro is, however, unlikely to exceed 9000 MW, leaving a gap of 13,000 MW to be met by conventional thermal or nuclear plants. The availability of fossil fuel is also severely limited; the proven reserves correspond to 4 TOE per capita compared to the world average of 130 TOE. Indeed Pakistan has to import about 75% of its total oil needs from abroad. This imposes a major drain on its limited foreign exchange earnings. The recent increase in oil prices by about 5 dollars per barrel would put an additional foreign exchange burden of 250 million dollars per year.

As for coal, the local deposits are mostly lignite with high sulphur content inhibiting the construction of coal-fired plants for reasons of pollution and high cost of desulphurization. Gas reserves amounting to a mere 350 million TOE are too meagre to be dedicated to power generation in preference to domestic and petrochemical uses. The power plants based upon gas and indigenous coal would not be able to contribute more than 5000 MW. This would leave a shortfall of 8000 MW to be bridged either by imported coal and oil or by uranium power. Cost comparison between conventional thermal and nuclear plants indicate that nuclear power is competitive (Figure 3). Taking all these factors into account, it is estimated that nuclear power plants should contribute at least 5000 MW to the country's electricity supply by the turn of the century. There are thus compelling technical, economic and environmental considerations for Pakistan to embark on a vigorous nuclear power programme during the 1990's.

Pakistan's Experience in Nuclear Power:

Among the developing countries, Pakistan took a relatively early start in the establishment of a nuclear power plant, and a 137 MW pressurized heavy water reactor called Karachi Nuclear Power Plant (KANUPP) was commissioned in 1972 with the help of Canada. This plant has been in operation for the last 17 years and has contributed significantly towards meeting the power needs of Karachi. In 1976, Canada unilaterally terminated all technical cooperation and thereby withdrew from the trilateral arrangement to which IAEA was also a party. Supply of materials and spare parts was stopped even though KANUPP was and still is under Agency safeguards which Pakistan has fully respected. The shipment of equipment for a fuel fabrication facility for which a contract has been signed was also stopped. This caused considerable difficulties for Pakistan which was compelled to fall back upon its own limited techical resources and develop necessary materials and technology for the continued operation of KANUPP. Pakistan, therefore, had no choice but to develop its own fuel, and materials, an un er ak manufacture of essential spare parts.

In the operation of KANUPP, it is essential to give highest priority to safety. Therefore, the Pakistan Atomic Energy Commission is doing everything possible to maintain and strengthen the safety of this reactor which is already 17 years old. In this connection it has sought the help of the IAEA and the international nuclear community. It was among the first countries to invite an OSART Mission which came in January 1985 and made valuable recommendations regarding its operation. We nevertheless continued to face great difficulty in obtaining safety-related technical data and information about power plants. Recently some positive trends have emerged. The Agency succeeded in bringing various countries together in September 1988 for an informal meeting focussing on basic safety and operational aspects of nuclear power plants. In January 1988, the second OSART Mission to Pakistan visited KANUPP. In February, safety of PHWR plants was discussed at a technical meeting sponsored by IAEA in Vienna.

Through the IAEA, it has thus become possible to enlist the support of many countries for seeking advice including that of Canadian experts. Pakistan has been invited to join Candu Operators Group (COG) which will help to exchange information and provide valuable inputs. In addition, Pakistan is a member of the Tokyo Chapter of WANO which will help interchange experience with other countries in Asia and elsewhere. PAEC is anxious to continue to operate this plant safely and upgrade its safety standards in the light of the post-Chernobyl guidelines. In this connection, it seeks the help of utilities and organizations of other countries. It is willing to share its operating experience with others and benefit from the large reservoir of knowledge and expertise available in the advanced countries.

Nuclear Fuel Cycle:

Pakistan has made some progress in the nuclear fuel cycle and has acquired a degree of self-reliance in the front end of the fuel cycle.

Pakistan has gained experience in the exploration, mining and refining of uranium. According to the surveys made by PAEC, Pakistan has a considerable potential for uranium in its sandstone rocks which cover 15% of its land area. Sufficient uranium has already been located to meet the near-term requirements. It plans to use latest exploration techniques including satellite imagery for locating more promising deposits for meeting its long-run needs. Uranium mining is currently being carried out at Baghalchur and a uranium mill is in operation to meet local needs. The yellow-cake produced in Pakistan is refined and converte into uranium oxide in a nearby plant. Over the last 15 years, Pakistan has acquired some experience in the production of nuclear grade uranium oxide.

A fuel fabrication plant is located at Kundian where fuel bundles for KANUPP have been manufactured since 1978. So far several thousand fuel bundles have been loaded into KANUPP and the overall performance of locally manufactured fuel has been satisfactory.

Pakistan has sizeable deposits of zirconium bearing sand along its Baluchistan coast, west of Karachi. A pilot plant for the production of zirconium from local ore has been in operation for the last 10 years. Pakistan has been able to produce zirconium sponge and ingots and it is expected that it will be able to make its own zircolay tubes in the foreseeable future. Pakistan has also started a modest research and development programme in uranium enrichment in order to meet its anticipated needs of fuel for light water reactors. For this purpose the necessary facilities for the production of uranium hexafloride including production of HF have been in operation for some time.

Coming to the back-end of the fuel cycle, Pakistan's programme is still in the early stages. In 1976, Pakistan signed an agreement with France for the construction of a small reprocessing plant under IAEA safeguards. However, this agreement has not been implemented by the contractor. Pakistan has established a small facility for the post-irradiation examination and processing so that it can evaluate the safety and behaviour of locally manufactured fuel. Similarly, some work has been initiated in waste management. At the present time Pakistan is storing all its irradiated fuel from KANUPP at the plant which is kept under IAEA safeguards.

Long-Term Plans for Nuclear Power:

As indicated earlier Pakistan desperately needs nuclear power to overcome its serious shortage of electricity. Based on purely economic reasons it can use at least 5000 MW of nuclear capacity by the year 2000 and there is need for several thousands megawatts more in the ensuing decade. There is no doubt that nuclear power will become the mainstay of Pakistan's electric power generation system in the years to come. In order to realize the anticipated share of nuclear power in the future energy supply mix of the country, Pakistan has evolved a policy based on international cooperation as well as an increasing commitment of indigenous effort. As far as the former is concerned, Pakistan is anxious to cooperate with any advanced country in building nuclear power plants in Pakistan using light water or heavy water reactors. It is willing to accept IAEA safeguards on the construction of such plants. In the long run Pakistan would like to develop indigenous capability in the design, engineering and construction of nuclear power plants so as to reduce the foreign exchange burden for the importation of these plants. In this connection, it has initiated a programme for developing local engineering and design facilities, collaboration with local industry for the manufacture of components and construction and installation of heavy components. This cooperation is aimed primarily at improving quality assurance procedures in manufacturing so that components meeting nuclear specifications can be made and the industrial potential of the country is also enhanced. Precision engineering concepts are being introduced for making higher value added products and facilitating the indigenisation of nuclear power.

Research and Development:

Among the major inputs necessary for a programme of nuclear science and technology, research and development occupies an important place. Even in transfer of well established technologies many problems arise which must be overcome by highly trained personnel. In order to keep up with the ever-expanding technological horizons and to attract talented scientists and engineers, a core of basic research must be supported which would also help to train high quality manpower. With this view, a large multidiscipline institute has been established near Islamabad, called the Pakistan Institute of Nuclear Science and Technology (PINSTECH). It houses a 5 MW research reactor using highly enriched uranium. This reactor is now being re-designed for 20% enrichment. A small training reactor is also under construction. Research activities being pursued at PINSTECH include Analytical Chemistry, Nuclear Materials, Metallurgy, Fuel Development, Digital Electronics and Control Instrumentation and Computational Physics.

For the development of technically trained manpower several facilities have been established. The Centre for Nuclear Studies (CNS) at PINSTECH offers a Master's Course in Nuclear Engineering and also caters to training requirements in health physics, nuclear medicince, instrumentation and basic nuclear orientation. For the training of nuclear ower operators and engineers, the Karachi Nuclear Power Training Centre runs regular courses. A Computer Training Centre has also been established in collaboration with a consortium of universities. In fact, all of our basic research facilities are open to scientists and engineers from universities as well as other research organisations in the country. The Commission also provides safety related services for its own installations as well as for other institutions where radiation and radio-isotopes are used.

Pakistan would like to cooperate in all research and development work with advanced nations like Japan as well as countries in the Third World. The PAEC is the largest R&D organization in the country and its interaction with universities and other research institutions has been very fruitful. The success achieved by PAEC has helped encourage R&D work in other research organization. Indeed the nuclear programme of Pakistan has served to stimulate interest in science and technology within the country and we would like to strengthen our scientific base with the help of international collaboration.

Agriculture:

The economy of Pakistan is agro-based and the agriculture sector directly or indirectly contributes as much as two-thirds of the GDP. The productivity of this sector is, however, very low both on the basis of per worker and per unit area. It is, therefore, essential to introduce improved management, new technology and better crop varieties. The Commission has played a pioneering role in promoting the application of nuclear and other advanced techniques in agriculture. It runs three nuclear agricultural research institutes in different ecological zones of the country. The emphasis of work is on practical objectives related to the soil conditions and climate of the different regions. The main areas of activity include evolution of improved varieties of crops through radiation-and ce. mutation, reduction of post-harvest losses through nuclear and chemical techniques, biological reclamation of saline soil, microbial degradation of biomass for energy production etc. The Commission has been entrusted with the responsibility of setting up the National Institute of Biotechnology and Genetic Engineering to help bring new technologies within the field of agriculture and medicine.

Recently a breakthrough has been achieved in evolving a high yielding mutant of cotton which has increased production dramatically over the last few years. In the latest season about 6.9 million bales out of the total cotton production of 8.5 million was attributable to this variety. Over the past five years its average yield as compared to other varieties has been about 25 to 30% more. This has resulted in an additional income of $ 200 to 300 million per year for the farmers. It has also put the textile industry on a sound footing and thus contributed to higher foreign exchange earnings.

<u>Medicine:</u>

Nine medical centres are being run in different parts of the country; these specialize in the use of radioisotopes and radiation sources for diagnosis and therapy of such diseases as cancer, glandular disorder and organ malfunction. Besides providing services to about 150,000 patients each year, these clinics undertake research on selected topics and train post-graduate students.

The major impact of these centres has been in providing social benefits to the poor people. This service has enhanced the acceptance of atomic energy within the country. This positive use of nuclear radiation to improve public health and ameliorate the suffering of the sick needs to be brought out more effectively in the advanced and developing countries. Pakistan's programme in this regard offers a good illustration of what can be done even by a developing nation. We are ready to cooperate in this field with other countries in Asia.

Nuclear Policy:

The Prime Minister of Pakistan, after assumption of office in December 1988, has stated categorically that Pakistan's nuclear programme is solely for peaceful purposes to meet our energy needs. This has been and will remain Pakistan's nuclear policy. Pakistan wants to use nuclear energy for socio-economic progress and for accelerating its industrial, scientific and technological development. As a country, we have neither the capacity nor indeed any desire or intention to enter into a nuclear arms race. We want to use our limited resources for economic development. We are ready to place any nuclear power plant supplied to us under IAEA safeguards. Pakistan is also a firm supporter of global nuclear disarmament and complete test ban. We are ready to join hands with other countries, both internationally and regionally, to promote nuclear non-proliferation on a non discriminatory basis. In particular, Pakistan is prepared to make agreements at a regional level on the model of the Treaty of Tlatelolco for Latin America.

The non-proliferation regime in South Asia was severely strained by the fact that India exploded a nuclear device in 1974. We would like to eliminate the possibility of any further nuclear tests in our region. We sincerely believe that the peoples of South Asia are too poor to afford the wasteful and self-defeating pursuit of nuclear arms. As far back as 1972, Pakistan proposed the establishment of a nuclear weapon free zone in South Asia. This proposal has been overwhelmingly endorsed by the United Nations General Assembly in every session since 1974. Pakistan has also made definitive proposals to promote nuclear non-proliferation in South Asia both bilaterally and internationally. These include:-

i) simultaneous accession by India and Pakistan to the Nuclear Non-proliferation Treaty;

ii) simultaneous acceptance by both countries of full-scope International Atomic Energy safeguards;

iii) mutual insepction of each other's nuclear facilities;

iv) joint declaration, renouncing the acquisition or development of nuclear weapons;

v) establishment of a nuclear weapon free zone in South Asia.

vi) ban on nuclear testing in the region.

In addition, Pakistan is willing to consider any other proposals which would contribute to nuclear non-proliferation in the region. We are prepared to enter into comprehensive dialogue to discuss the above proposals or any other measures in order to ensure that South Asia remains free of nuclear weapons. Recently, a small but significant step has been taken in this regard by Pakistan and India signing a pact not to attack each other's nuclear facilities. This represents a confidence building measure and could pave the way for other steps in the future. Pakistan would like the support of international nuclearcommunity in the strengthening of non-proliferation regime in South Asia which is strategically one of the most important areas of the World, comprising one-fifth of the global population.

Concluding Remarks:

Pakistan is committed to non-proliferation of nuclear weapons. Its nuclear programme is geared towards production of electricity and enhancing productivity in all sectors of our economy. It is willing to do every thing possible on its part to ensure nuclear non-proliferation in the region. Pakistan is severely limited by the shortage of conventional energy resources and is in urgent need of nuclear power to bridge the gap. It is willing to accept IAEA safeguards on its nuclear power plants. It would welcome help and cooperation in the implementation of its peaceful nuclear programme. We are willing to share our limited experience with other developing countries in Asia and outside. We believe that the cause of world peace will be served better through cooperation than non-cooperation and this applies particularly to the nuclear field.

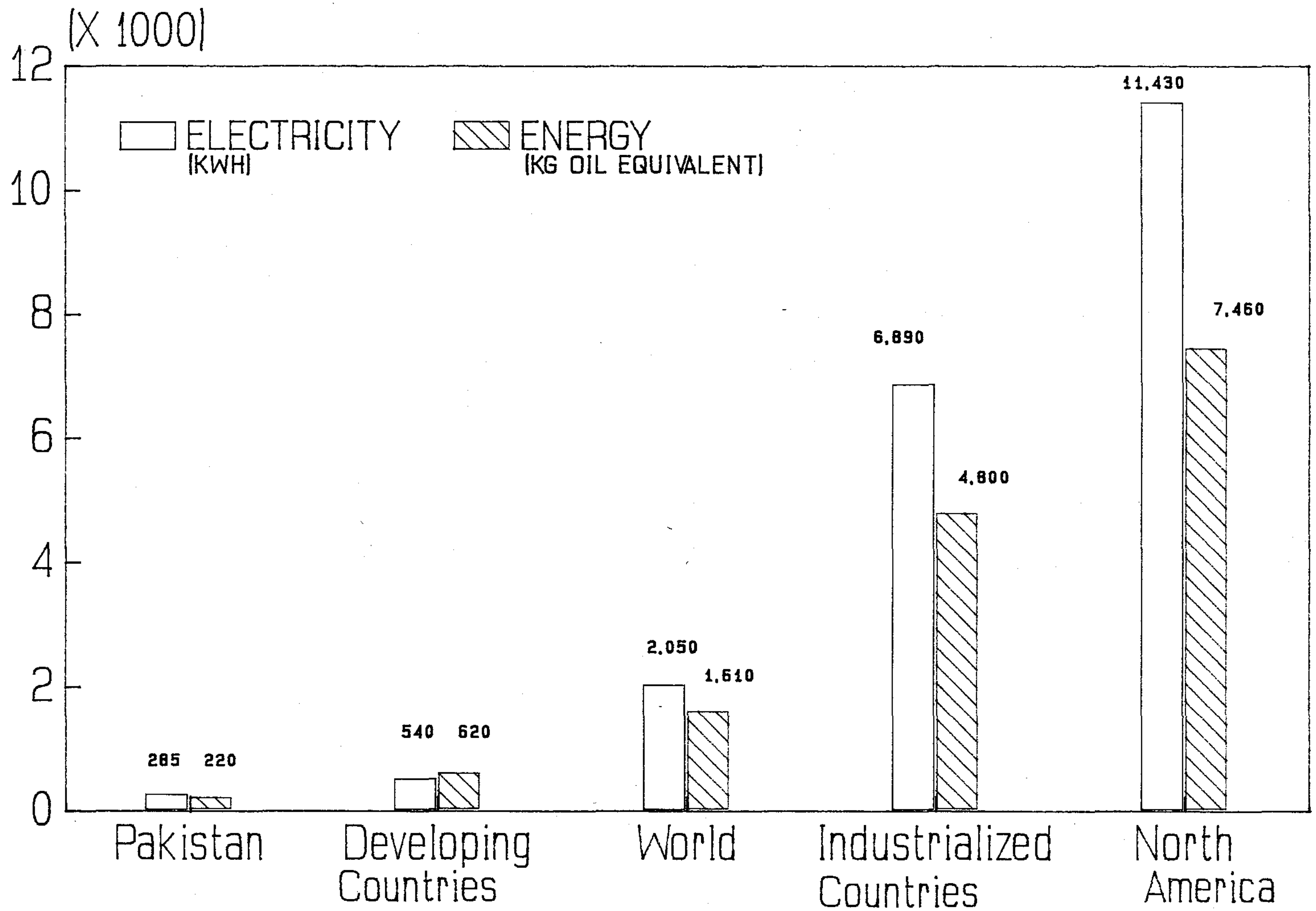


Fig. 1 : Per Capita Consumption of Primary Energy and Electricity (1987)

Status in June 1988

Installed Capacity	:	6,720 MW
Capacity Shortfall	:	1,000 MW
Needed Capacity	:	7,720 MW

Relative Growth Rate Electricity Vs GDP	:	1.5*

	Capacity (MW) Needed In 2000		
	Low	Medium	High
Required**	18,500	22,000	25,500
Expected			
Hydro	______	9,000	______
Coal-Fired	______	800	______
Gas-Fired	______	4,000	______
Shortfall	4,700	8,200	11,700

* Same as experienced during the last 10 years

** Average annual GDP growth rate:

Low	:	5% (as projected by World Bank for developing countries).
Medium	:	6% (as envisaged by Planning Commission).
High	:	7% (assumed for optimistic growth).

Figure 2. Requirements of Electricity generation capacity in Pakistan for the year 2000.

	Nuclear 937 MW	Oil-Fired 882 MW	Coal-Fired 900 MW
Specific Capital Cost $/KW	1,823	848	1,220
Generation Cost (Mills/KWh)			
Fixed Charges			
Interest	30.4	14.1	20.3
Depreciation	1.9	0.9	1.3
O&M Cost	2.5	1.2	2.9
Fuel Cost	6.2	34.2	22.0
Total	41.0	50.4	46.5

Assumptions

		Fuel Oil	Coal
I.	FOB Price	$ 110/Ton ($ 15/BBL)	$ 40/Ton
	Sea Transportation:	$ 5/Ton	$ 17/Ton
	Port Handling/In-Land Transportation:	$ 25/Ton	$ 3/Ton
	Delivered Price:	$ 140/Ton	$ 60/Ton
II.	Nuclear Fuel Costs in 1993:	$ 31/lb U_3O_8 (Same as in 1987).	
III.	Escalation Rate:	6.5% P.A. For Capital And O&M Costs.	
IV.	Interest Rates:	9% For Foreign Component And 12% For Local Component.	
V.	Plant Factor:	68.5%	

Figure 3. Economic comparison of nuclear, oil-fired and coal-fired power stations (all costs in U.S. dollars of 1993).

STARTING THE DEVELOPMENT OF CHINA'S NUCLEAR POWER

Huang Qitao
Vice President
China National Nuclear Corporation

Mr. Chairman, Ladies and Gentlemen:

I am very glad to head the delegation of China National Nuclear Corporation to attend the 22nd Session of Japan Atomic Industrial Forum, Inc. Annual Meeting on Invitation, and avail myself of this opportunity to introduce why China needs to develop nuclear power, the current status, the principle and the envisaged program of the development of nuclear power to our counterparts from each country who attend this annual meeting.

1. CHINA URGENTLY NEEDS TO DEVELOP NUCLEAR POWER

Chinese government has determined the goal of economic development by the end of this century. That means the gross national industrial and agricultural output value has been targeted for a fourfold increase by 2000 as compared with 1980. According to the experts' prediction, for achieving this ambitious goal of the nation, the energy production should achieve the following index by 2000:

Gross output value of energy (0.1 billion tons of standard coal)	14.3
Electricity generation (o.1 billion KWh)	12000

For achieving this goal, the burden is heavy, so we must pay much attention to the development of energy industry and a series of significant measures should be taken, otherwise the said goal will be failed. Even if this goal is achieved, the energy supply is still very tense as viewed from the satisfaction of the requirement of the national economical development. Therefore, we should simultaneously adopt the significant measures to economize the energy, the balance between supply and demand can be achieved under this tense conditions.

Although the installed capacity of generating equipments in our country has exceeded hundred million KW by the end of 1987, the gross output value of energy has reached 0.951 billion tons of standard coal, the output of raw coal and crude oil has separately reached 0.97 billion tons and 0.137 billion tons, the total electricity generation has reached 543 billion KWh, yet the supply and demand of energy is still not commensurate with the economic development. In present years, the situation of demand exceeds supply is prominent ever since. In 1988, this tense situation has somewhat developed again. In many areas and factories the normal production cannot be maintained due to undersupply of electricity.

Why the relation between supply and demand is so tense? There are two following reasons:

Firstly though the absolute value of energy deposits in China ranked the forefront in the world, yet due to a large population, the average reserve per capita is very low. According to the proven deposits, the gross deposit of coal ranked third in the world, but ranked tenth per capita; the gross deposit of petroleum ranked tenth in the world , but ranked twenty nineth per capita in the world; the reserve of hydraulic resources of our country ranked first in the world, but the developable quantity per capita is lower than the avarage level of the world. As viewed from the total quantity of energy resources per capita, China is only about half of the average level of the world.

At present, the average energy consumption per capita of our country is far lower than the average level of the world. The energy production achieves the target by 2000, the annual consumption of electricity is nearly 1000 KWh per capita, this consumption of electricity is still on the low level.

Secondly, the pattern of energy resources in the West and the economic development in the East increases the contradiction of energy needs. 80 per cent of coal deposits is located in the northern part of China. Of the hydroelectric resources, over 90 per cent is concentrated in Sou th-west China. The 3 major regions of East, North-east and South Central China are relatively well-developed. The industrial output value of these 3 regions accounted for about 70 per cent of the whole country, while accounting for 60 per cent of the population, but the coal deposits only accounted for 12.3 per cent of the whole country.

For meeting the requirements of economic development in the East, the paradox was solved for a long period by transporting coal to the South from the North, and transmission of electricity to the East from the West. This is to say that the coal in the North is transported to the South by railway, and the electricity of the West is transmitted to the East by high-tension line. Such measures met some difficulties. About 40 per cent of freight volume of our country is for the transportation of coal that of course caused overloading of China's transportation system and it almost comes to the extent of unable load-bearing capcaity. The construction of long distance high-tension line and the development of hydroelectric resources in the West are greatly limited, due to the need of tremendous investment and very difficult construction conditions.

Therefore, the severe short of energy resources has became an important factor to restrict the economic development of our country. Simply depending on conventional energy cannot cope the difficulty of China's energy sources. We must develop a new energy to meet the supply demand. In the world of to-day, it was universally accepted that only nuclear energy is a realistic alternative energy source. On the basis of this reality, China adopted the policy decision for the development of nuclear power.

In the middle of 1960s, China has already prepared the development of nuclear power. Through a period of zigzag course, till 1981, the first nuclear power plant, i.e. the construction of the first stage engineering of Qinshan Nuclear Power Plant was executed. Afterwards, the Daya Bay Nuclear Power Plant to be jointly invested and constructed with Hongkong was also included in the plan. In 1986, the accident of Chernobyl Nuclear Power Station in Soviet Union has shocked the whole world. After overall and scientific analyzing that accident, Chinese government stated that the determined policy for the development of nuclear power will be unchanged, so the construction of nuclear power plant in China that has already been started will be continuously going on.

2. THE PROGRESS FOR THE CONSTRUCTION OF CHINA'S NUCLEAR POWER

The first stage engineering of Qinshan Nuclear Power Plant (300MWe) is a prototype nuclear power plant. The design, construction and operation of that nuclear power plant were completely relying on our own technical efforts. Besides a part of components was purchased from foreign countries, most of the components are domestically made. Till now, the pouring of concrete for the containment has been completed, the pressure vessel of reactor was hoisted and placed in the position, the welding of main pipeline is being under-taken, two third of auxiliary system and equipments have been placed in the position. Half of the process tubes is erected. The components of conventional island, such as low pressure cylinder of turbine, low pressure heater, deaerator and de-aerating tank etc are all placed in the position. The condenser has prepared the conditions for penetrating tubes. All implemented works should strict inspection and the quality is in compliance with the requirements. At present, the Pre-Operational Safety Assessment Review Team (PRE-OSART) organized by the experts of IAEA is undertaking the scheduled inspection in Qinshan. We shall conscientiously improve our works accroding to the comments and suggestions of OSART.

The first stage of Qinshan Nuclear Power Plant is expected to generate electricity and will be connected to electric network by the end of 1990. In this connection, the washing of system will be implemented and it is provided with the condition of overall commissioning. The commissioning will be implemented next year. It will generate electricity and be connected to the electric network by the end of next year. We have recognized that we shall still meet many difficulties during the implementation of this plan, but we are confident that we shall exert our utmost to implement this task.

Since the first pouring of concrete of Daya Bay Nuclear Power Plant (2 X 900MWe) on August 7, 1987, the pouring concrete for the containments, the welding of the steel liners and the construction of internals in the reactor buildings of unit 1 and unit 2 are being carried out on schedule. About 50 per cent of the working quantity has been completed for the design of nuclear island to be undertaken by the Framatome of France and of conventional island to be undertaken by the General Electric Company of England. The following main components of unit 1 reactor are assembling: such as pressure vessel, reactor internals, pressurizer, steam generator, main pump, high and low pressure cylinders, rotor of turbine, generator and condenser etc.

It is expected that the unit 1 of Daya Bay Nuclear

Power Plant will be put into operation in October 1992, and the unit 2 will be put into operation in July 1993. Under the plan, the building of unit 1 will be completed all its pouring tasks in 1989. The following equipments will be successively erected in that year: such as deaerator, condenser, main steam pipeline, feed water pump and main transformer etc.

The second stage engineering of Qinshan Nuclear Power Plant (2 X 600MWe) was approved and included in the national plan by the end of 1987. The preparation work is undertaking smoothly, the corresponding organizations were already established. At present, it is in the selection of foreign partners for cooperation.

Due to the tension of energy sources and the advantage of nuclear power is increasingly understood by the people, therefore many provinces and cities which are undersupply of electricity are successively requesting for the construction of new nuclear power plant. For the suitability of this condition, we selected some spots in some areas to develop the work of site feasibility study for the preparation of other new projects.

3. THE PRINCIPLE AND PROGRAM FOR THE DEVELOPMENT OF NUCLEAR POWER

The following principles shall be observed for the development of China's nuclear power:

1. "Chinese-foreign cooperation, and taking ourselves as the dominant factor"

Although China's nuclear undertaking is beginning to start, yet China possesses over 30 years experience in the whole nuclear industry. After 30 years of making unremitting efforts , we have established a fairly complete nuclear fuel cycle system, ranging from uranium ore mining, hydrometallurgy, the production of enriched uranium, the manufacture of fuel elements, the reactor operation, reprocessing of spent fuel and wastes treatment; we have also established a complete set of nuclear industry scientific research system, ranging from uranium ore geology, the production of nuclear fuel and radioisotopes, the manufacture of nuclear equipment, the nuclear research and design , the construction of nuclear engineering and safety protection. In the course of the formation of these systems, a nuclear technical team was brought up and a considerable practical experience was accumulated. On this basis, in recent years, after overall practice and examination through the construction of Qinshan and Daya Bay Nuclear Power Plants, we can develop the nuclear power undertaking mainly relying on our own efforts. The supply of nuclear fuel elements is based on self-reliance. But, after all we are still a new hand. In order that China's nuclear power undertaking can develop smoothly and more effectively, we wish to have wide cooperation with our counterparts of all over the world in the field of nuclear power. The method of cooperation can include the purchasing of hardware and software, join design and construction, engaging experts for consultation and the development of activities of technical exchange etc. Through these cooperations, we modestly learn good qualities from all countries; digest and absorb their experiences for our own use. Therefore, we determined that "Chinese-foreign cooperation and taking ourselves as the dominant factor" is one of principles for the development of nuclear power.

2. "Safety first, quality first"

From the beginning date for the establishment of nuclear industry, Chinese government has determined that "Safety first, quality first" is the principle that should be obeyed. Nuclear power accident is a big problem to be greatly concerned by the public in the world, because its effect has already broken through the restriction of country's border. China has fully recognized this fact. Therefore, when the development of nuclear power was starting, we particularly emphasized the principle of "Safety first, quality first". The National Nuclear Safety Administration was established in 1984. The National Nuclear Safety Administration is the highest organ of state power that exercises its independent supervising authority over the safety of civilian nuclear installations throughout the country. The National Nuclear Safety Administration has prepared and issued nuclear safety codes of our country referring to the NUSS safety series of IAEA. The National Nuclear Safety Administration strictly reviewed and assessed the safety of Qinshan Nuclear Power Plant and Daya Bay Nuclear Power Plant based on these codes, has established the corresponding safety supervision regional offices in regions where these two nuclear power plants were located, and sent regional resident supervisors to the sites to exercise safety supervision for the construction of these two nuclear power plants in time. Till now, there isn't any major defects related to the quality and safety during the period of construction of these two nuclear power plants, no subversive hidden danger was discovered after safety review and assessment.

Taking into consideration the economic strength of our country, the development of nuclear power cannot have great progress. At present, during the construction of nuclear power plants, the purpose for mastering the technology is greater than the purpose of generate electricity. China will appropriately develop the nuclear power, this is because we shall follow the advanced technology of the world, in order that we shall make the technical preparation for further development in the next century.

At present, we hold identical views for developing nuclear power with suitable scale in China in this century, its plan is to construct approximately 6000MWe and annual generating electricity of 30 billion KWh. Among the 6000MWe, besides two nuclear power plants of Qinshan (300MWe) and Daya Bay (1800MWe), it is mainly to develop 600MWe class PWR nuclear power units. This is because this grade of capacity can be well matched with the scale of China's electric network, can be suited to the status of all departments of design, equipment manufacture and construction, and easy to implement the principle of "Chines-foreign cooperation and taking ourselves as the dominent factor". But that doesn't mean we exclude other grade of capacity, other reactor types of nuclear power plant. It is only to state that in this century we have selected 600MWe class PWR nuclear power unit as the main force. Through the way for implementing standardization, batch process and domestic manufacture, we can attain the goal of wholly mastering the nuclear technology, reducing the construction cost and shortening the construction period. All these formed a sound foundation for the great development of nuclear power in the next century. If the condition is suitable for all respects, for the purpose of increasing the capacity of electric generation, China also doesn't exclude to construct 1000MWe class or other types of nuclear power plant.

At present, shortage of funds is the great difficulty for the construction of nuclear power of our country. The method for coping with this difficulty is mainly relying on our own efforts to collect funds from various ways. At the same time, we wish to absorb foreign investment for the construction of nuclear power plant under the principle of equality and mutual benefit. It can be China-foreign joint venture for construction and operation of nuclear power plant, or sole foreign-invested enterprise for the construction and operation of nuclear power plant in China, after recouping capital outlay the ownership of the plant will belong to China or it can be considered that foreign enterprises sell idle equipment of nuclear power plant to China with preferential price.

4. FURTHER RESEARCH AND DEVELOPMENT OF NUCLEAR POWER

The proven uranium resources can support China's mid-term and short-term development program of nuclear power, and a certain quantity can be exported. It is estimated that by the middle of next century, the nuclear power generation will account for 20 per cent of total electricity generation. In order to meet the needs of energy sources for economic development, when we grasp the construction of 6000MW nuclear power in this century, at the same time we must positively arrange the further exploration of uranium resources and the work for the research and development of nuclear power.

In the technical line for the development of nuclear power, the relevant experts have proposed the assumption of two-stage development. This assumption is in compliance with the way of rational and plentiful use of uranium resources, and scientifically develop nuclear energy.

The goal of the first stage is to solve the issues of short-term energy sources. Firstly, we construct the light water PWR nuclear power plant that has held sway on all fronts in the international, and that makes the preliminary development of nuclear power in China. On this basis, we develop the advanced light water PWR nuclear power plant. As compared with the existing plant, it has simple system, less investment and high level of safety. It is expected that the demonstration reactor will be constructed in 1990s and afterwards it will be vigorously popularized. Both types of reactor will be coexisted, and then proceed to construct the advanced type for new built PWR nuclear power plant.

The goal of the second stage is to solve the long-term energy sources, due to the limited use of uranium resources for the thermal reactor. In order to meet the need of long-term energy sources, we should devote to develop the fast reactor nuclear power plant. At present, the technology of fast reactor nuclear power plant becomes maturity in international, and our country also has a considerable basis in the research of fast reactor. We are vigorously follow the advanced level of the world, positively develop its work, and strive for the construction of a 50-100MW_{th} experimental fast breeder reactor before or after the year 2000, then we further construct the commercial fast reactor nuclear power plant. Furthermore, we also develop the fusion reactor or hybrid fusion-fission reactor that will be the hopeful measures for ultimately solving the energy problem.

Besides the development of nuclear power, we also pay attention to the nuclear heating problem. In the consumption of primary source of our country, the proportion of energy sources, used as heat source is very large, accounted for about 65 per cent, that is equivalent to the threefold of the energy consumption to be used for the production of electricity. It is very pity that large quantity of valuable chemical material is burn out as fuel, and also causes the serious consequence of environmental pollution. In order to improve this condition, we also reseach and develop nuclear heating and strive for the selection of a suitable city in the northern area of China to build a low temperature demonstration reactor and then we construct it according to the needs and possibility.

My introduction is stopped here.

Thank you.

Владимир ГУБАРЕВ

ГЛАСНОСТЬ И РАЗВИТИЕ АТОМНОЙ ЭНЕРГЕТИКИ В СССР

Сегодня - I2 апреля - знаменательный день в истории нашей цивилизации. Ровно 28 лет назад стартовал в космос Юрий Гагарин, открыв человечеству путь в космос. Казалось бы, это событие весьма далеко от тех проблем, которые мы сегодня обсуждаем, но это не так. Полет Гагарина стал символом нашего века, он оказал огромное влияние на развитие тех процессов, которые мы именуем "научно-технической революцией" и которые в корне изменили характер жизни на планете Земля. Атомная энергетика - часть этого процесса.

Так уж случилось, что мне посчастливилось быть свидетелем главных событий как в истории космонавтики, так и в становлении и развитии ядерной энергетики. Я провожал космонавтов в их полеты, присутствовал на многих запусках, осуществленных в СССР, а также на некоторых - в других странах, в том числе и в США. В то же время на моих глазах зарождалась и развивалась атомная энергетика и использование ядерной мощи не только в военных, но и в сугубо мирных целях. Я был единственным журналистом, который был при гашении газовых и нефтяных фонтанов в Средней Азии с помощью ядерных взрывов, присутствовал при создании подземных хранилищ и искусственных озер, которые опять-таки создавались с помощью той гигантской энергии, которая в 45-ом уничтожила Хиросиму и Нагасаки.

В силу своей профессии, а также работы в "Правде", мне пришлось быть участником создания Энергетической программы в СССР.

Как известно, по древней мифологии "мир держится на трех китах". Современная энергетика тоже. Это гидравлические, тепловые и атомные станции. Другие источники энергии играют свою роль, но не столь значительную пока.

Итак, именно на этих "трех китах" и базировалась Энергетическая программа, которая была создана в начале 80-х годов. Оговорюсь сразу: она принималась келейно, сравнительно узким кругом специалистов, без обсуждения широкой общественности. Правительство приняло эту программу, и для всех советских людей она "была спущена сверху" - лишь для исполнения, а не для обслуживания.

В Сибири и на Дальнем Востоке предполагалось строительство мощных ГЭС. Плюс к этому - две-три АЭС.

На основе Ачинского месторождения - крупные ТЭС, общей мощностью около 40 миллионов киловатт.

В Европейской части страны предусматривалось резкое, "скачкообразное" возведение атомных станций. В плане было заложено возведение 100 крупных реакторов, в основном - типа РБМК-1000, и несколько реакторов на "быстрых нейтронах" по типу тех, что действуют в Шевченко и под Свердловском. Эти станции предполагалось разместить вдоль Волги, Днепра, на Кавказе, в Крыму, в Прибалтике. Причем это должны были быть "АЭС-гиганты", каждая мощностью от 8 до 12 миллионов киловатт.

Чернобыль в корне изменил всю ситуацию.

Я был первым журналистом, который приехал в зону аварии. Первые две недели, проведенные там, заставили меня пережить гораздо больше, чем за всю предыдущую жизнь. Работа в зоне аварии, анализ происшедшего, в корне изменил и мои взгляды. Что скрывать, до Чернобыля я иначе смотрел на судьбу атомной энергетики, более того - я принадлежал к тем людям, которые пропагандировали АЭС, поддерживали строительство каждой станции, убеждали, что без широкого использования атомной энергии у нас нет будущего.

Чернобыль заставил иначе взглянуть на эту проблему.

Сначала несколько личных впечатлений.

Облет на вертолете станции и города Припять.

Реактор еще "дымит". В воздухе чувствуется "металлический привкус", значит, уровень радиации очень высок. Видны страшные разрушения 4-го блока - обрушившиеся перекрытия, отброшенные в сторону бетонные глыбы. Взрыв, бесспорно, был очень мощным.

Странно, непривычно выглядит город. Белоснежные многоэтажные здания, широкие проспекты, парки и стадионы, игровые площадки рядом с детскими садами и магазины... Но город пуст. Ни одного человека на улицах, а по вечерам ни в одном из окон не загорается свет. И лишь изредка показывается на улице специальная машина - это служба дозиметрического контроля...

Город без людей... Это страшно...

Мертвый город, оставленный своими жителями. Взрослыми и детьми, пенсионерами и домохозяйками, физиками и дворниками, - всеми...

И еще одно впечатление. От этого же города, но события происходят два года спустя. В очередной раз я приехал в зону аварии...

Город без жителей умирает быстро. Теперь он встречает глазницами пустых окон, закрытыми фанерными щитами витринами магазинов, сеткой от кровати, упавшей с грузовика, и тишиной, столь глубокой и неожиданной, что ты постоянно оглядываешься - чудится будто кто-то идет за тобой, а это эхо разносит стук каблуков по кварталам... В скверах уже царствует бурьян, кое-где он пробивается сквозь асфальт. Как же все-таки быстро растут сорняки?! Когда ехали на станцию, видели поля. Их не убирали после аварии, а потому зерно осыпалось, и теперь уже дает новые всходы, но все шире и шире по этим угодьям растекаются бурые пятна - то сорняки побеждают пшеницу. И наверное, уже этой осенью они восторжествуют окончательно...

В город бурьян прорвался с полей,и не остановила его ни колючая проволока, которая опоясывает нынче Припять, ни "санитарный пояс", созданный вокруг города. Впрочем, вероятнее всего, нечисть таилась в самом городе, теперь пришло ее время, и она вылезла из-под земли... Горькая полынь рождает боль на душе, она захватывает тебя, и теперь уже не отпустить никогда, потому что невыносимо тяжело видеть, как умирают города.

Но так надо. Во имя жизни. И потому машина за машиной выводятся кровати и ковры, телевизоры и диваны, - все, что еще осталось в квартирах припятчан. Дезактивация! Слов-то за минувшие годы стало привычным, а сегодня в Припяти оно означает, что надо полностью освободить квартиры от мебели и рухляди, потому что в них накопилась радиактивная пыль. Все подлежит уничтожению...

Теперь из города станция видна как на ладони. И ее белые корпуса, и темная пирамида 4-го блока. Дезактивация дезактивацией, но что там, в сердце зоны?

Вокруг АЭС ни травинки, нет привычных цветных клумб, газонов. Серое поле бетона. Чуть позже, из галереи, соединяющей блоки станции, толщину этого бетона довелось увидеть воочию: рельсы узкоколейки шли будто в тоннеле, а раньше, до аварии, они были на поверхности. Со всей площадки убран грунт, потом положен бетон и асфальт. В этом году еще предстоит "поковыряться" в земле - там проходят коммуникации, их нужно вскрыть, дезактивировать, отремонтировать. А уже в будущем сюда, на площадку АЭС, будет завезен грунт, почва и вновь разбиты клумбы и газоны - станция и зона вокруг нее должны приобрести тот же вид, что и до аварии...

К сожалению, на это потребуется много десятилетий...

Уроки Чернобыля. В чем они?

Прежде всего, это было испытание "гласности в СССР". Первые дни молчания- почему? Почему только короткие сообщения из зоны катастрофы, хотя все газеты мира пишут о трагедии, подчас не подозревая, а потому и преувеличивая, ее размеры?

Простить "зону молчания" нельзя. Это безусловно, один из рецидивов прошлого, когда ведомства старались замолчать, это в лучшем случае - исказить информацию. Но, повторяю, это лишь одна из причин. Главная - лежит гораздо глубже. Она в той "психологической атмосфере", которая на протяжении десятилетий создавалась вокруг атомной энергетики.

На всем, что связано с созданием ядерного оружия, всегда лежало "табу". Атомная энергетика рождалась в тех же самых институтах, теми же учеными и специалистами, которые делали оружие, а потому их работала по-прежнему была "секретной". Закрывалось прежде всего то, что могло бы послужить критикой со стороны общественности. Недостатки, аварийность, наконец, принципы размещения и развития АЭС - все это оставалось в кабинетах, обсуждалось за закрытыми дверями и только узким кругом специалистов, которые присвоили себе право решать "от имени народа".

"Специалист подобен флюсу" - гласит народная поговорка. Непогрешимость технических решений, амбициозность, наконец, узковедомственные интересы, которые обслуживались прессой и телевидением, создали атмосферу вседозволенности. Причем специалисты и ученые столь много говорили о безопасности АЭС, что прежде всего убедили себя в этом. Во главу угла они поставили иной принцип - дешевизма. А там, где главное - экономичность, приходится поступаться безопасностью в первую очередь, т.к. именно она требует больших затрат.

Крупнейшие ученые страны во главе с президентом

АН СССР А.П.Александровым утверждали, что АЭС абсолютно безопасны, более того – известные атомщик договорился до того, что он готов поставить свой дом на территории станции!

Трагедия в Чернобыле показала, что в этой системе доказательств существуют очень опасные заблуждения и прорехи.

Что характерно: сразу после аварии именно ученые... не поверили в нее! Их утверждение: "Этого не может быть!" – дезинформировало правительство. Только приезд академика В.Легастова в Чернобыль прояснил ситуацию...

Благодаря прессе, журналистам, которые работали в Чернобыле и писали о том, что видели сами, советские люди узнали реальное положение дел. Они поняли, насколько сложное положение в атомной энергетике. Как и во всем народном хозяйстве страны.

Более 60 тысяч писем легло на мой стол в "Правде". Около миллиона писем пришло в ЦК КПСС и Совет Министров. Общественность активно включилась в обсуждение проблем, связанных со строительством АЭС.

На Чернобыльской АЭС вокруг 4-го энергоблока выросли стены саркофага. Проще говоря, могильника, в недрах которого похоронен аварийный реактор. Непривычное и необычное это сооружение. Первое в истории цивилизации. Хотим мы этого или не хотим, но саркофаг и нашим потомкам будет рассказывать о нынешних событиях. Символом чего станет эта громада из бетона и стали?

Память бережно хранит впечатления первых дней после аварии. Потом пришло время анализа и размышлений, и тысячи писем читателей "Правды" заставляли по-иному видеть происходящее: вместе с эвакуированными переживать горечь потери тепла домашнего очага, рядом с солдатами вести ту не понятую до конца работу, именуемую чуждым словом "дезактивация", наблюдать, как идут к энергоблоку раненой станции дежурные смены, радоваться каждому новому дому, построенному для лишившихся родного крова семей... И нелегко ответить на вопрос, который обязательно задают на встречах разные люди: "Что после Чернобыля?"

Теперь, спустя время, ответ однозначен: при аварии на Чернобыльской АЭС ярко и всесторонне проявились величие души народа, его героизм и мужество, сострадание и ощущение общей беды.

Чернобыль - это открытая рана не только на берегу Припяти, но в душе каждого человека. Где бы он ни жил, где бы ни работал - на Крайнем Севере или жарком юге, в Бресте или во Владивостоке.

Один из главных уроков случившегося в том, что мы убедились - существует лишь ничтожная прослойка людей в нашем обществе, которые паниковали, растерялись, струсили. Чернобыль будто рентгенов высветил их, и общественное порицание не заставило себя ждать. Трудное испытание выпало на долю народа - он с честью выдержал его.

"Мы с вами, чернобыльцы!" - эти слова стали для большинства советских людей не только лозунгом, но и делом. А проявляется это по-разному: в тысячах заявлений с просьбой направить на работу в опасную зону, в денежных переводах на счет № 904, в студенческих строительных отрядах, трудившихся в Киевской и Гомельской областях, в рабочих сменах, отработанных в фонд Чернобыля, наконец, в заботе о детях из пострадавших районов и в словах сочувствия.

Но есть и иное отношение к случившемуся. Авария вызвала негативное отношение вообще к атомным станциям. Сейчас не считаться с таким настроением нельзя.

"Некоторые производства у нас работают не годами, а веками, – пишет из Ворошиловграда Н.Синельникова. – Но и на них случаются аварии. Наверное, они будут повторяться и на атомных станциях. Если не у нас, то в других странах. На улицах от автомашин дышать нечем, а тут еще и атом... Так некоторые из нас думают, и так мы относимся к атомной ~~станции~~ энергетике".

Легче всего пренебрегать этим мнением, но уроки аварии в Чернобыле требуют иного: кропотливой и вдумчивой разъяснительной работы, обязательного анализа доводов таких людей. Особенно, если речь идет о расположении новых АЭС. К примеру, трудно оправдать и объяснить появление таких станций в курортных зонах или по соседству с действующими ТЭЦ и ГЭС, или в сельскохозяйственных районах, славящихся своими почвами, – отчуждение их под строительство любых промышленных объектов, в том числе и атомных станций, чаще всего экономически неоправданно. Возможно, на нынешнем этапе развития науки и техники имеет смысл вернуться к идее академика Н.Доллежаля, который в конце 60-х годов предложил создавать на "бросовых землях" – в пустынях, малозаселенных районах – мощные энергопромышленные комплексы, которые включают в себя атомные станции и энергоемкие производства... В общем, специалистам и экономистам есть смысл еще раз проанализировать схему размещения АЭС.

На многое в атомной энергетике мы обязаны сегодня смотреть сквозь призму Чернобыля. И не только в ней...

Об уроках аварии говорили в парткоме АЭС, о них размышляли рабочие станции, конструкторы, академики Е.Велихов, и В.Легасов, врачи и специалисты, с которыми довелось беседовать и на станции, и в штабе, и на контрольно-пропускных пунктах зоны, в партийных и государственных учреждениях. Еще кружили над поврежденным реактором вертолеты, сбрасывая на него свинец и песок, еще продолжалась эвакуация населения, еще не были до конца известны размеры бедствия, а все, с кем встречался, обязательно говорили об уроках Чернобыля. Слишком многое обнажилось в первые дни аварии. Многое из того, о чем не принято было размышлять, что казалось очевидным, но при серьезном испытании рассыпалось в прах, и выяснилось, что существует лишь на бумаге да в победных рапортах...

Помню, как председатель колхоза выбил стекла в доме и распорядился нарезать стеклянные пластинки для анализа крови, потому что их не оказалось у медиков..

Помню, как распределяли дозиметры, но батареек к ним на складе не было...

Помню, как генерал въезжает на площадку четвертого энергоблока на черной "Волге", бравируя своей смелостью.

Помню сидевшего с удочкой на Берегу Припяти солдата, которому никто до нас не объяснил, насколько это опасно...

Помню растерянность и беспомощность некоторых руководителей, которые обязаны были не только знать все о случившемся, но и моментально принимать необходимые меры, а не ждать указаний из Москвы...

Многое хранит память.

И распахнутые ворота крестьянских дворов, готовые принять пострадавших... И бьющуюся от радиации стрелку прибора... И срезанный пласт земли, который долго не сможет кормить человека...

Многое сохранил память.

Пламя на крыше машинного зала рассказывало не только о героизме пожарных. Оно высветило просчеты и преступную халатность тех, кто проектировал и строил ее.

Пожарные, что были на крыше машинного зала, прекрасно знали, какую опасность несет радиация. Но до конца оставались на своем посту. Это был их долг, и они его выполнили.

С фотографий на нас смотрят молодые лица ребят. Не дрогнувших в трудную минуту, заслонивших беду собой, свершивших подвиг – и память о них в народе будет жить вечно. Но честное слово, лучше бы, если бы они дежурили в защитной одежде и масках на крыше машинного зала, сделанного по всем нормам противопожарной безопасности...

"Безответственность и халатность, недисциплинированность привели к тяжелым последствиям..." – говорится в постановлении Политбюро ЦК КПСС.

Да, некоторые виновные в происшедшем уже понесли наказание. Другие предстали перед судом. Но есть еще наш общий суд - суд памяти. И, воздавая должное героизму одних, мы обязаны помнить, что были преступная халатность и безответственность других. Только в этом случае мы сделаем верные выводы из уроков аварии.

Очень дорогой ценой достается сегодня опыт в атомной энергетике. Но, судя по всему, кое-кто считает, что раз он далеко от Чернобыля, то события на четвертом энергоблоке станции его не касаются. Заблуждение! Они имеют отношение к каждому из нас, потому что прежде всего из-за отвутствия должной технологической дисциплины случилась беда. И повышенная бдительность обязательна не только в атомной энергетике, а и на транспорте, в шахте. В наш век научно-технического прогресса безопасность можно гарантировать только высоким качеством труда, высочайшей дисциплиной, собранностью и профессионализмом.

Политбюро ЦК КПСС прямо и откровенно сообщило всем нам, что "авария произошла из-за целого ряда допущенных работниками этой электростанции грубых нарушений правил эксплуатации реакторных установок". Правительство приняло ряд мер, которые помогают исправить положение. Создано Министерство атомной энергетики, расширена сеть тренажеров для обучения операторов АЭС. Предусмотрен комплекс мер, которые будут обеспечивать безопасность реакторов. Но проблема шире, она выходит за рамки одной области народного хозяйства.

До сих пор не верится, что дежурная смена отключила аварийную систему охлаждения 4-го реактора! А вечером диспетчер "Киевэнерго" "попросил" некоторое время не ставить реактор на ремонт, так как "не хватает энергии"... И реактор продолжал работать, да и к тому проводился эксперимент... Для мало-мальски технически образованного человека такое скопление нелепостей и грубейших ошибок кажется невероятным. Но тем не менее они случились, что и привело к взрыву в реакторе. Стечение обстоятельств? Безусловно. Но их появление вызвано более глубокими причинами.. Авария в Чернобыле высветила "болевые точки". Да, мы обсуждали их, дискутировали, вместе сетовали, но потом забывали, что проблемы надо решать не "чужому дяде", а самим.

Разве нас не беспокоит, что падает престиж профессии инженера и конструктора, что диплом о высшем образовании еще не означает, что народное хозяйство получает высококвалифицированного специалиста? И сколько раз сетовали на страницах газет многие выдающиеся ученые и конструкторы на то, что требования в высшей школе и на производстве к молодым кадрам снижаются, что рост талантливых инженеров и конструкторов сдерживается?

В зеркале аварии отразилась еще одна беда. Размеры определить ее трудно, да и измерить невозможно ни в рентгенах, ни в киловаттах, у нее иные параметры. А она реальная, ощутимая, и ущерб ее может сказаться в далеком будущем, если не начать борьбу с ней сегодня же.

Эту беду можно определить словом "невежество".

В последние годы уж слишком много появилось пропагандистов "летающих тарелочек", "пришельцев", "ясновидящих" и прочих. Да и все больше вопросов задают читатели об астрологах, о предсказаниях новоявленных прорицателей, о чудесных исцелениях "живой" водой, о раковых заболеваниях, которые можно лечить "лучами", испускаемыми ладонями "биологических феноменов". Подчас слышишь вопросы или читаешь записки и думаешь: уж не в средневековье ли попал?

Понятие "культурный человек" в наше время приобретает иной смысл, чем в прошлом веке.

Однажды в Центральном Доме работников искусств проходила дискуссия. Все единодушно сошлись на одном: тот, кто не знает героев "Анны Карениной", не может считать себя культурным человеком.

Согласен. Однако можно ли говорить о "культуре" человека, если ему неведомо, почему бывает зима и лето? Довелось в одной аудитории, где было 100 человек с высшим образованием, задать этот вопрос. И что же показал экспеример? Правильно ответила лишь одна девушка: оказалось, она занималась в астрономическом кружке...

Может быть, и не стоило вспоминать этот анекдотичный случай, если бы он не имел, на мой взгляд, прямого отношения к аварии в Чернобыле.

Инженер из Харькова не в состоянии определить разницу между взрывом водорода и взрывом водородной бомбы, его коллега из Киева понятия не имеет, что такое естественный радиационный фон, молодая женщина из Краснодара убеждена, что "дети из Припяти заразят всех в округе радиацией", педагоги из Полтавы требуют, чтобы "в этом году не продавали рыбу из Днепра", и так далее и тому подобное. Хочется спросить: дорогие товарищи, чему же вы учились в школе? Наконец, в вузе?... Да, можно простить старушку из села, что на Гомельщине, когда она просит рассказать о радиации - она могла и запамятовать, но тем, кому 20 или 40 лет, - разве простительно незнание?!

Каково же было мое удивление, когда в беседах с жителями Припяти выяснилось, что они весьма смутно представляют, что такое ядерная энергетика, а о радиобиологии и ионизирующих излучениях, уж не говоря об изотопах, вообще понятия не имеют. Казалось бы, имн жителям атомного города, положено это знать!

А тем руководителям, которые в масштабах области и республики отвечают за атомную энергетику? И вдруг в разговоре выяснилось, что руководить-то руководили, а книги по физике, по радиационной безопасности (популярные, конечно) взяли в руки лишь после аварии не станции.

Мы часто произносим слова "научно-техническая революция", "ускорение научно-технического прогресса" - век у нас такой. Стоит оглянуться всего лишь на два-три десятка лет в прошлое, сразу поймешь, насколько преобразился окружающий нас мир. В него пришли сложнейшие технические системы, он наполнен физикой и электроникой, машинами и механизмами, подчас настолько сложными, что даже трудно понять, как и почему они действуют. Но наш век космонавтики, атома, электроники и информатики требует Знания. Причем постоянной учебы - багажом прошлого не проживешь. И когда мы говорим о перестройке, то ее прежде всего надо начинатьс себя. С борьбы за Знание, которое должно соответствовать времени,иначе так и не сможешь оценить достоинства рождающейся новой техники и технологии. Если же не поймешь ее, то как же за нее бороться?

Невежество порождает страх, паникерство, и как следствие этого - злопыхательство.

Первые дни после аварии показали, что многих она застала врасплох. Да, не было опыта. Да, такого масштаба авария случалась впервые. Да, многое было неожиданно.

Все это верно, и следует учитывать необычайную сложность обстановки. Но можно ли было нечто подобное предвидеть? И даже будучи уверенным, что возникновение такой аварии практически исключено, тем не менее предусмотреть план действиий? И вновь это не что иное, как дань невежеству, потому что только те, кто во власти незнания, способны утверждать: "Этого не может быть, потому что не может быть никогда"!

Уже новые поколения выросли после пуска первой атомной станции и полета Юрия Гагарина. Они вошли в жизнь, во воспринимая атомную энергетику как нечто обычное и естественное. А ведь это новейшая область науки и техники, и по сути она только первые шаги делает. Но этого ощущения новизны не воспитываем мы у молодых. Помню, сколько научно-популярных книг выходило в пятидесятых годах. Дискуссия о "физиках" и "лириках" привлекала внимание едва ли не всей молодежи страны... Тогда "лирики" победили, а "физики" в тишине продолжали свое дело - создавали технологии. Но "лирика" продолжает властвовать среди молодежи, а свидетельство тому конкурсы в вузах - технические"горят". Уже не о том во многих вузах идет речь, чтобы из шеренги претендентов отобрать лучших, а лишь бы вообще набрать курс... Пройдет всего пять-шесть лет, и не сядут ли за пульты атомных реакторов и электронных систем, энергетических гигантов и автоматических линий те самые выпускники шокл, которые сегодня еле-еле перебираются через порог вуза, да и там учатся с трудом, потому что знаний нехватает, а "план" по выпуску никто не отменил.

Приобщение молодежи к технике - одна из самых актуальных задач сегодня. Это сделать принуждением нельзя.

Только пробуждением, фантазии, воображения, любознательности - широчайшей по своим масштабам просветительской работы.

Вот почему надо чаще спрашивать: отчего бывают зима и лето?

Уроки Чернобыля касаются разных сторон нашей жизни. Идя в завтрашний день, мы должны учитывать эти уроки. Чернобыль обязывает каждого из нас к дисциплине, к высококвалифицированному труду. И еще об одном надо обязательно помнить: каждый человек на планете должен понять, насколько опасен атом, вышедший из-под контроля. Случилась трагедия - появилась ядерная рана в одной точке земного шара, а как нелегко ее залечивать?! А если вся планета станет такой? Чернобыль напомнил, сколь катастрофична ядерная война, он подтвердил, что единственный путь к безопасности человечества - разоружение. И в первую очередь - ядерное...

На промплощадке станции вокруг 4-го энергоблока выросли стены саркофага. Он должен стать памятником героизму и сомоотверженности людей, которые ценой своей жизни и здоровья загасили ядерный огонь. И их имена, уверен, будут выбиты золотыми буквами на мраморной плите, что будет прикреплена к стене, и у нее всегда будут лежать живые цветы.

Саркофаг в Чернобыле обязан стать символом нашей победы над атомной стихией, но он может превратиться и в символ слабости, заблуждений и ошибок нашего времени, если сегодня, сейчас каждый из нас и все вместе мы не учтем уроков аварии в Чернобыле и не сделаем всех выводов из нее.

Сегодня уже ясно: крупнейшие ошибки, совершенные при проектировании и строительстве АЭС, не позволяют развивать атомную энергетику в тех масштабах, которые прдусматривались Энергетической программой СССР.

АЭС в Армении, где происходят катастрофические землетрясения, - грубая ошибка. Под влиянием общественности, правительство приняло решение о закрытии и перепрофилировании станции. Один блок остановлен в феврале, второй - в марте. Из-за просчетов ученых и специалистов стране нанесен огромный ущерб.

Экспертиза показала,что нельзя строить АЭС в Крыму, Здесь также возможны сильные землетрясения.

Размещение крупных станций в густонаселенных районах, рядом с такими городами, как Минск или Горький, мягко говоря, не самое оптимальное решение. Принято постановление о прекращении работ на этих объектах.

Закрыто строительство станции на Северном Кавказе. Здесь очень хорошие земли, развитие промышленности,что и подразумевало строительство АЭС, нецелесообразно.

Разве это не разумные решения? Безусловно, да. Они приняты под действием общественности, в результате широкого и всенародного обсуждения.

Трудное положение сложилось сегодня в энергетике. Но отказ от АЭС играет и свою положительную роль. Приоритет теперь получают энергосберегающие технологии. Резервы в этом направлении огромны - на протяжении десятков лет считалось, что опережающее развитие энергетики позволяет нам строить любые предприятия - в том числе и расходующие огромное количество энергии.

Но с другой стороны мы должны понимать, возведением только ГЭС или ТЭЦ проблема не будет решена. Страна не может полностью отказаться от АЭС.

Мост нужно строить с двух сторон... Работа ученых и специалистов должна проходить при полной открытости, гласности, развитие АЭС обязано выноситься на общенародный референдум.

Но и общественность должна идти навстречу к ученым. Прежде всего требуется, чтобы уровень образованности у населения был поднят - по сути в этих проблемах царит полная неграмотность. Пока превалирует страх "перед атомом", учитывая размеры трагедии в Чернобыле и ее влияние на умы и сердца людей, живущих сегодня и наших потомков, надо эту работу проводить постоянно, с фактами в руках - призывами сегодня никого не убедишь.

Новая цивилизация в истории человечества началась всего чуть более четверти века назад. И это мы должны понять сегодня - завтра будет поздно. Иначе человечества может оказаться в "саркофаге" подобном тому,что возведен вокруг четвертого реактора в Чернобыле.

（仮 訳）

グラスノスチとソ連の原子力開発

ソ連「プラウダ」紙

科学部長 V．グーバレフ

今日、4月12日はわれわれの文明の歴史において記念すべき日付であります。ちょうど28年前のこの日、ユーリー・ガガーリンが宇宙へ出発し、人類に宇宙への道を切り開いたのです。この出来事は、一見、今日私たちが議論する問題からはかけ離れているようですが、じつはそうではないのです。ガガーリンの飛行は、私たちの世紀の象徴になり、われわれが「科学技術革命」と名付けた一連の過程、すなわち地球上の生活様式を根本的に変化させたあの一連の過程の発展に巨大な影響を与えたのです。原子力開発は、この過程の一部を成すものです。

私は、たまたま、宇宙開発の歴史においても、また核エネルギー技術の確立と発展の過程においても、その主要な出来事に証人として立ち会う機会に恵まれました。私は、宇宙飛行士たちの飛行を見送り、ソ連で行なわれた多くのロケット打ち上げに立ち会い、またアメリカを含むいくつかの国における打ち上げにも立ち会っています。その一方では、原子力技術の誕生と発展が私の目の前で進行し、軍事目的だけでなく、純粋に平和目的の核エネルギーの利用の場にも立ち会っています。私は、中央アジアでガスと石油が噴出炎上した際、核爆発によってその火災を鎮火させた現場に居合わせた唯一のジャーナリストでした。地下貯蔵庫および人造湖の造成にも立ち会いましたが、これもまた、1945年に広島と長崎を壊滅させたあの巨大なエネルギーを用いて作られたものでした。

私の職業がら、また『プラウダ』紙での仕事の関係もあって、ソ連におけるエネルギー開発計画の作成に参加することにもなりました。

古代の神話によると、「世界は3頭の鯨に支えられている」そうですが、現代のエネルギー産業についてもそういうことが言えます。それは、水力、火力、それに原子力発電所です。その他のエネルギー源もそれなりの役割を果たしていますが、今のところそれほど大きなものではありません。

ですから、80年代の初めに作成されたエネルギー開発計画は、まさにこれら「3頭の鯨」に立脚するものでした。ここですぐに断わっておきたいのですが、この計画は、比較的狭い範囲の専門家たちにより、広範な社会的論議なしに内密に採択されたものでした。この計画は政府により採用され、ソ連のすべての人々に対し、それを討議するためではなく、履行するためにのみ「上部から下ろされた」のです。

シベリアおよび極東地方においては、いくつかの大型水力発電所の建設が見込まれており、さらに原子力発電所を2、3か所建設することになっていました。

アチンスク炭田を基盤として合計出力が４千万キロワットに上る大火力発電所群の建設が見込まれています。

わが国のヨーロッパ部では、原子力発電所の建設を急激に、「飛躍的に」推進することが予定されていました。計画によると、１００基にのぼる大型炉の建設が見込まれており、その主力はエル・ベー・エム・カー１０００型炉（チャンネル型大出力炉）で、それにシェフチェンコ市やスヴェルドロフスク市郊外で稼働しているのと同じ型の「高速中性子」型炉も数基見込まれていました。これらの原子力発電所は、ボルガ川、ドニェプル川流域、カフカーズ地方、クリミア半島、バルチック沿岸地方などに配置されることになっていました。その際、各発電所の出力が８百万から１千２百万キロワットに上る「巨大原子力発電所」でなければならないとされていました。

チェルノブイリはすべての状況を根本的に変えてしまいました。

私は、事故地区に最初に到着したジャーナリストでした。現地で過ごした最初の２週間は、それまでの全人生で体験してきたことをはるかに上回る体験となったのです。事故地区での仕事、発生した事態の分析は、私自身の考え方をも根本的に変えてしまったのです。なにを隠しましょう、チェルノブイリ以前の私は原子力発電の将来について違う見方をしていたのです。それどころか、私は、原子力発電を宣伝し、すべての発電所の建設を支持し、原子力の広範な利用なしにはわれわれには未来はないと説得してきた者たちの一員でした。

チェルノブイリは、この問題に対する考え方を変えさせました。

最初に個人的な印象をいくらか述べてみましょう。

ヘリコプターで発電所とプリピャチの町の上空を旋回する。

原子炉はまだ「くすぶって」いる。空気中には「金物の味」が感じられる、つまり、放射線レベルが非常に高いということだ。第４ブロックの恐るべき破壊の有様が見えるー崩れ落ちた屋根、はね飛ばされて散乱するコンクリート塊。爆発の凄まじさは疑いようもない。

奇妙だ、町の眺めがどこか異様だ。白亜の高層建物、幅広い大通り、公園とスタヂアム、幼稚園に隣り合った遊園地、商店・・・だが町は空っぽだ。通りには人っ子一人いないし、夜になっても灯の点る窓はただの一つもない。ごくまれに特別車が通りに現れるーあれは放射能検査の車だ・・・

人のいない町・・・恐ろしい・・・

住人に捨てられた死の町。大人も子供も、年金生活者も家庭の主婦も、物理学者もアパート管理人も、すべての人が見捨てていった・・・

もう一つの印象があります。その同じ町についてですが、時期はあのときから２年後のことです。何回目でしょうか、私は再び事故地区にやってきました・・・

住民のいない町は急速に死んでいく。私を出迎えるのは、落ち窪んだ眼窩のような空虚な窓、ベニア板の打ち付けられた商店のショーウインドー、トラックからこぼれ落ちたベッドの金網、そして静けさ。それは、ひっきりなしに振り返りたくなるような深くまた思いがけない静けさ、自分の後からだれかがつけてくるような感じ、だがそれは周囲の建物にこだまする自身の靴音・・・辻の小公園ではすでに雑草が支配しており、所々でアスファルトを突き抜けている。それにしても雑草の伸びのなんと早いことか？！発電所へ行く途中で畑を目にした。事故のあと収穫していないので、麦はそのまま地面に落ち、今やそれが新たな芽を吹いている。だがこうした農地では褐色の斑点がどんどん広がってきている。雑草が小麦に勝ちつつあるのだ。恐らくこの秋にはもう最終的な決着がついていることだろう・・・

雑草が原野から町に侵入し始めると、それは今やプリピャチを囲んでいる鉄条網も、町の周囲に設定された「衛生ベルト」も押しとどめることはできなかった。もっとも悪の種は町の中自体に潜んでいたと考えるべきだろう。今やそのときが来て、地中から這い出てきた・・・苦よもぎは、心に痛みを生み付け、人をその虜にし、今やそれを振り払うことはできない。なぜなら、どんなふうに町が死んで行くかを見るのは耐え難いほどに辛いことだから。

だがそうでなければならないのだ。生命のために。そこで、トラックが次ぎから次ぎへとベッドやカーペット、テレビやソファーなど、プリピャチ市民のアパートにまだ残されているすべてのものを運び出している。除染！この言葉はこのところ耳慣れたものとなったが、今日のプリピャチではそれは、家具やがらくたを運び出し、アパートを完全に空っぽにせねばならないということを意味する。なぜならアパートには放射性のホコリが積もっているからだ。すべてを破棄せねばならない・・・

今では町からは発電所が手のひらの上にあるようによく見える。その白い建屋も、第４ブロックの暗いピラミッドも。除染は除染として、あすこ、事故地区の心臓部はどうなっているのか。

原子力発電所の周囲には草一本生えておらず、よくある芝生も花壇もない。あるのは灰色のコンクリートに覆われただだっ広いスペースだけ。すこし後で、発電所の各ブロック間を結ぶ回廊からこのコンクリートの厚さを目の当たりにすることができた。狭軌鉄道のレールがまるでトンネルの中にあるように走っているのだが、以前は、事故までは、地表を走っていたのだ。全敷地から土をはぎ取り、コンクリートとアスファルトを敷き詰めたのだ。今年はまだ地中を「ほじくる」予定になっている。連絡パ

イプ類が通っている場所を掘り返し、除染作業をし、補修せねばならない。将来的には、ここには、原子力発電所の敷地内には、土が運び込まれ、新たに花壇や芝生が設けられることになっている。発電所とその周辺地域は事故の前と同じ光景にしなければならない・・・

残念ながら、そのためには数十年の年月が必要だろう・・・

チェルノブイリの教訓ですが、それはどのようなものでしょうか。

なによりもまずそれは「ソ連における公開性＝グラスノスチ」の試験でした。最初の数日間の沈黙はなぜだったのでしょうか。世界中のすべての新聞があの悲劇について、ときにはその規模の大きさに思いも及ばず、またしたがって、ときには誇張して報道しているときに、事故地区（ゾーン）からは断片的な情報しかもたらされなかったのはなぜでしょうか。

「沈黙地帯（ゾーン）」を許すことはできません。これは疑いもなく、役所が沈黙を守ることに努め、最善の場合でも情報を歪めようとしてきた過去の再生現象の一つです。くりかえしますが、これは原因の一つでしかありません。主要な原因は、はるかに深いところにあるのです。それは、何十年にもわたって原子力発電の周辺に醸成されてきた「心理的雰囲気」にあります。

核兵器の開発と結び付くすべてにおいて常に「タブー」が存在してきました。原子力発電は、兵器を作っていたのと同じ研究所で同じ学者や専門家たちによって生み出されたので、彼らの仕事は以前と同様に「機密」だったのです。社会の側からの批判にさらされる可能性のある事項がなによりも先に非公開とされていました。欠陥、事故、果ては、原子力発電所の配置および開発の基本方針、こうした情報のすべてが密室内に留め置かれ、閉じたドアの内側で、「人民の名において」決定する権利を自らに付与した狭い範囲の専門家たちによってのみ討議されてきたのです。

「専門家というのは溶剤のようなものだ」というポピュラーな言い方があります。技術的決定の無謬性、傲慢さ、そして自分の所属する機関の利益がすべてという発想、そうした傾向に手を貸してきた新聞やテレビ、こうしたことが何をしても許されるという雰囲気を作ったのです。しかも専門家や学者たちは原子力発電所の安全性についてあまりにも多くのことを語ったため、まず最初に自分たち自身がそれを信じこんでしまいました。彼らがなによりも重要視したのは安さでした。経済性を主要なものとする場合、まず最初に犠牲にされるのは安全性です。というのもまさに安全性こそが大きな出費を強いるものだからです。

ソ連科学アカデミー総裁A．P．アレクサンドロフを頂点とするわが国の代表的な学者たちは、原子力発電所は絶対的に安全だと断言してきましたし、それどころかある有名な原子工学者は、自分の家を発電所の敷地内に設けてもいいとまで言っています！

チェルノブイリにおける悲劇は、このような証明のしかたに非常に危険な思い違いや破綻があることを示しました。

特徴的だったのは、事故直後まさに科学者たちが事故を信じなかったのです。彼らによる「そんなことは有り得ない！」という断言は政府に誤った判断をさせることになりました。アカデミー会員V．レガソフがチェルノブイリへ到着して初めて状況が明らかになったのです・・・

チェルノブイリで活動し、目の当たりにしたことを報道したマスコミやジャーナリストのおかげでソ連の人々は現実の事態を知ることになりました。人々は、原子力発電がどのくらい複雑な状況にあるのかを理解したのです。これはわが国の国民経済全般についても言えることですが。

『プラウダ』紙の私のデスクには6万通以上の投書が山積みにされました。党中央委員会と内閣には約百万通の手紙が舞い込みました。世論は、原子力発電所の建設に関わる諸問題の討議に積極的に参加してきたのです。

チェルノブイリ原子力発電所では第4エネルギーブロックを囲む石棺の壁が立ちあげられました。端的に言って、これはその核心部に事故を起こした原子炉が埋葬されている墳墓です。これは一風変わった異様な構築物で、文明の歴史においても前例のないものです。それを望もうが望むまいが、石棺は今日の事件をわれわれの子孫に物語ることになるでしょう。鋼鉄とコンクリートから成るこの巨大な塊りはなにを象徴することになるのでしょうか。

記憶は、事故後の最初の日々の印象を大切に保管しています。その後で分析と思索のときがやってきました。それに『プラウダ』紙の読者からの何千通もの手紙は、起こりつつある事態を別の角度から見ることを迫ってきました。投書を通じて、避難させられた人たちと一緒に家庭のぬくもりを失う悲哀を体験する、兵士たちと並んで耳慣れない「除染」という言葉で呼ばれるよくわからないあの作業を行なう、傷ついた発電所のエネルギーブロックへ当直要員が向かっていく様子を見守る、家を奪われた家族たちのために建てられた家が一軒完成するごとに一緒に喜ぶ・・・それでもいろいろな人に会うたびに必ず出される質問「チェルノブイリ以後はどうなるのか？」に答えるのは容易なことではありませんでした。

今では時間も経過して一義的な答えができます。チェルノブイリ原子力発電所の事故に際しては、人民の心の偉大さ、その英雄主義と勇気が鮮やかに全面的に発揮され、同情それに災難はみんなのものであるという実感がはっきりと感じ取れました。

チェルノブイリ、それはプリピャチ川の岸辺で口を開いている傷というだけでなく、一人一人の心の中に開いた傷口なのです。その人がどこに住んでいようが、どこで働いていようがこのことに違いはありません。極北地方だろうと暑い南部地方だろうと、西のブレストだろうと東のウラジオストークだろうと。

発生した事態から得られた主要な教訓の一つは、わが社会でパニックに陥ったり、茫然自失したり臆病風に吹かれたりした人々はほんの一握りにすぎないということに確信を持ったことです。チェルノブイリはそうした人々をエックス線で透写するように際立たせてくれましたし、ただちに社会的非難にさらされました。困難な試練が人民の肩にかかってきましたが、人民は名誉をもってそれに耐え抜きました。

「チェルノブイリの皆さん、われわれはあなたと共にあります！」この言葉は大多数のソ連の人々にとって単なるスローガンではなく、実際の行動になりました。それはさまざまなかたちで現われました。危険地域での仕事に派遣してほしいという申請書のかたちで、義捐金口座番号９０４への送金のかたちで、キエフ州やゴメリ州で働いた学生建設隊のかたちで、チェルノブイリ基金のために追加の交代勤務に就くというかたちで、そして被害地域の子供たちへの心配や同情の言葉というかたちで。

しかし事態への別の対応もあります。事故は原子力発電所全体に対する否定的な対応を呼び起こしました。現在では、そのような気分を考慮しないわけにはいきません。

「産業によっては何年というより何世紀もの間、働き続けているものがありますが、そうした産業においてさえ事故は起こるのです。おそらくそれは原子力発電所でも繰り返されることでしょう。わが国では起こらなくても他の国で起こるかもしれません。自動車のせいで息をする空気もなくなっているというのに、そのうえ原子とは・・・私たちの中にはそんなふうに考えている人たちがいますし、私たちは原子力発電にそういう態度をとっています」とヴォロシロフグラード市のN．シネリニコワさんは書いています。

こうした意見は無視してしまうほうが簡単ですが、チェルノブイリ事故の教訓は異なった対応を迫っています。つまり、懇切ていねいで思慮深い説明、そうした人々の論拠の義務的な分析などです。これは、新たに建設される原子力発電所の立地に関する場合、とくに重要です。たとえば、保養地あるいは稼働中の火力発電所や水力発電所に隣接した場所にそのような発電所を建設することを正当化したり説明することは困難です。また、肥沃な土壌に恵まれている農業地帯においても同様です。そのような土地を、原子力発電所を含むなんらかの工業施設のために収用することは、多くの場合経済的に正当化し得ないのです。科学技術発展の現段階においては、アカデミー会員N．ドレジャリの考えに戻ってみるのも意味のあることかもしれません。彼は、６０年代の末に、荒野や人口稀薄地区のような「捨て地」に、原子力発電所やエネルギーを大量消費する工場を含む大規模なエネ

ルギー・工業複合施設を建設するという案を提案しています。全体的に、専門家や経済学者たちは原子力発電所配置プランをもう一度分析し直してみるべきでしょう。

原子力発電における多くの問題は、今日では、チェルノブイリのプリズムを通して見る必要があります。それは原子力発電に限りませんが・・・

事故の教訓については、原子力発電所の党委員会で議論されていましたし、発電所や事故対策本部、地区出入り口のチェックポイント、党機関や国家機関などで私が話をする機会を持った発電所の労働者、設計家、アカデミー会員E．ベリホフやV．レガソフ、医師や専門家などはみなその事について考えていました。破損した原子炉の上空をまだヘリコプターが飛び回り砂や鉛を投下していたとき、まだ住民の避難が続いていたとき、まだ災害の規模が完全には把握されていなかったとき、出会ったすべての人たちは必ずチェルノブイリの教訓について話していました。事故発生直後の日々にあまりに多くのことがむき出しにされました。自明の理であるように見え、考える必要もないとされていたが、深刻な試練にさらされると脆くも崩れ去り、結局、勝利の報告書の類いの紙の上にしかないことが明らかにされた多くのことがです。

コルホーズ議長が家の窓ガラスを叩き出し、血液検査用のガラス板に切り分けるよう命じていた情景をおぼえています。医者のところにはそれがなかったからです・・・

線量計を分配する情景をおぼえています。しかし倉庫には線量計用の電池がありませんでした・・・

将軍が自分の勇敢さを誇示するかのように黒塗りの「ボルガ」で第４エネルギーブロックのヤードに乗り入れた情景をおぼえています。

プリピャチ川の岸辺で釣糸を垂れていた兵士のことをおぼえています。彼はそれがどんなに危険なことか私たちに言われるまで誰からも聞かされていませんでした・・・

茫然自失してなす術を知らなかったいく人かの指導的幹部のことをおぼえています。彼らは、発生したすべての事態を掌握していねばならなかったばかりでなく、ただちに必要な手段を講じなければならなかったはずなのですが・・・モスクワからの指示を待つだけではなく・・・

多くのことが記憶に残っています。

罹災者を迎える用意があることを示すために大きく開かれた農家の中庭の門のことも・・・放射線のために激しく振れる計器の針のことも・・・永く人を養うことはないであろう切り取られた土壌のことも・・・

多くのことが記憶に残るでしょう。

機械室の屋根の上に立のぼる炎は消防士のヒロイズムを物語っていただけではありません。あの炎は、設計と建設にあたった者たちの誤算と犯罪的な怠慢を浮き立たせていたのです。

機会室の屋上にいた消防士たちは、放射線がどのような危険をはらんだものであるかをはっきりと知っていました。でも最後まで部署を守ったのです。それは彼らの義務であり、それを彼らは遂行しました。

写真の中からいかにも若者らしい顔が私たちを見詰めています。困難のときにたじろぐことなく、災難を自分の身をもって塞ぎ、英雄的行為を成し遂げた若者たち。彼らの記憶は民衆の中に永遠に残ることでしょう。しかし本当のところは、もし彼らが防護服とマスクを身に着けて、すべての防火基準に従って建設された機械室の屋上で当番の任務についていたらよかったのですが・・・

「無責任さと怠慢、無規律さが重大な結果をもたらした・・・」と党中央委員会政治局の決議に述べられています。

確かに、発生した事態に責任を負う何人かはすでに処罰を受けました。また他の者たちは裁判にかけられました。しかしまだわれわれ全体による審判一記憶による審判があります。ある人たちのヒロイズムにしかるべき敬意を払う一方では、他の人たちの犯罪的な怠慢と無責任をわれわれは、しっかりと記憶しておかねばなりません。そうして初めて、われわれは事故の教訓から正しい結論を引き出すことになるのです。

今日、原子力発電における経験を得るのに非常に高い代償を払っています。しかし、チェルノブイリからは遠いし、発電所の第４エネルギーブロックでの事件など自分には関係ないと考えている人もいるようです。とんでもない間違いです！あの事件はわれわれ一人一人に関係があるのです。なぜなら、なによりもしかるべき作業規律が欠如していたことにより災害は発生したのです。それに高度の警戒心は原子力発電においてだけでなく、運輸においても鉱山においても不可欠です。科学技術進歩のわが世紀においては安全性は、労働の質の高さ、最高度の規律、几帳面さ、それにプロ意識によってのみ保証することができるのです。

党中央委員会政治局は、率直に公然と、われわれすべてに「事故は、この発電所の職員によって犯された一連の乱暴な原子炉運転規則違反によって引き起こされた」と知らせています。政府は、事態を正すのに役立つ一連の対策を講じました。原子力発電省が創設され、原子力発電所オペレーター訓練施設網が拡充され、原子炉の安全性を確保するための複合的な対策が策定されました。しかし問題はもっと幅広く、国民経済の一分野の枠をはみ出すものです。

当直要員が４号炉の非常冷却システムを遮断してしまったということは、今になっても信じがたい思いです！夕刻には、キエフ電力管理局の配電係が、「電力が不足している」ので、しばらくのあいだ原子炉を修理に回さないよう「要請してきた」のです・・・それで原子炉は作動し続け、そのうえ実験が行なわれていました・・・ほんのわずかでも技術

教育を受けた人間にとっては、そのような馬鹿げた行為と乱暴極まりない過ちの集積はとうてい信じられないものです。それでもそれは起こってしまい、結局それが原子炉の爆発へと導いたのです。悪い状況がたまたま重なって起こった？もちろんそうでしょう。しかしそうした状況の発生はより深い原因によって引き起こされたものです。チェルノブイリの事故は「痛点」に光を当てました。確かにわれわれはそれらのことについて議論し、論争し、共に嘆きましたが、問題は「他人任せ」ではなく自分たち自身の手で解決しなければならないのだということを忘れてしまっていたのです。

技師や設計士といった職業の権威が低落していること、高等教育の卒業証書は国民経済に高度な資格を持った専門家が送り込まれているということを意味しない、などの事実をわれわれは心配していないでしょうか。高等教育機関や生産現場において学生や若い要員に対する要求水準が低下していること、才能ある技師や設計士の成長が停滞していることなどについて多くの優れた学者や設計家がどれほど繰り返し新聞の紙面で嘆いたことでしょうか。

事故の鏡にはもう一つの不幸が反映されています。その大きさを判定するのは難しく、それにレントゲンやキロワット単位で測れるようなものではありません。その指標はちょっと異質なものです。しかしこの不幸は現実のものであり、実感できるものであり、今日只今からそれとの闘いを開始しないと、それによる損害は遠い将来において非常に大きなものとなるかもしれません。

この不幸は「無知」という言葉で表現することができます。

近年「空飛ぶ円盤」とか「異星人」とか「千里眼」とかの類いの宣伝家が大量に出現しています。それに、読者からは、占星学者について、新参の予言者の予言について、「命の」水による奇跡的な治癒について、「生物学的天才」の手のひらから発せられる「ビーム」で治療できる痼疾患についてというような質問がますます多く寄せられています。そうした質問を耳にしたり手記の類いを読んでいると、一瞬、中世時代に逆戻りしたのではないかという思いにとらわれます。

「文化的人間」という概念は、われわれの時代には、前世紀とは異なった意味をもっています。

あるとき芸術活動者中央会館で議論が行なわれていました。その席で出席者全員が一致したのは、「アンナ・カレーニナ」の主要登場人物を知らない人は、自分を文化的人間と見なすことはできないという点でした。

同意しましょう。しかし、もしその人が、なぜ夏と冬があるのか知らないとしたら、その人の「文化」について語ることができるでしょうか。高等教育を受けた１００人の人たちが出席していたある席で、この質問をする機会がありました。この実験はどうだったで

しょうか。なんと正しく答えられたのは娘さん一人だけで、彼女は天文クラブのメンバーだということでした・・・

もしこのケースが、私の考えですが、チェルノブイリの事故と直接的な関係を持つものでなければ、このような笑い話的なケースを思い起こす意味はなかったかもしれません。

ハリコフ市の技師は、水素爆発と水素爆弾の爆発との違いを区別することができなかったし、キエフ市の同僚は、自然放射線バックグラウンドとはどんなものかまったく理解していませんでした。クラスノダールの若い女性は、「プリピャチの子供はまわりの人たちすべてに放射能を伝染させる」と信じてい、ポルタワ市の教師は、「ドニエプル川から水揚げされた魚を今年は売らないよう」要求し、という具合です。そこでつい質問したくなるのですが、親愛なる皆さん、あなた方は学校でなにを勉強してきたのですか、大学にも行っているのでしょう?・・・ゴメリ地方の村に住むお婆さんが放射線について説明するよう求めてくるのは許せます。彼女が忘れてしまったということはあるでしょう。しかし２０歳あるいは４０歳の人たちが知らないというのは許せるでしょうか!?

プリピャチの住民たちとの会話の中で、彼らが原子力発電とはどんなものか非常にぼんやりとしたイメージしか持っていないこと、放射性同位元素についてはもちろん、放射線生物学や電離放射線についてまったく理解していないことを知ったときの私の驚きは大変なものでした。あの「原子の町」の住民こそがそうしたことを知っていなければならないはずなのですが!

州や共和国の単位で原子力発電に責任を負う指導幹部たちについてはどうでしょうか。ここでも会話の中で突然明らかになったのですが、指導することはしていたものの、物理や放射線安全についての本(もちろん、一般向けに書かれたもののことですが)をようやく手に取ったのは発電所で事故が起こった後のことでした。

私たちはしばしば「科学技術革命」とか「科学技術進歩の加速」とかいう言葉を口にしますが、今やそういう時代なのです。たかだか二、三十年前を振り返ってみるだけで、われわれを取り囲む世界がどのくらい変容したかすぐ理解できます。極度に複雑な技術システムが入り込み、物理学や電子工学に満ち満ちており、時にあまりに複雑でどのようにしてなぜ作動するのか理解するのも難しい機械や機構に囲まれています。宇宙開発、原子工学、電子工学それに情報工学のわが世紀は知識が不可欠のものとなっています。しかも絶え間ない学習が必要なのです。過去に蓄積した知識だけでは生きて行けません。われわれがペレストロイカ=改革について語るときにも、なによりもまず自分自身から改革を始めねばなりません。時代に合致した知識を得る闘いからです。さもなくば新たに生まれつつある技術の特長を評価することはできないでしょう。そしてそれを理解できなければどうやって新たな技術のために闘うことができるでしょうか。

無知は、恐怖、パニック騒ぎ、そしてその結果として、敵意に満ちた態度を生み出します。

事故後の最初の日々の示すところでは、事故は多くの人々の虚を突いて襲いました。経験がなかったということもあります。あのような規模の事故は初めてだったということもあります。多くのことが予想外だったということもあります。こうしたことはすべてその通りでしょうし、状況の異常な複雑さも考慮すべきでしょう。しかしそれで類似の状況を予見できたでしょうか。そのような事故の発生は実質的に有り得ないと確信していて、行動計画を立てておくことができたでしょうか。これもまた無知の代償以外のなにものでもありません。なぜなら、無知に支配されている者のみが「そんなことは絶対に有り得ないのだから、それは有り得ない！」というような断言ができるからです。

最初の原子力発電所が始動し、ユーリー・ガガーリンが宇宙を飛行した後、すでに新たな世代が大人になっています。彼らは原子力発電をごく普通の自然なものと受け止めつつ世に出ていきました。しかしそれは科学技術の最新の分野であり、実質的には最初の数歩を歩んだにすぎないのです。われわれは、この新しいものなのだという感覚を若い人々に教え込んでいません。５０年代にいかにおびただしい数の大衆むけ科学啓蒙書が出版されたかをおぼえています。「物理学者」と「叙情作家」についての議論はわが国のほとんどすべてのと言ってもいいくらい多くの若者の注目を浴びていました・・・当時「叙情作家」が勝利を収め、「物理学者」は静けさの中で自分の仕事を続けていました、つまり技術の創造に取り組んでいました。しかし「叙情」は若者の間で支配的な力を持ち続けており、その証拠は大学での入学試験に見ることができます。技術系の学部は「危機的な」状況にあるのです。今や多くの大学では受験生の中から最良の部分を選抜することが問題になっているのではなく、学科の定員を埋められればいいというところまできています・・・あと５、６年経つと、原子炉や電子システム、巨大発電所や自動ラインのコントロールパネルの前に、ようやくのことで大学の敷居を乗り越え、知識の不足のために満足な勉強もできないのに卒業者数の送り出し「計画」をだれも変更しなかったために社会に出ていく、今日の高校卒業生たちが座ることになるのでしょうか。

若者を技術になじませること、これは今日最も切実な課題の一つです。それを強制することはできません。創造力、空想、好奇心を呼び起こすことによってのみ、最も広範な啓蒙活動によってのみ可能になるのです。

そういうわけで、冬と夏はなぜあるのかという質問をもっと頻繁に行なう必要があるのです。

チェルノブイリの教訓は私たちの生活のさまざまな側面に関係しています。明日に向かって私たちはこれらの教訓を考慮しなければなりません。チェルノブイリは、私たち一人

一人に規律を守ること、高度の熟練労働を要求しています。さらにもう一つのことを必ずおぼえておかねばなりません。すなわち、地球上の人間一人一人が、コントロールの利かなくなった原子がいかに危険なものであるかを理解しなければならないのです。悲劇が起こったら、地球上の一地点に核の傷が発生したら、それを癒すのはどんなに大変なことか！もし全地球にわたってそういうことになったら？チェルノブイリは、核戦争がいかに破滅的であるかを思い起こさせましたし、人類の安全への唯一の道は軍縮であることを再確認させました。それも、なによりもまず核軍縮を・・・

発電所の第４エネルギーブロックを囲んで石棺の壁が建ち上がりました。それは、自分の命と健康と引き換えに核の火を消した人たちのヒロイズムと自己犠牲精神の記念碑にならねばなりません。彼らの名は、壁に取り付けられる大理石の石板に金文字で刻み込まれ、そこにはいつも新鮮な花が絶えないであろうことを確信しています。

チェルノブイリにおける石棺は、「原子的自然」に対するわれわれの勝利の象徴にならねばならないのです。しかしもし今日、今すぐにわれわれ一人一人が、またわれわれ全員が一緒に、チェルノブイリ事故の教訓を考慮せず、そこから全てのしかるべき結論を引き出さないならば、この石棺はわれわれの時代の弱さと誤解と過ちの象徴となるかもしれません。

今日すでに明らかになっていることですが、原子力発電所の設計と建設の際に犯された重大な過ちのために、「ソ連エネルギー開発計画」に見込まれていたような規模での原子力発電の発展は許されない状況にあります。

破滅的な地震が発生するアルメニアにおける原子力発電所は乱暴な誤りです。世論の圧力のもとで、政府は、発電所を閉鎖し用途変更を行なう決定を下しました。１基は２月に停止され、２基目は３月に停止されました。学者や専門家の計算違いにより国は巨大な損害をこうむったのです。

専門家による鑑定により、クリミアに原子力発電所を建ててはならないことが示されました。そこでも強い地震の可能性があるからです。

人口密度の高い地区、ミンスクやゴーリキーのような都市に隣接して大型発電所を配置することは、婉曲に言って、最適の決定ではありません。こうしたプロジェクトに関する作業の中止決定が下されました。

北カフカーズでの発電所建設は停止されました。ここの土地は非常に肥沃で、それを潰して工業開発を進めることは、これには当然原子力発電所の建設も含まれるのですが、合理的ではありません。

これは賢明な決定ではないでしょうか。もちろんそうです。これらの決定は、広範な全国民的な論議の結果、世論の作用のもとで採択されたのです。

今日、エネルギー産業は困難な状態にあります。しかし原子力発電所の拒否はそれなりに肯定的な役割も果たしています。今や省エネルギー技術が優先的に扱われています。この方向での余力には巨大なものがあります。というのも、何十年ものあいだ、エネルギー産業の先行的な発展によって、あらゆる種類の企業、莫大なエネルギーを消費するものも含みますが、の建設が可能になるのだと考えられてきたからです。

しかし他方では、水力または火力発電所のみを建設していたのでは問題は解決されないということを理解せねばなりません。わが国は原子力発電所を完全に拒否することはできないのです。

橋は両側から架けてゆく必要があります・・・学者や専門家の仕事は完全な公開性のもとで進められねばなりませんし、原子力発電所の開発は全国民的な判定にかけられねばなりません。

しかし世論の側も学者の方へ歩み寄らねばなりません。なによりもまず住民の知識水準を引き上げることが要求されています。事実上、こうした問題においては全面的な無知が状況を支配しているのです。「原子に対する恐怖」が支配的であるあいだは、チェルノブイリにおける悲劇の規模と、それが現に生きている人々とわれわれの子孫の頭と心に与えている影響を考慮して、教育活動を絶え間なく進めていかねばなりません。それも事実を示すことによって意味を持つのです。呼びかけのみでは、今日ではだれをも説得することはできません。

人類史における新たな文明はわずかに四分の一世紀余り前に始まったにすぎません。このことは今日理解する必要があるのであり、明日では遅すぎます。さもなくば人類は、チェルノブイリの４号炉の周囲に築き上げられたものと同様の「石棺」に入ることになりかねません。

セッション2
社会のなかの原子力

原子力論争この一年
評論家
田　原　総一朗

わが国の市民運動の特徴
学習院大学法学部教授
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犬　養　智　子

中部電力㈱副社長
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評論家
田　原　総一朗

学習院大学法学部教授
田　中　靖　政

わが国の市民運動の特徴

学習院大学

田　中　靖　政

本日、私に与えられました課題は「わが国の市民運動の特徴」であります．いうまでもなく、「市民運動」は市民の要求を行政に反映させることを目標にする政治運動の一種であります．本日は内外から原子力に関係のある方々がお集まりでありますので、このような「市民運動」を原子力の領域に限定して俯瞰してみたいと思います．

時間の制約もありますので、（1）「沈黙の大多数」が見る原子力、（2）「沈黙の大多数」とマスコミ、（3）原子力の「リスク」と「ベネフィット」、そして（4）日本の民主主義と原子力、という4つのトピックについて話題を提供させていただくことに致します．

1．「沈黙の大多数」が見る原子力

御承知の通り、１９８６年4月のチェルノブイリ原発事故の直後、世界各国の世論は反原発に大きく傾きました．例えば、アメリカでは「新しい原子力発電所の建設」に「反対」５２％、「賛成」３８％、西ドイツでは「原子力発電所の新規建設」に「反対」６９％、「賛成」２９％と、いずれも「反対」が「賛成」を大きく上回りました．しかし、１９８６年8月の朝日新聞世論調査では、「日本の原子力発電は、今後、どうしたらよいと思いますか」という質問に対して、１０％が「増やすべきだ」、６０％が「現状程度にとどめる」、１３％が「減らす方がよい」、９％が「止めるべきだ」と答えており、全体として原子力肯定が７０％、否定が２０％という数字が得られました．日本の行政官庁をはじめ、原子力産業の間に楽観的空気が支配的だったのは、理由のないわけではなかったのです．

日本で反原発運動がにわかに活発になったのは、１９８８年の春からであります．これにはいくつかの複合的な理由が考えられますが、何といっても最大の理由は、チェルノブイリ原発事故によって汚染した食品がヨーロッパから輸入され、「口からの危険」が特に主婦層に強く意識されるようになったためであります．以来、ほぼ１年にわたって続いている反原発市民運動の大きな特徴は、いままでほとんど原子力問題に興味をもたなかった「沈黙の大多数」が活発に原子力論争に参加するようになったことであります．

従来の反原発運動は、原発サイト周辺の人びとと、それを支援する社会党や労働組合を中心とした、いわゆる《オールドウェーブ》反対派を主流としてきました．現在は特に今まで政治やイデオロギーを敬遠してきた主婦層を中心に、「口からの危険」を懸念し、「脱原発」を求める、いわゆる《ニューウェーブ》反原発市民運動が活発化しています．

この間、「ニューウェーブ」反原発運動の発火点となったいわゆる「ヒロセ・タカシ現象」の主人公、広瀬隆氏個人のエネルギッシュな活動も無視できません．著書や雑誌論文など、活発な執筆活動もさることながら、広瀬氏の全国を股にかけた行脚はまさに記録的であります．昨年７月から今年３月までの９ヵ月間に、全国で３５０回以上の反原発集会が記録されていますが、広瀬氏はそのうちの８０回以上に講師として参加しています．

このように、全国的に反原発運動に弾みがついたことは、もはや否定できない事実であります．それとともに、「沈黙の大多数」はこれまでの沈黙を破って、積極的に発言、行動するようになりました．たとえば、北海道では、１９８８年夏、有権者のほぼ4分の1にあたる１００万人の反原発署名が集められました．また、１９８９年1月には、１０月を一応の目処に、『脱原発法』制定１０００万人署名運動が始まっています．

２．「沈黙の大多数」とマスコミ

書店も、雑誌も、新聞も、テレビも、原子力がいかに危険であるか、原子力がいかに不要であるか、を印象づけるような内容で一杯です．概して日本のマスコミは原子力に対して好意的でないといわれます．マスコミは「沈黙の大多数」の不安に応ずる側に重点を置き、原発における微小な異常や故障や、反原発運動について報道するからであります．これに対して、行政や電力会社は、マスコミに対しても、また「沈黙の大多数」に対しても、十分な情報の提供や、素人にも分かりやすい原子力の安全性や必要の説明に、必ずしも満足するような成果をあげていません．「情報の風通しをよくすること」「素人にも分かるように話し掛けること」「意見が異なる相手であっても、相手を尊重すること」、そして、「言葉だけではなく、行動で示すこと」――これらが、マスコミに接する時の、またマスコミを通じて「沈黙の大多数」に接する時の、行政や電力会社に必要とされる「作法」であります．

現に、行政や電力会社にとって最大の問題は、女性を含む「沈黙の大多数」が情報や理解の不足から、行政や電力会社の誠意や信憑性に疑問を抱き、自分たちの「知る権利」や「選択する自由」を蔑ろにされたと感じ、行政や電力会社の「押しつけ」を嫌って、次第に「反対派」の主張する「脱原発」に傾きつつあることにあるといえます．情報化が進み、

文化的な価値観や生活様式が多様化した今日の社会では、「沈黙の大多数」それ自体が一枚岩的な存在ではありせん．性別、年令、職業、地域などによって、「原子力」の受け取り方も多様化、細分化しています．細分化した「沈黙の大多数」をそれぞれ納得させるコミュニケーションの工夫が、行政や電力会社のサイドで、これからはますます必要になると考えられます．

従来、電力業界においては、自動車産業、ファッション・アパレル産業、あるいは食品産業などに比べて、大衆消費者の分析がかなり遅れていたように見受けられます．これらの産業では、大衆消費者の移り気によって企業の命運が決まるという戦略的な必要から、大衆消費者の属性、好み、ライフスタイルなどの変化について、また各種の広告の効果について、長年にわたって膨大なデータの蓄積に努めてきました．これらのデータから引き出される大衆消費者のイメージが、生産や販売の現実的戦略決定に大きく係わってくるからです．片や電力業界では、電気は作れば必ず売れるわけですから、こうした戦略的なデータを集めたり、分析したり、消費者のイメージを描いたりする必要はほとんどありません．ここに、「相手を知らない」電力業界の脆さがあるように思います．

マスコミや「沈黙の大多数」を大切にするためには、他の産業のように「お客様は神様です」という精神に徹し、まず細分化された「お客様」の実態を知ることから着手すべきでしょう．比較的最近、原子力のＰＡに「マンガ」を使う新たな試みが見られます．このように「沈黙の大多数」に一歩でも近づこうとする努力は、内容の良し悪しはともあれ、一応評価されて然るべきでしょう．

3．原子力の「リスク」と「ベネフィット」

全国的に反原発運動には弾みがついてきていることは事実であるにしても、「沈黙の大多数」のすべてが原子力を全面的に拒否しているわけではありません．例えば、昨年１０月にＮＨＫが実施した「原子力世論調査」（表１）の結果を眺めてみましょう．

まず、「安全性」（表２）については、７０パーセント近くの回答者が原子力を「危険」と感じていることが分かります．「安全」と感じている回答者は３０％そこそこです．

次に、「安全性についてのデータ公開」（表３）ですが、７０％以上の回答者が「データ公開が不十分」と不満を表しています．「十分」と答えた回答者は２０％を切っています．

しかし、注目に値することには、「原子力発電の推進」（表４）について回答者の６

０％が「肯定的」な回答をしていることです．これに対して「否定的」な回答者は３０％しかいません．

もう一つ興味ある発見（表５）は、これだけ反原発運動に弾みがついてきているのにもかかわらず、ほぼ５０％の回答者は「反対運動に関心はあるが、共感できない」と答えており、「関心があり、共感できる」と答えた３０％を大きく上回っていることであります．

要約しますと、現状における「沈黙の大多数」の過半数は、「原子力を危険と感じており、また原子力の安全性に関するデータ公開が不十分と不満を感じているが、今後とも原子力は必要と考えており、反原発運動にはあまり同情的でない」といえましょう．

一方で「危険」と感じながら他方で「必要」と考えるというのは論理的矛盾のように思われますが、こうした矛盾した心理――心理学では「アンビヴァレンス」と呼ばれます――は、実際にはそう珍しい現象ではありません．次に、私が以前に行った社会心理学的研究の中から例を取り、こうした矛盾した心理の絵解きをしてみることにします．

図１は、原子力に関わりのある専門家の「頭の中の絵」を２次元的にプロットしたものです．縦軸は【危険】と【安全】、横軸は【有用】と【無用】をそれぞれ意味する軸です．図のなかで、「左上」の空間は【危険】で【無用】、「右上」の空間は【危険】で【有用】、「右下」の空間は【安全】で【有用】、「左下」の空間は【安全】で【無用】をそれぞれ意味する空間であります．人びとは【危険】で【無用】な事象は拒否ないし回避します．逆に、【安全】で【有用】な事象は接近ないし受容します．「核兵器」「癌」「地震」などはいずれも拒否の対象となる悪者で、逆に「Ｘ線」「日本の原発」「ウラン」などは受容の対象となる必需品となっていることが分かります．「プルトニューム」は微妙に【有用】の方が【危険】より勝っており、拒否というよりは受容されやすくなっています．

図２は、原子力の素人（大学生とその両親）の「頭の中の絵」の２次元的プロットであります．専門家の「頭の中の絵」と著しく異なるのは、「Ｘ線」を除くすべての原子力関連事象が【危険】の方向に引かれていることであります．これは、暗黙に「沈黙の大多数」の頭の中では、原子力に関連する事象が、全体として受容よりも拒否に近い意味を持っていることを示しています．したがって、「沈黙の大多数」に対するコミュニケーションは、親切に、分かりやすく、事実に基づき、さらに言葉よりも行動によって、【危険】感を減じ、【有用】感を増すような内容のものでなければなりません．このうち、最も重要なのは、行動によるコミュニケーションです．口で安全を説くことは容易ですが、

もし大事故が起これば、信憑性は完全に破壊されてしまいます．ここでいう行動とは、社会的に問題となるような「大事故を起こさない」の一語に尽きます．

最後に、昨年、大学生を対象に行った同種の分析の結果（図３）を御紹介します．図で見ると、最近の大学生の「頭の中の絵」には、「原子力発電所」よりももっと悪い悪者がいることが分かります．悪者の第一は「喫煙」です．第二は「食品添加物」、第三は「野菜に対する放射線照射」です．これらはいずれも「健康」に直接関連する事象であり、【危険】で【無用】だと切り捨てられています．これに対して「原子力発電所」は【危険】ではあるが【有用】と評価されています．この結果は、四面楚歌の原子力にとって、やや明るい材料といえましょう．

４．日本の民主主義と原子力

最後に日本の民主主義について、一言つけ加えておきたいと思います．わが国の民主主義は戦後に発達したものでありますが、戦後４５年を経て、今や成熟期に達しつつあるということができます．今日、すでに戦後世代が国民の大多数を占めています．それとともに、「知る権利」や「選択の自由」は、社会的・文化的諸価値の多様化とあいまって、時代の精神となっています．原子力の場合も例外ではありません．原子力の選択は、国民の理解と納得を得て、初めて民主主義の原則に適うものとなります．かつてヘフリー氏がいみじくも指摘したように、原子力が単なる技術の問題でなくなってから１０年以上も経ちます．いまや原子力は、技術というよりは、社会の問題であります．半数を女性が占める「沈黙の大多数」の理解と納得を深め、原子力の究極的安全性と資源に乏しい日本にとっての計りしれない恩恵を確信してもらうために、単なる「ことば」だけではなく、実際の「行為」による「沈黙の大多数」との対話が必要とされる所以であります．

ＮＨＫ「原子力」世論調査

Opinion Poll On Nuclear Power Conducted by Japan Broadcasting Corporation (NHK)

調査日 １９８８年１０月２２日・２３日

Dates of the Poll October 22 and 23, 1988

回答者 全国１８００人個人面接

Respondents A Total of 1800 National Samples Interviewed

放送 １９８８年１１月４日、ＮＨＫ「朝のニュース」で放送

Broadcasting Results of the Poll were summarized and broadcast over a TV morning news program on November 4, 1988.

１． 原子力発電の安全性について

Safety of Nuclear Power Generation

安全 Safe	５％
どちらかといえば安全 Rather Safe	２２％
どちらかといえば危険 Rather Dangerous	４６％
危険 Dangerous	２０％
その他 Other	８％

２．安全性についてのデータ公開

Accessibility to Data Regarding Nuclear Safety

十分公開している Sufficient	３％
どちらかといえば公開している Rather Sufficient	１４％
どちらかといえば不十分 Rather Insufficient	４７％
不十分 Insufficient	２５％
その他 Other	１２％

３．原子力発電について

Nuclear Power Generation

積極的に進めるべきだ Should Be Positively Pursued	７％
慎重に進めるべきだ Should Be Pursued With Caution	５３％
これ以上進めるべきでない Should Not Be Further Pursued	１９％
やめるべきだ Should Be Stopped	１１％
その他 Other	１０％

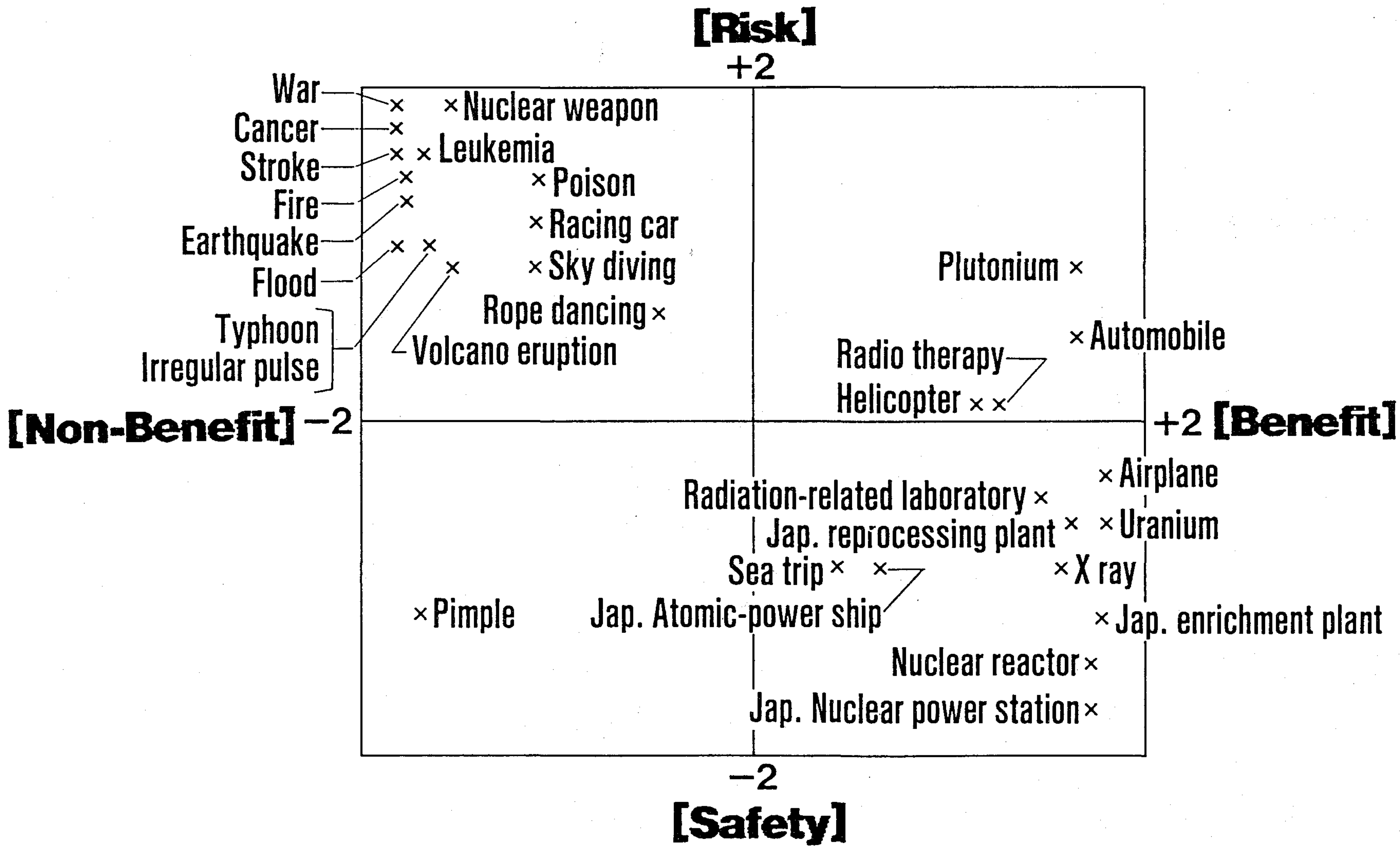
４．反対運動について

Anti-Nuclear Campaigns

関心があり、共感できる Interested, and Sympathetic	２８％
関心はあるが、共感できない Interested, But Not Sympathetic	４８％
関心がない Not Interested	１７％
その他 Other	８％

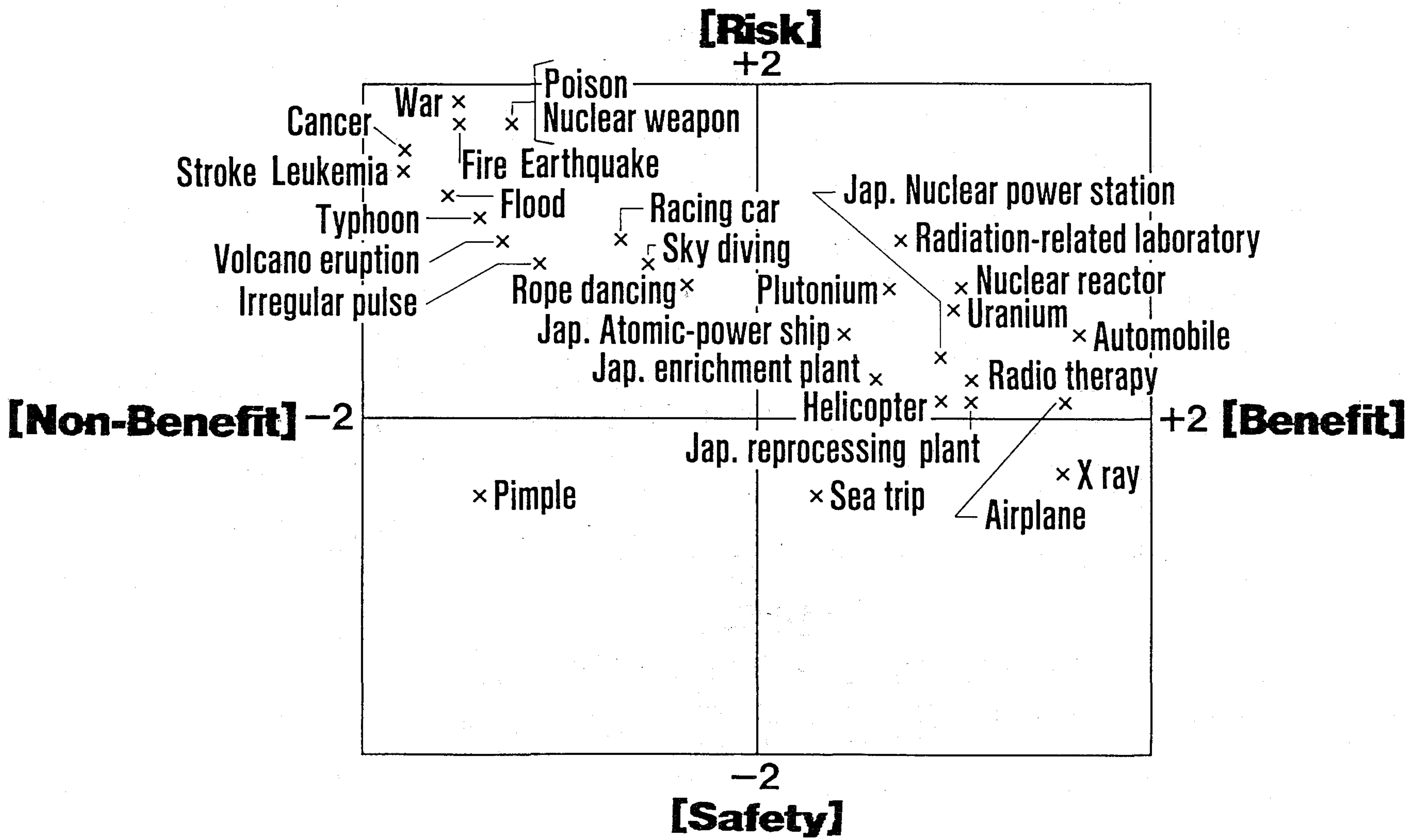
"RISK" AND "BENEFIT" TRADE OFF ON 30 EVENTS

1. SPECIALISTS N=545 (TANAKA. 1981)



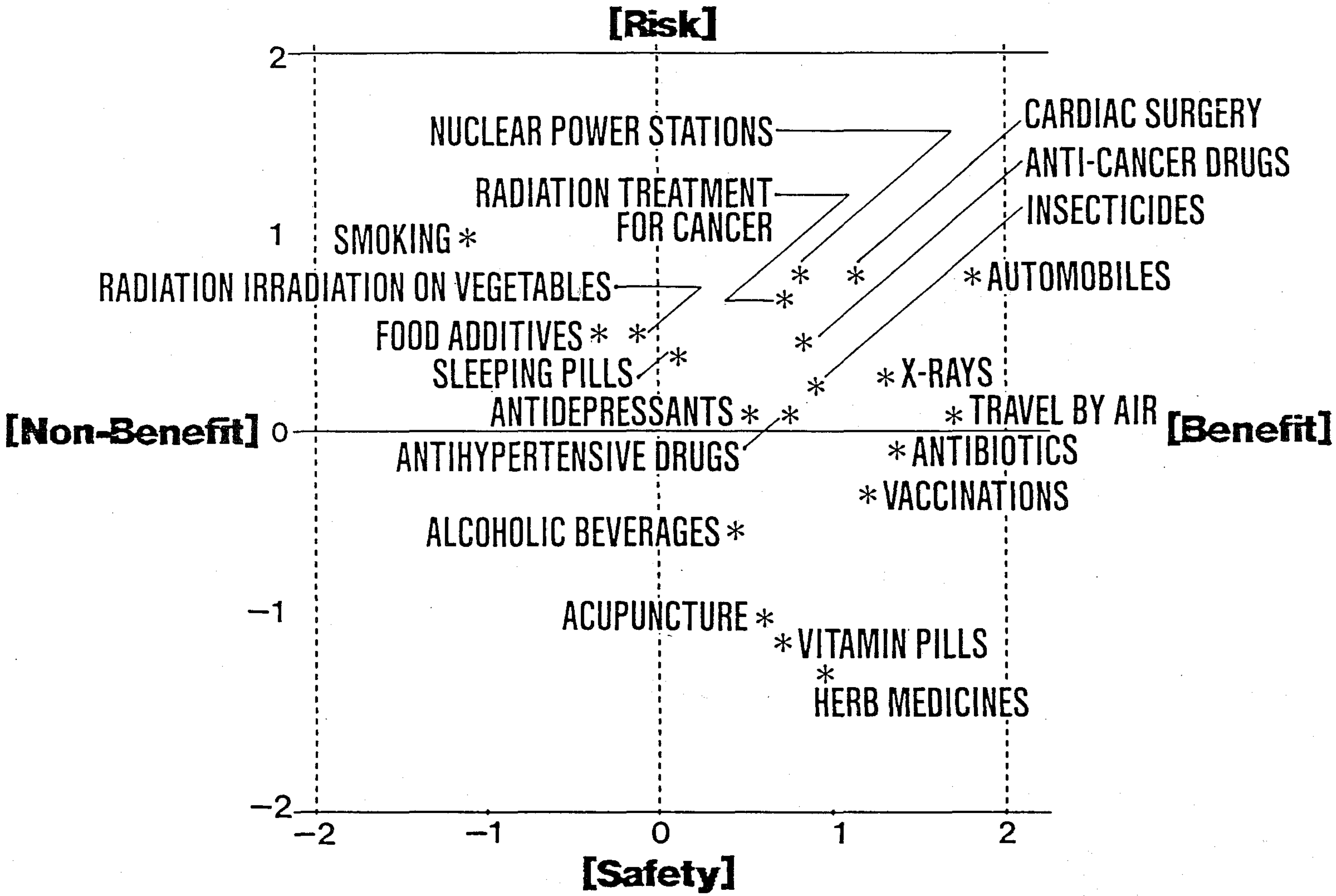
"RISK" AND "BENEFIT" TRADE OFF ON 30 EVENTS

2. LAYMEN (COLLEGE STUDENTS AND THEIR PARENTS) (Hirano.1983) N=474



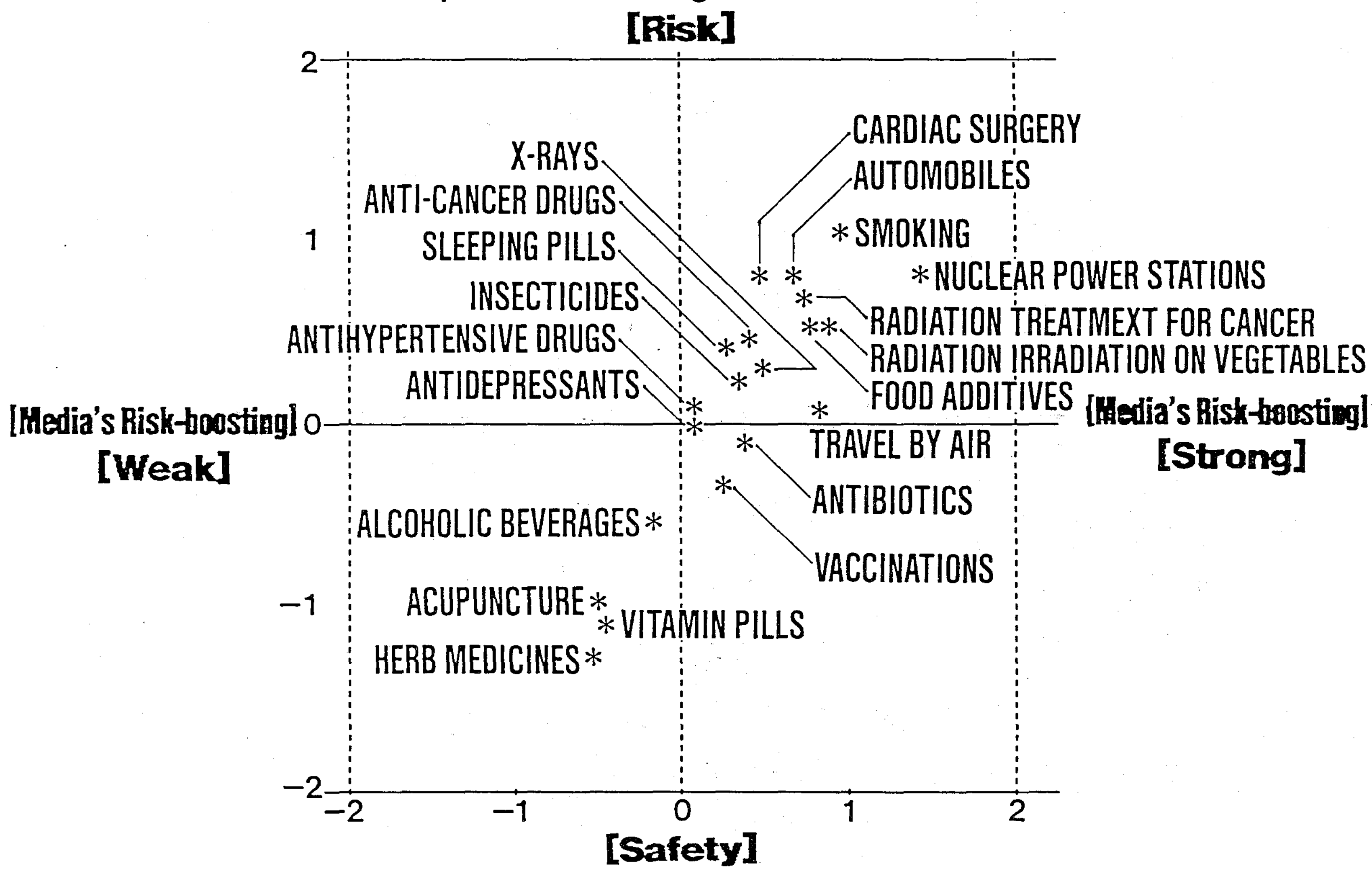
"Risk" and "Benefit" Trade-Off on 20 Critical Events (Tanaka, 1988)

Respondents: College Student N=630



Media Effect on "Risk Perceptions" on 20 Critical Events (Tanaka, 1988)

Respondents: College Student N=630



午餐会

通商産業大臣所感

通商産業大臣
三塚　博

特別講演：現代人の生き方

作家
曽野綾子

通商産業大臣　所感

一（はじめに）

通商産業大臣の三塚博でございます。

本日は、第二十二回原産年次大会、午餐会にお招きあずかり、原子力の開発、利用に長年携わってこられた皆様と、親しくお話しできる機会を得ましたことに対し、まずもってお礼申し上げます。

二（原子力推進の必要性）

御高承のとおり、エネルギーの安定的な供給の確保は、経済の発展及び国民生活の向上に不可欠の前提であります。天然資源に乏しく、石油依存度が高いといった脆弱なエネルギー供給構造を有している我が国は、その克服に向けて、石油代替エネルギーの開発導入に総力を挙げて取り組んできております。なかでも原子力は、供給安定性、経済性、更には環境面等においても優れた特性を有しており、我が国は石油代替エネルギーの中核として、官民協力してその開発・利用を着実に進めてまいりました。今や、原子力は、我が国の一次エネルギー供給の約一割、総発電電力量の約三割を賄うに至っております。

しかし中長期的には、世界のエネルギー需給は、発展途上国を中心とした需要の大幅な増大等により、石油需給の国際的逼迫が予想されるところであります。我が国は、他の諸国に比し、より深刻な状況に直面することは避けられず、私としては安定的成長を確保するため、今後とも、長期的エネルギー需給の見通しに立ち、原子力の利用拡大を進めて参る所存であります。

三（安全確保対策の充実）

原子力の利用拡大を進めるに当たっては、申すまでもなく安全確保が大前提であります。

幸い、我が国の原子力発電は、概ね四半世紀に亘り、官民挙げて安全確保の努力を重ね、世界最高水準の安全運転実績を挙げて参りました。最近においては残念ながら、東京電力の福島第二原子力発電所３号機における故障・トラブルが、地元住民の方々に不安感を与えております。

通商産業省といたしましては、こうした状況に対し、事故・トラブルの原因究明の徹底や所要の研究開発の積極的な推進等により安全確保対策の一層の充実を図るべく、最大限の努力を傾注していく所存であります。関係の事業者の皆様におかれましても原子力の安全確保に一層の努力を払われるよう期待するものであります。

四（Ｐ．Ａ．対策の充実）

また、原子力の開発利用の推進は、国民の十分な理解と信頼なくしては不可能であります。特に最近、国民の間で原子力に対する関心が高まりを見せており、原子力の必要性と安全性について、国民に正しい知識をもって頂くことが以前にも増して重要になっております。政府といたしましては、全国の国民各層を対象に、よりきめ細かな広報活動を積極的に展開し、原子力に対する国民の理解と信頼の確保に努めてまいる所存でございます。

五（核燃料サイクルの確立）

さらに、原子力のもつエネルギー・セキュリティー面での優位性を十分に発揮するためには、核燃料サイクルの確立を図ることが不可欠であります。かかる観点から、現在、青森県六ヶ所村において進められている、核燃料サイクル三施設の建設計画の円滑な推進は、我が国原子力利用全体にかかわる重要課題であります。

通商産業省としては、本施設を、原子力分野にとどまらず、東北地域における地域振興の中核ともなり得るものと認識しており、引き続き積極的に支援し

て参る所存であります。

六（国際協力の推進）

原子力の開発利用を進めるに当たっては、世界的な視野も忘れてはなりません。原子力については元来、平和利用や安全の確保のために国際協力が行われて参りましたが、最近では、地球温暖化等の環境問題への対応策として、原子力の役割への期待が高まってきております。通商産業省といたしましても、国際機関の活動への積極的な参画等、国際面で協力を強化してまいる所存であります。民間におきましても、本年三月に、原子力発電事業者国際協会のアジア地域センターが東京に設立されたところであります。アジア地域の原子力先進国である我が国が、高い技術力を生かして、安全確保に積極的役割を果たしていくものと期待しております。

七（おわりに）

以上、我が国としての原子力の開発利用に対する基本的考え方を申しあげてまいりました。

私と致しましても、御列席の皆様方を始めとする内外の関係者全員の英知が、原子力の安全で着実な開発利用に向けて結集されることにより、本大会が世界の原子力開発利用の推進に多大の貢献をされますことを強く期待するものであります。

最後になりましたが、年次大会をかくも盛大に開催されました日本原子力産業会議の皆様に敬意を表しますとともに、皆様の御発展を心からお祈り申し上げまして、私の挨拶といたします。

セッション３
原子力技術の新展開

燃料供給技術 ── ウラン濃縮と改良型乾式転換法
イギリス原子燃料公社（ＢＮＦＬ）副社長
Ｗ．Ｌ．ウィルキンソン

ＦＢＲ燃料サイクル技術
動力炉・核燃料開発事業団理事
佐々木　壽　康

未来のための革新的設計の液体金属炉
ゼネラル・エレクトリック社（ＧＥ）副社長
Ｂ．ウォルフ

原子燃料のリサイクル利用 ── 技術革新への挑戦
フランス原子力庁（ＣＥＡ）原子力研究開発計画局長
Ｒ．ラルマン
コジェマ社（フランス核燃料公社）副社長
Ｊ．Ｐ．ルジョー

原子力ロボット
極限作業ロボット技術研究組合技術委員会原子力部会長
井　元　一　彦

クリーンな環境をつくる放射線
日本原子力研究所高崎研究所長
町　　末　男

がん治療での放射線の医学利用の最前線
国立がんセンター病院放射線治療部長
柄　川　　順

PRESENTATION BY DR W L WILKINSON,
British Nuclear Fuels plc

Introduction to Video

BNFL has always put great importance on the need for technical innovation to support its nuclear fuel cycle activities. The Company is perhaps best known in Japan for its activities at the back-end of the fuel cycle; that is for irradiated fuel transport, storage, reprocessing and waste management. However, BNFL's operations extend over the whole nuclear fuel cycle. The video you are about to see, whilst reviewing briefly all the areas of the Company's application of advanced technology, concentrates on two areas at the front-end of the fuel cycle.

The two areas are the use of advanced centrifuge technology for the enrichment of uranium and the integrated dry route (IDR) for the conversion of enriched uranium hexafluoride to ceramic grade uranium dioxide powder.

After a brief introduction to nuclear fuel cycle services offered by BNFL,the video you are about to see first reviews the development of enrichment technology in the UK starting with the Diffusion Plants built in the 1950s, the establishment of the Urenco organisation to develop and exploit the centrifuge process, to the development of the laser isotope enrichment process.

The video then describes the single step integrated dry route (IDR) to convert enriched uranium hexafluoride into ceramic grade uranium dioxide powder and highlights the advantages this process has over the alternative multi-stage wet route, both in the process itself and in the quality of the product produced.

VIDEO PRESENTATION HERE

Summary

The video you have just seen provided you with an insight into two important areas of the fuel cycle which benefit from advanced technology.

In the case of the IDR process BNFL has successfully developed an innovation of the early 1970s and customers in 10 countries are benefitting from the process and recognise its reliability and versatility

BNFL has nearly 20 years experience in the production of IDR powder on a commercial scale and has refined the process to a high degree.

Since the Springfields plant began operations in the early 1970s it has produced more than 6000 te U of which more than two-thirds has been exported. The remaining one-third was used to meet requirements of British AGR reactors and over 1500 te U of this fuel has used uranium recovered from the reprocessing of Magnox fuel. The IDR process therefore already has an impressive record in dealing with reprocessed uranium.

The important advantages of the process are:-

(i) it carries out the conversion process in one step;

(ii) the exceptionally pure and consistent uranium dioxide powder can be used to meet the specific pellet requirements of the many fuel types required by different nuclear reactor systems;

(iii) the IDR process produces minimal effluents;

(iv) it is the ideal technology for use in the fabrication of fuel from recycled uranium and is better suited to this than the traditional wet routes.

In the field of enrichment, major advances have been made possible because of the considerable R&D effort committed by the Urenco partners to the centrifuge project. This has been a great success, not only in technical terms but also in the field of international collaboration. The result is a low cost, flexible and efficient process. It has the important added advantage of being able to handle recycled uranium.

Further development of the centrifuge is planned and a machine will be available by the mid-1990s which will have a unit output some twenty-five times that of the machines running in the early 1970s.

Whilst laser isotope separation may currently show little economic advantages over these advanced centrifuge machines, its long term potential is considerable. BNFL therefore intend to exploit this exciting and promising new technology and we are already engaged on a substantial programme of development. International collaboration, so successful in the centrifuge process, could also offer significant advantages in this complex and expensive field of work.

6 April 1989

ＦＢＲ燃料サイクル技術

動力炉・核燃料開発事業団
理　事　　佐々木　壽康

Ⅰ．序

1.　ウランの潜在的なエネルギーは莫大なものであり，この貴重なエネルギー資源を，当面のエネルギーの確保はもとより，将来の世代が必要とするエネルギーの確保の観点からも，有効利用する必要がある。

2.　この前提に立って，動力炉・核燃料開発事業団は，高速増殖炉（ＦＢＲ）とその核燃料サイクル技術，つまり，Pu燃料の成型加工技術，使用済燃料再処理技術の開発を進めている。

3.　以下に，ＦＢＲ燃料サイクル技術の開発状況について紹介する。

Ⅱ．経済性目標

1.　ＦＢＲ開発の主たる目標は，資源の有効利用とエネルギーの安定確保である。しかし，ウラン需給の緩和状況が，当分続きそうな現実を踏まえると，経済性に対する要求も厳しいと受け取るべきである。

2.　したがって，石油や石炭と競合できれば良いとする考え方を取らず，今後の改良も見込んだ軽水炉との比較において，経済性達成目標を設定してみた。

3.　ＦＢＲの場合，高速中性子とNa冷却材のもたらすメリット，デメリットがある。現状では，開発の初期であることにより，デメリットが大きく影響し，建設費は軽水炉よりかなり高い。

4.　事業団の炉の開発担当部門の試算によると，今後，メリットを活用し，デメリットを緩和するための革新的な技術の開発に成功

すれば，炉の建設費を軽水炉並みにする可能性は十分ある。

5. ここでは，当面の目標として，ＦＢＲの建設費が軽水炉の 1.1倍で，燃焼度を15〜20万ＭＷＤ／Ｔとすることができたとして，燃料サイクル・コストがいくらであれば良いかを検討した。

6. 原子力の場合，炉の資本費が高く，燃料費が安いという特性があるため，この建設費の１割の割高分は，燃料サイクル費を数割減らすことを必要とする。

7. 「平準化・減額方式」（Levelized Discount Method），つまり，必要な経費（建設費，運転・維持費，燃料サイクル費等）あるいは収益（発電量，回収Puクレジット等）をその生ずる時間の経過にしたがって減額して評価してえた発電コストでは，燃料重量当たり，対軽水炉比が，再処理費で 2.5倍，成型加工費で３倍以下を達成すれば，ＦＢＲは，軽水炉と経済的に競合しうることになる。

8. この時の両者のコストを比較したものを図－１に示す。コスト試算の前提条件は，表－１の通りである。

   - 図－１に示す如く，前述の条件を満たすＦＢＲは，改良型軽水炉と経済的に競合できる。
   - 燃料サイクル費は，軽水炉が全体の約30%，ＦＢＲが約20%になっている。

9. 燃料サイクル費の内分を図－２に示す。

   - 核燃料取得に必要な経費は，軽水炉のウランの購入費と濃縮費にＦＢＲのPu購入費が対応し，増殖の効果もあって，ＦＢＲが安い。
   - 成型加工費は，ＦＢＲの場合，重量当たりは高いが，燃焼度を高くすることによってほとんど補償される。
   - 再処理等のバック・エンド費は，ＦＢＲの場合，重量当たりは高いが，燃焼度を高くすることによって，むしろ軽水炉より安

くなる。

Ⅱ. 再処理技術開発

1. 開発スケジュールを図－3に示す。
   - これまで，コールド・モックアップ試験施設「ＥＤＦ」による工程機器開発，遠隔保守技術開発等及びホット・ラボ「ＣＰＦ」によるプロセス・テストを行って来ている。今後は，現在計画中のホットの工学規模の試験施設「ＲＥＴＦ」による先進機器のホット試験を進める。
   - その成果を，もんじゅ及び実証炉の燃料を処理するパイロット・プラント「ＦＲＰＰ」に反映し，さらに，将来の実用プラントへ繋げて行くこととしている。

2. ＦＢＲ燃料の特徴を表－2に示す。また，ＦＢＲ使用済燃料再処理技術の主な開発項目を表－3に示す。
   - ①集合体構造が異なること　②燃焼度が高いこと　③Pu含有度が高いことから，軽水炉再処理技術と異なった技術を必要とする。

3. ＲＥＴＦに向けて現在開発中の技術の概要を以下に示す。

1) 燃料集合体解体，剪断

① 解体機

・ＦＢＲ燃料は軽水炉燃料と違い，ラッパ管で燃料ピンを拘束しているので，その切断除去が必要となる。これに，機械式回転刃に比べ部品の交換頻度が少ないレーザー法を開発中である。

・主な開発事項は

ａ．最適切断条件の選定（被覆管を損傷しないで，ラッパ管切断）

ｂ．構造コンパクト化

ｃ．解体・剪断の一体化

② 剪断機

・軽水炉燃料との以下のような違いを考慮して，開発中である。

ａ．グリッドがないこと（剪断中の燃料ピンの拘束）

ｂ．ラッピング・ワイヤがあること

ｃ．燃料ピンが細いこと

ｄ．被覆管の材質が異なること

・主な開発事項は

ａ．詰まり防止（被覆管，ワイヤ等の切り屑の詰まりによる摺動部の作動不良防止）

ｂ．剪断片の均一化（開口部形状の均一化）

2) 燃料溶解

・Pu含有量が多く臨界管理が厳しいことから，連続化による処理能力の向上を計る。このため，ロータリー型の連続溶解槽を開発中である。

・その利点は

a．装置をコンパクト化でき，また，臨界管理上有利であること

b．将来の処理量増大に対応が可能であること

c．オフ・ガスの均一化が計れること

・主な開発事項は

a．溶解特性の把握（燃焼度，Pu富化度の違いによる変動）

b．臨界管理方法

c．ハル洗浄方法（残留溶解成分の減少）

d．遠隔保守性

3)　溶解液清澄

・高燃焼度のための不溶解性残渣（Ru，Rh等）が多いため，高効率の遠心清澄機を開発中である。

・その利点は

a．保守頻度の軽減（従来のパルス・フィルタは，フィルタ・エレメントの目詰まりによる処理能力低下を防ぐため，定期的な洗浄，交換が必要）

b．廃棄物発生量の低減（フィルタ・エレメントが不要になるため）

c．施設のコンパクト化

・主な開発事項は

a．運転条件の確認（運転条件と限界捕集粒径の関係の把握）

b．遠隔保守性の確認

4)　ＦＰ除去，Ｕ，Pu抽出

・Pu含有量が多く臨界管理が厳しいことから，処理能力の向上を指向するため，遠心速抽出器を開発中である。技術的特徴

を指向するため，遠心速抽出器を開発中である。技術的特徴は，次の通り。

	ﾐｷｻ･ｾﾄﾗ	ﾊﾟﾙｽ･ｶﾗﾑ	遠心速抽出器
ホールドアップ	百数10	数10	1
立ち上げ時間	10数時間	数時間	数　分
所要スペース	20	40	1

・その利点は

a．コンパクトで所要スペースが少なく，臨界管理も有利なこと

b．平衡到達時間が極めて短いこと

c．溶媒の放射線による損傷が少ないこと

・主な開発事項

a．抽出特性の把握

b．遠隔保守性（モータ等の定期的交換）

c．混入固形分への対応（不溶解残渣等の固形分が，抽出特性や機器の耐久性等へ与える影響の把握）

5)　遠隔保守

・保守作業時間の短縮及び保守作業時の放射線被曝低減のため，プロセス機器をモジュール化またはカセット化し，統一された寸法の架台に組み込む，ラック・システムを開発中である。

・また，これをサポートする手段として，外部との配管，電気ケーブルの遠隔継手，セル内機器を保守する両腕型サーボ・マニプレータを開発中であること。

・その利点は

a．ラック内に複数基のプロセス機器を立体的に配置するため，セル内空間を効率良く利用できること。

b．プロセスの変更，新型機器の導入及び故障した機器の交

換を容易にできること

c．大型機器のデコミッショニングを比較的容易にできること。

① ラックシステム

・主な開発事項は

a．耐震性の確認

b．アクセルが容易な機器配置及びラックの構造

c．セル壁及び床への固定方法

② 遠隔継手

・主な開発事項は

a．信頼性の確認（閉じ込め機能，耐硝酸性，耐震性等）

b．遠隔操作性（マニプレータ等によるアクセス）

③ 両腕型サーボ・マニプレーター

・主な開発事項は

a．操作性（できるだけ人間の腕に近い性能）

b．耐久性（耐硝酸性，耐放射線性等）

c．保守性

Ⅳ．ＭＯＸ燃料成型加工技術

1\. 実験炉常陽の燃料の製造を含めて，約 100トンのＭＯＸ燃料の成型加工実績があり，技術的には確立している。昨年，もんじゅ燃料の製造を主目的とする施設「プルトニウム燃料第3開発室」の運転を開始した。

2\. ＭＯＸ取扱いの技術的特徴を図－４に示す。

・包蔵性管理，放射線被曝管理，臨界管理，保障措置，核物質防護が厳しい。

・ＦＢＲ用ＭＯＸ燃料加工の特徴を表－４に示す。

・工数の比が 2.3～5倍となっており，この条件下で，コスト目標値対軽水炉比3倍を達成する必要がある。

3. 現在の技術，即ち，事業団のもんじゅ燃料製造施設をベースとする経済性の見通し

・現施設は，5 t／年の製造能力で，目標コスト・レベルの約5.5 倍。

・これに施設の一部追加で，15 t／年に能力増加可能で，目標値の約 3.5倍。

・同じ技術を用いた50 t／年程度の商用プラントでは，スケール・メリットで約 2.5倍となる。

・目標を達成するには，さらに半分以下にコスト・ダウンが必要。

・40%程度を占める集合体部材費を需要増で3分の1程度に，40%弱の施設建設費を技術開発によって半分程度に，また，操業の効率化によって，これを達成する可能性はある。

・技術開発項目は次の通り。

a．製造設備の高速処理化及びコンパクト化

 。多次元混合機の開発

 。メインテナンスフリー・ロータリープレスの開発

 。高速搬送システムの開発

 。分析，検査設備の高度化

b．ＭＯＸ加工技術の革新

 。粉末処理工程の簡素化

 。短時間焼結法の開発

 。遠隔自動保守技術の開発

 。グローブ・ボックスに代わる新包蔵技術の開発

Ⅴ．新燃料サイクル・システム

1. 高速中性子炉の特徴であるＦＰの反応度への影響が小さいこと

及びＴＲＵの燃焼に適していることの活用

2. 再処理施設の精製プロセスの簡素化（低除染あるいはPu・Ｕ非分離）

3. ＭＯＸ燃料成型加工のセル内完全自動，遠隔保守

4. 炉と燃料サイクル施設の同一サイトでの一体化

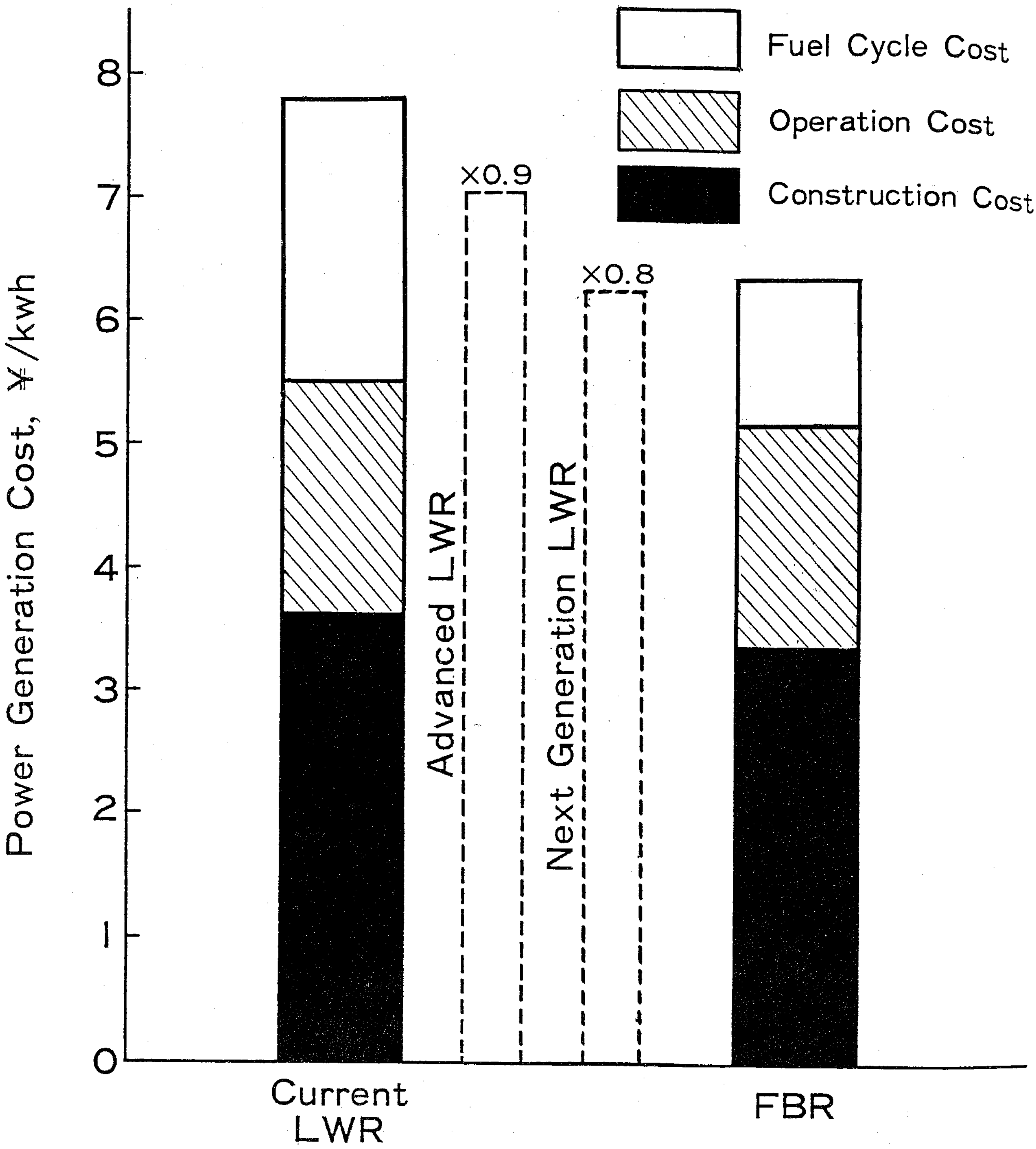
・核物質の動きを，外部から隔離することによる保障措置，核物質防護の強化

・施設（燃料貯蔵，廃棄物管理等）の共用による経済性向上

Ⅵ．まとめ

1. プラントの信頼性と安全性の確保が大前提である。

2. 事故の防止はもとより，ＡＬＡＲＡの精神に基ずき，環境への放射能放出の低減，運転員の放射線被曝の低減を計る。



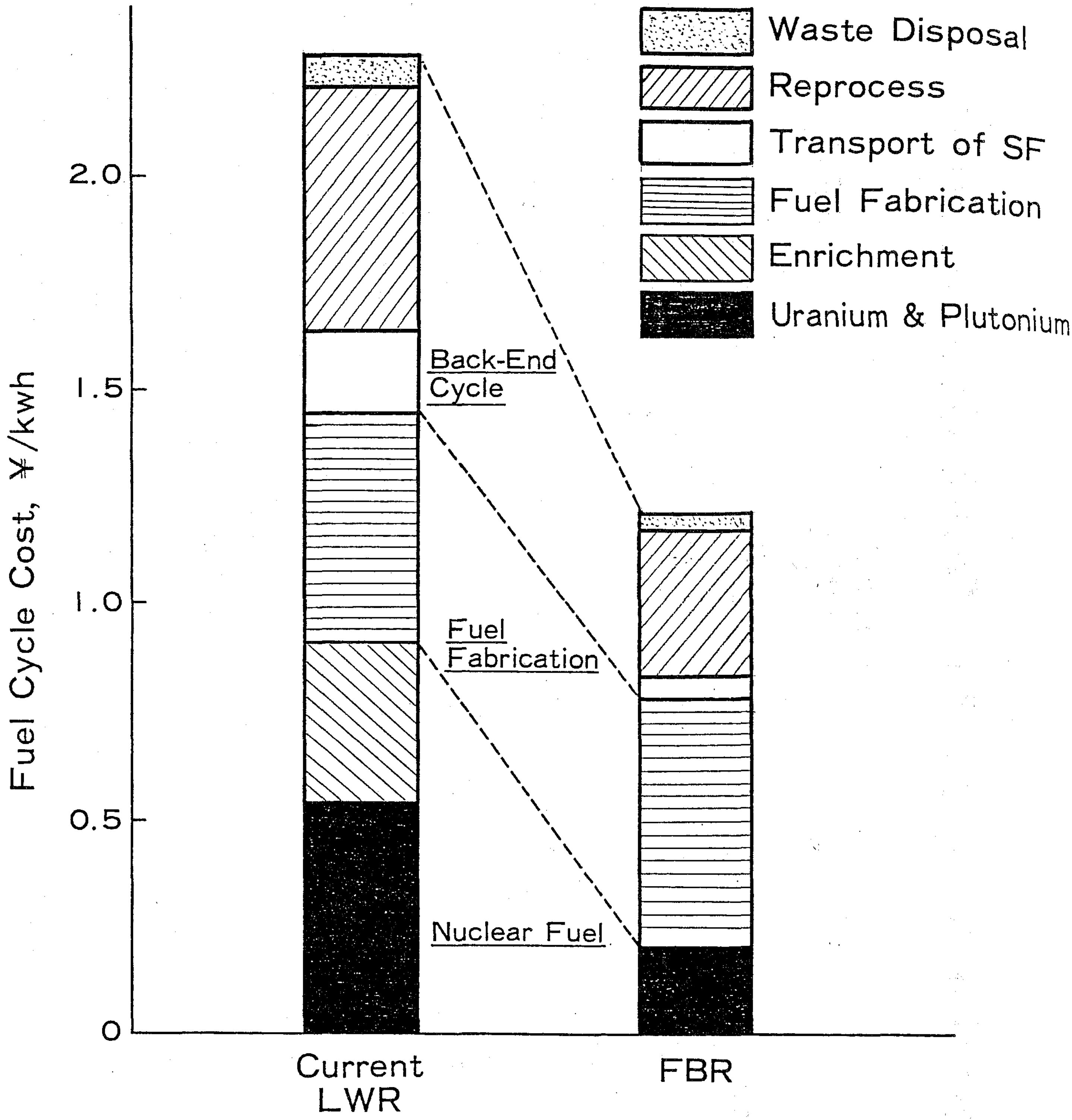
図－1

Power Generation Costs for LWR and FBR

表－1

Assumptions Used for Cost Calculations

	Current LWR	FBR
Electrical Output	1,000 MWe	1,000 MWe
Life of Plant	30 years	30 years
Construction Cost	¥3×10^5/KWe	Ratio of 1.1 to LWR
Fuel Burnup	30,000 MWd/t	150,000 MWd/t
Unit Costs for Fuel Cycle		
Uranium	\$34.6/lbU_3O_8	\$34.6/lbU_3O_8
Plutonium	\$15/gPuf	\$15/gPuf
Enrichment	\$125/kgSWU	—
Fuel Fabrication	¥87,000/kgHM	Ratio of 3 to LWR
Reprocess	¥180,000/kgHM	Ratio of 2.5 to LWR
Discount Rate	5%/year	5%/year



図－2

Fuel Cycle Costs for LWR and FBR

Long-term Schedule on FBR Fuel Recycling Technologies Development

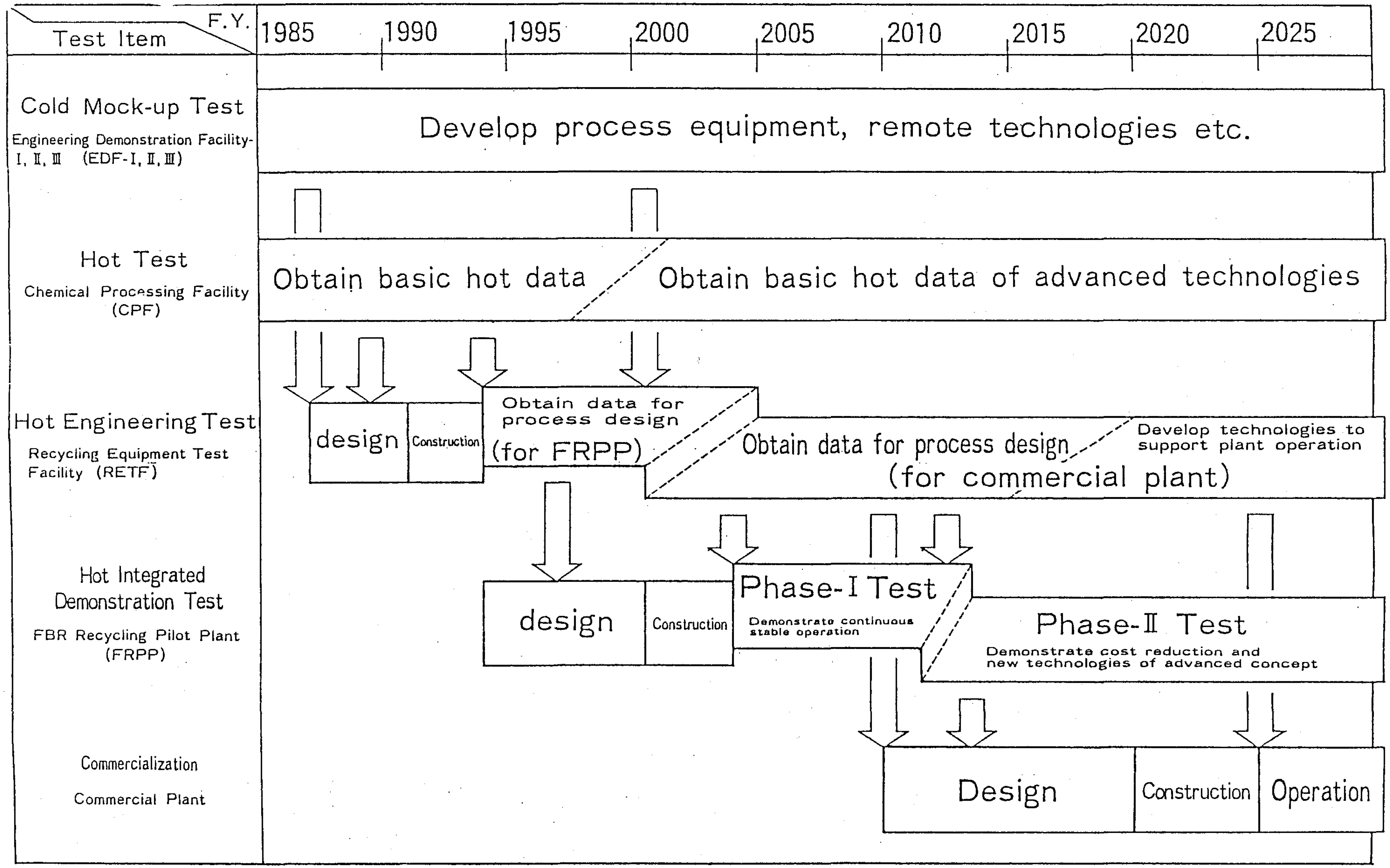


表 2

Characteristics of Assembly

Item	LWR fuel	FBR fuel
Structure of fuel assembly	Grid type	Wrapper-tube type (with wrapping wire)
Burn-up	around 50,000 MWD/T	150,000～200,000 MWD/T
Plutonium content	< 1 %	10～30%

表 3

Development Item on FBR Fuel Recycling Technologies

Item	Matters to be accomplished	Target
Structure of fuel assembly	• Disassembly of wrapper-tube	• To develop laser-beam disassembling machine • To integrate disassembly and shear into one system
Burn-up	• Removal of insoluble residue • Reduction of radiation damage on extracting solvent • Evaluation of fuel solubility	• To get higher performance of centrifugal clarifier • To develop centrifugal contactor • Hot dissolution test
Plutonium content	• Criticality safety control • Rapid processing with compact equipment	• To develop rapid processing systems (ex. continuous dissolver, rapid contactor)

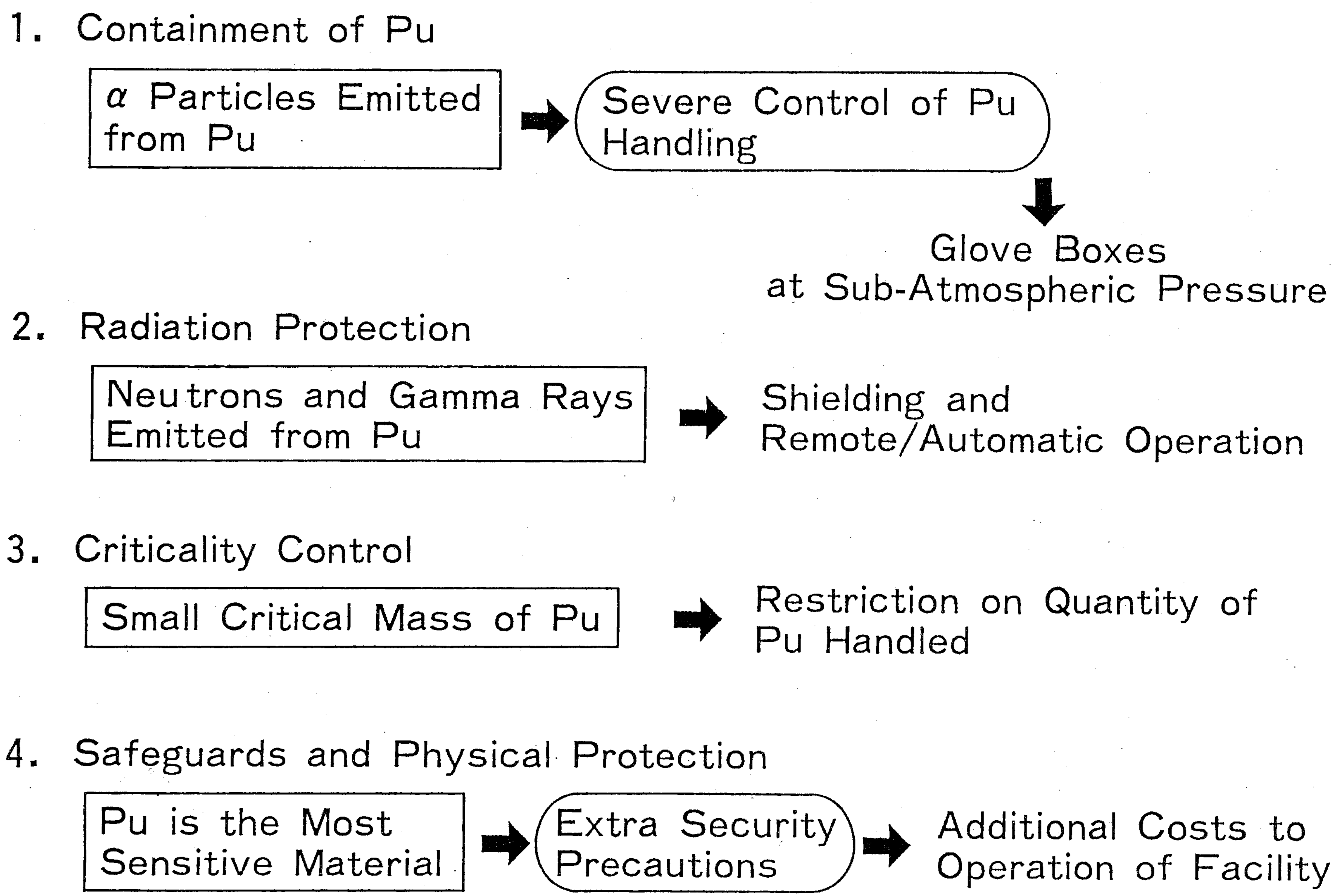


図 - 4

Restrictions and Characteristics Concerning *Pu Handling*

表－4

Features of FBR Fuel Fabrication*

Fabrication Process	Items	FBR	LWR (Pu)
Powder Process	Pu Content of MOX	13% Puf	3% Puf
	Quantity of Pu Handled	130 kgPuf	30 kgPuf
	Ratio to LWR	4.3	1
Pellet Process	Pellet Diameter	7.5 mm	8.2 mm
	No. of Pellets Handled	310,600 Pellets	134,800 Pellets
	Ratio to LWR	2.3	1
Pin Fab. Process	Quantity of Fuel per Pin	390 gMOX	1,980 gMOX
	No. of Pins Handled	2,560 Pins	510 Pins
	Ratio to LWR	5.0	1
Assembling Process	Quantity of Fuel per S/A	100 kgMOX	500 kgMOX
	No. of S/A Handled	10 S/A	2 S/A
	Ratio to LWR	5	1

* Figures based on 1 ton of fuel to be fabricated.

AN INNOVATIVE LMR DESIGN FOR THE FUTURE

Dr. B Wolfe and Mr. R.C. Berglund

GE NUCLEAR ENERGY

INTRODUCTION

In considering the development of the breeder reactor one might reflect on the early history of the light water reactor. At the start of the development of peaceful nuclear power in the mid-50's, nuclear reactors were below the 200 MWe size range and costs of construction were in the $100 million range. The 60 MWe Shippingport PWR was ordered in 1953, and started operation in 1957, at a construction cost of 120 million dollars. The 5 MWe Vallecitos Boiling Water Reactor, which was the prototype for the first commercial BWR plant, Dresden 1, was built in two years for a cost of under $5 million. The 175 MWe Dresden 1 plant was sold to Commonwealth Edison and associated utilities in 1955 for $45 million and construction was completed in 5 years. Today the size of nuclear plants has escalated to the 1000 MWe range and even trouble free projects such as those in Japan involve costs of $1 to $2 billion. One is led to 1000 MWe and larger size Light Water Reactors by the law-of-scale which has the cost per kilowatt decreasing rapidly as the size increases.

The Liquid Metal Breeder Reactor has attempted to follow the Light Water Reactor development pattern. However, there are problems with both costs and time. As we have learned from the SNR Project, Monju, Phoenix-2, and the ill-fated Clinch River Project, first of a kind large new prototype reactor construction projects now involve costs of several billion dollars. Since several prototype reactors are likely to be required before the design of a new type reactor is refined to achieve acceptable financial and operating characteristics, the cost of developing a large 1000 MWe reactor can approach the $10-20 billion figure and beyond without clear assurance of success. In addition to the cost problem there is the problem of time. Billion dollar development projects, in general, require a decade or more to design, construct and obtain the operating results which can be factored into the next development project. Allowing for several prototype projects implies development periods well beyond the creative part of most people's careers. Thus, aside from cost problems there is danger that the technical effort may become institutionalized to the point that it loses vigor.

The issue before us is whether the Breeder can be developed in a way which will overcome the difficulties outlined above. The PRISM reactor is intended as a vehicle to accomplish this objective.

PRISM was conceived during the latter part of the Clinch River Project when it became apparent that the costs of Clinch River were climbing several times over the original cost estimates. The PRISM concept makes use of small (150MWe) modules which are factory produced. The concept appears to have both technical and economic developmental advantages compared to the large size 1000 MWe and larger reactors for which Clinch River was a prototype.

The perceived advantage of the modular concept is that one can build a module, test it, modify it, and optimize it within costs and time periods which are small compared to that required to evolve an acceptable large, single-unit plant. The commercial plant is made up of a number of the optimized modules. Based on the initial work to date, the prognosis for the modular approach seems positive.

The need to aggressively pursue the development of the Liquid Metal Breeder Reactor lies in its unique capability to breed substantially more fissile material that it consumes. The utilization of this capability in modern Advanced Liquid Metal Reactors (ALMR's) may be essential in the coming century as the growth in nuclear power generation using thermal reactors consumes the currently abundant fissile uranium supply. This breeding capability alone justifies continued timely development of the ALMR, but as current studies show, there are important additional benefits that can be obtained, namely: (1) enhanced reactor performance through use of passive, inherent safety features and elimination of more complex, engineered safety systems; (2) improved standardization and licensability through certification of the design and modifications with time based on affordable full-scale prototypic tests; (3) improved economics and reduced cost and schedule risk resulting from both the more reliable licensing process and from design approaches that emphasize modular factory fabrication with minimum field labor, and (4) enhanced nuclear waste management via recycle capability which eliminates the long life high level actinides and can be further utilized to improve LWR waste management.

In 1981 GE initiated, under its own sponsorship, a program aimed at an innovative ALMR conceptual design. Work on the design concept has proceeded for the past four years under U.S. Department of Energy (DOE) programs and has resulted in the PRISM (Power Reactor Inherently Safe Module) concept. Substantial progress has been made by the U.S. PRISM team, headed by GE, which now includes Babcock and Wilcox, Bechtel, Borg Warner, Burns and Roe, Foster Wheeler, Stearns Roger Division of United Engineers and Constructors, and Westinghouse. Significant development support has been provided to this effort by National Laboratories in the U.S., including the Argonne National Laboratory in Idaho, the Energy Technology Engineering Center in Southern California, Oak Ridge National Laboratory in Tennessee, and Westinghouse Hanford Corporation in Washington.

Let me give you a brief description of this ALMR concept upon which a national effort is being focused in the U.S.

The PRISM design emphasizes a low pressure pool type LMR system enhanced by passive and inherent safety features, modular construction with maximum factory fabrication, seismic isolation and multiple loop operation capabilities. A PRISM power plant includes a number of standardized reactor modules, fabricated in a factory and shipped by whatever combination of barge, rail, and road transport that is most economic for a particular site. Except for the module and its structure, refueling facility and the reactor auxiliary systems, which are safety grade, the balance of the plant is not expected to require certification as nuclear safety grade construction.

OVERALL PLANT

The target commercial PRISM plant utilizes nine reactor modules arranged in three identical 465 MWe power blocks for an overall plant net electrical rating of 1395 MWe (Figure 1). Each power block has three standardized reactor modules, each with its own steam generator, that jointly supply saturated steam at 6.6 MPa (955 psi) to a single turbine generator. Since each power block operates independently, smaller plant sizes of 465 MWe and 930 MWe can be provided by using one or two of the standard power blocks, thus providing size flexibility to the Utilities in meeting their load demand growth.

All nuclear safety-related systems and buildings are enclosed within a double-fenced and barricaded high security area (Figure 2). The control center, intermediate heat transport system, steam generator system, and related structures, which are all not nuclear safety designated, are physically separated from the nuclear portion of the plant, and will be designed and built to high standards of industrial quality.

The reactor module, the intermediate heat transport system, and most of the steam generator system are below grade (Figure 3). Benefits that result from this include reduced capital cost and improved standardization by use of seismic isolation of the nuclear island, radioactivity containment, sodium fire mitigation, and protection from external threats such as sabotage and missiles.

The relatively tall, slender reactor geometry enhances uniformity and stability of internal flow distribution and natural circulation for shutdown heat removal (Figure 4). The relatively small reactor diameter results in a structure that is stiff in the vertical direction and thereby permits use of simple horizontal seismic isolation and eliminates any need for vertical isolation. Refueling operations are conducted, one module at a time, with the reactor shut down and the primary sodium cooled to 204°C. The other two modules of the power block will continue to operate, thus enhancing availability.

FUEL

Uranium-plutonium-zirconium metal fuel of the type under development by the Argonne National Laboratory ANL in its Integrated Fast Reactor (IFR) program has been selected as the reference for PRISM (Figure 5). This selection was based on the excellent negative reactivity feedback it provides for loss of cooling and transient overpower events, the competitive fuel costs expected to be achieved with it, and the excellent inherent safety performance demonstrated with metal fuel in the Experimental Breeder Reactor-II. Mixed oxide (UO_2/PuO_2) fuel is being retained as an alternative. The mixed oxide core will fit in the same space as the metal core with no change of internal structures required, and the two cores are interchangeable.

TEMPERATURE AND PRESSURE

The PRISM core outlet temperature is moderate, 485°C at full power. This selection enables the use of conventional, well characterized, fully qualified materials for the reactor structures, is expected to enhance fuel life, and provides significant temperature margin during accidental transients. PRISM operates at low pressure--the reactor cover gas pressure is approximately atmospheric at normal full power conditions; thus, there is minimum pressure loading on the reactor primary vessel and very little stored pressure energy available to be released if a breach of the vessel should occur. PRISM maintains overall temperature margin to boiling, over 400°C, at full power operating conditions. Even under reactor vessel breach conditions, the close coupled containment vessel will maintain excellent natural circulation for decay heat removal.

SHUTDOWN HEAT REMOVAL

Normal shutdown heat removal is via either the bypass condenser or an auxiliary air cooling system around the steam generator. In the rare event that the intermediate heat transport system (IHTS) becomes unusable during power operation, for example because of a main sodium pipe break or a sodium dump, the reactor will scram and the totally passive reactor vessel auxiliary cooling system (RVACS), which is always operating, will automatically take over full decay heat removal (Figure 6). Temperatures will rise and heat transfer to the atmospheric air circulating (by natural convection) upward around the containment vessel will increase until equilibrium between reactor heat generation and RVACS cooling is established (Figure 7). The calculated core outlet sodium temperatures for RVACS cooling after loss of all cooling by the IHTS at full power, with reactor scram, peaks after about 30 hours at a nominal value of less than 590°C with a 2σ margin below the American Society of Mechanical Engineers (ASME) service level C limit of 636°C.

The redundant air flow passages combined with substantial margins in the design make RVACS extremely tolerant of accidental flow blockages, as well as surface fouling. Even with 90 percent air blockage of the RVACS, the temperature remains well below the ASME service level D.

REACTIVITY SHUTDOWN

The plant control system (PCS) causes the six control drives to insert control elements to adjust power to respond to load requirements and to maintain the core outlet sodium temperature within specified limits. If an emergency event develops too rapidly for the PCS to control it, then the safety-grade reactor protection system (RPS) will independently sense this and will respond by "scramming" the reactor.

The PRISM core is designed to also provide strong inherent negative reactivity feedback with rising temperature. This design characteristic, combined with the RVACS heat removal capabilities makes PRISM capable of safely withstanding accidental transients without scram while maintaining investment protection. Such events include, for example: (1) Loss of all cooling by the intermediate heat transport system and loss of primary pump power from a full power condition, without scram; and (2) Withdrawal of all control rods at the maximum rate from a full power condition.

ECONOMICS

In addition to providing outstanding safety and performance characteristics, the design approach for the PRISM system (reactor and fuel) enables capital cost reductions through increased factory fabrication, expedited learning curve effects, fewer nuclear safety-related systems, and design standardization with NRC certification. The projected capital costs for the mature (Nth-of-a-kind) system over a range of plant sizes compare favorably with those projected for future LWR's and coal plants (Figure 8). Estimated busbar costs for this ALMR system also compare favorably with those projected for both future LWR's and future coal plants. While it is early in the development process, these competitive cost projections have been extensively reviewed and are felt to be achievable.

FUEL RECYCLE

The reference metal fuel pyroprocess being developed by Argonne National Laboratory (ANL) provides opportunity for reduced quantities of waste. The primary reason for this is the small process stream and fewer process steps to process metal fuel compared to processing oxide fuel. In addition, and very importantly, the higher, longer life actinides are processed with the plutonium and uranium in the metal fuel pyroprocess. Assuming the actinides are transferred with the reprocessed fuel, this could reduce the high level waste (HLW) storage requirement from millions (10^6) to hundreds (10^2) of years. (Figure 9).

ACTINIDE BURNING

The ALMR system is better suited to burn actinides than other reactor designs due to its harder neutron energy spectrum. Burning the higher, longer life actinides and selected fission products in the ALMR precludes their accumulation and requirement for subsequent burial. As indicated above, an attractive feature of the ALMR metal fuel recycle system is that the actinides are recycled with the fuel. This feature, in concert with the ALMR reactor capability to burn the actinides without significant technical or economic impacts offers an attractive waste management option. This would allow the ALMR to eat not only its own actinide waste but additionally to eat the LWR long life actinide waste as startup fuel through appropriate deployment of the ALMR system.

CONCLUSIONS

The modular approach to the breeder reactor provides a means of development which could be an order of magnitude less costly and less time consuming then that for the conventional monolithic design (Figure 10). The PRISM's features of few and simple safety systems, seismic isolation, passive decay heat removal, inherent reactivity control, and substantial margins from structural and fuel damage limits during potential accident situations result in significant gains in public safety and protection of the owner's investment. The use of a standardized and certified (by full scale test) modular design with minimum field construction and extensive factory fabrication coupled with the metallic fuel recycle system results in a plant and fuel system design that is economically competitive against projected coal plants and other nuclear design approaches in the next century.

The capability of the ALMR to efficiently burn long life actinides due to its harder neutron spectrum, could be a major asset in solving the nuclear waste management challenge. This potential for the ALMR system to not only eliminate long life high level waste from its own fuel cycle but also from the LWR spent fuel cycle could be a key factor towards better public acceptance of the nuclear option. This ALMR nuclear option offers an environmentally attractive long term energy security approach.

We believe that the program now under way in the United States for the concept just described will provide a viable road map to success at an affordable cost. The PRISM based ALMR project can be completed within 15 years from concept design, through verification testing to a standard plant certification at costs estimated in the Billion dollar range. Included in the timetable is a development program which contains all testing involving feasibility, key features, components and subsystems and, finally, full system tests which will result in a standard plant certification. The development program will derive strong support from the U.S. National Laboratories, but also incorporates an opportunity for International collaboration in areas of interest which can be of benefit in the respective ALMR programs of participating countries. We and our associates within the United States would welcome the synergistic approach to the development of a World class Advanced Liquid Metal Reactor that would result from such an International cooperative effort. We believe this would provide the industrial world with an option that would assure energy security for a millenia.

PRISM DESIGN DATA

* OVERALL PLANT

- NUMBER OF REACTORS PER POWER BLOCK	THREE
- NUMBER OF POWER BLOCKS	ONE/TWO/OR THREE
- NET ELECTRICAL OUTPUT	465/930/OR 1395 MW_E
- NET STATION EFFICIENCY	32.9%
- TURBINE THROTTLE CONDITIONS	6.6 MPA/282°C (SAT'D)

* REACTOR MODULE

- THERMAL POWER	471 MW_T
- PRIMARY SODIUM INLET/OUTLET TEMPERATURE	329°C/485°C
- SECONDARY SODIUM INLET/OUTLET TEMPERATURE	282°C/443°C

* REACTOR CORE

- FUEL	METAL (OXIDE BACKUP)
- REFUELING INTERVAL	18 MONTHS
- BREEDING RATIO	1.12, REFERENCE
	1.23, CAPABILITY

Figure 1

88-564-17r

PRISM POWER PLANT (3 POWER BLOCKS)

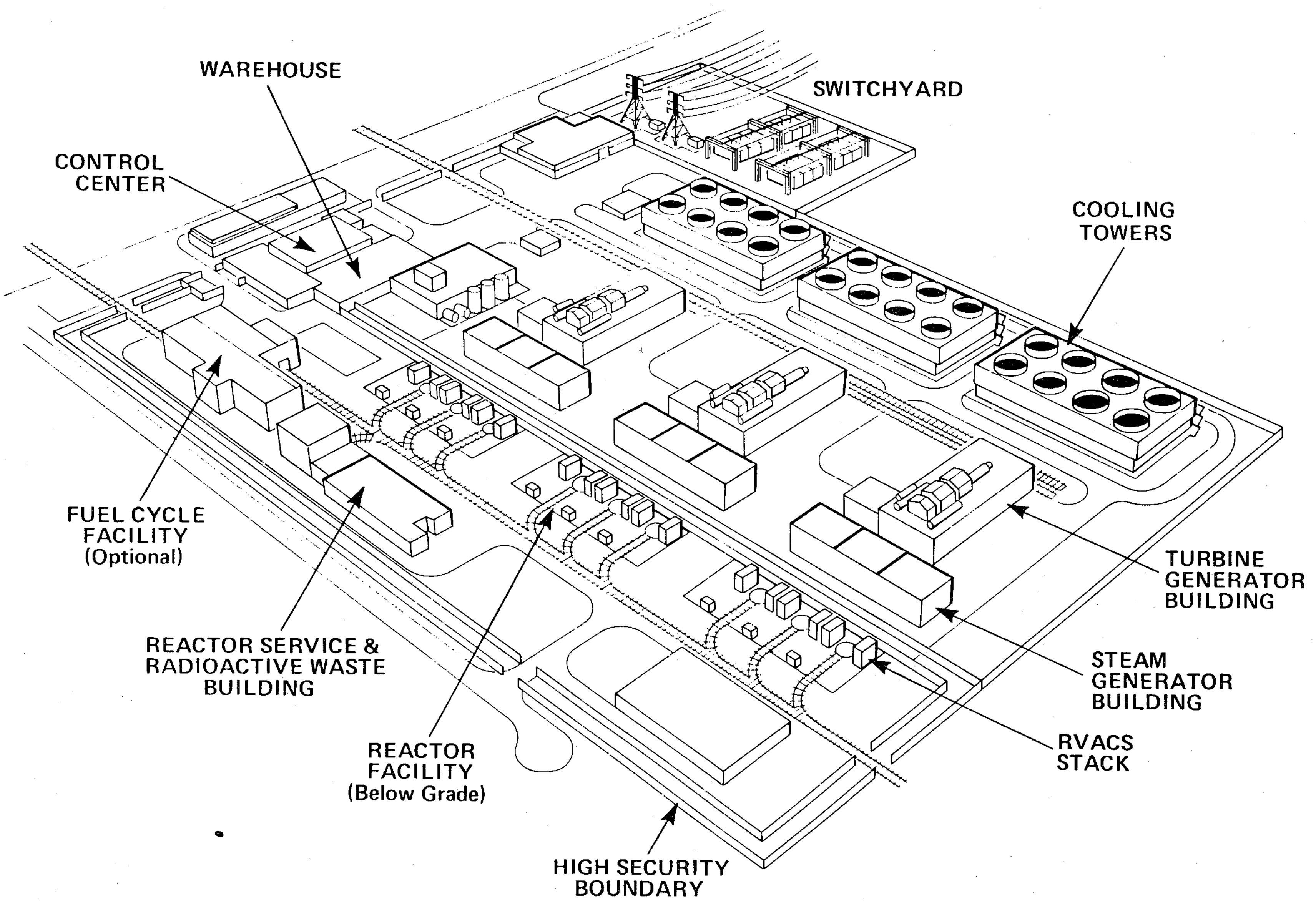


Figure 2

PRISM NUCLEAR STEAM SUPPLY SYSTEM

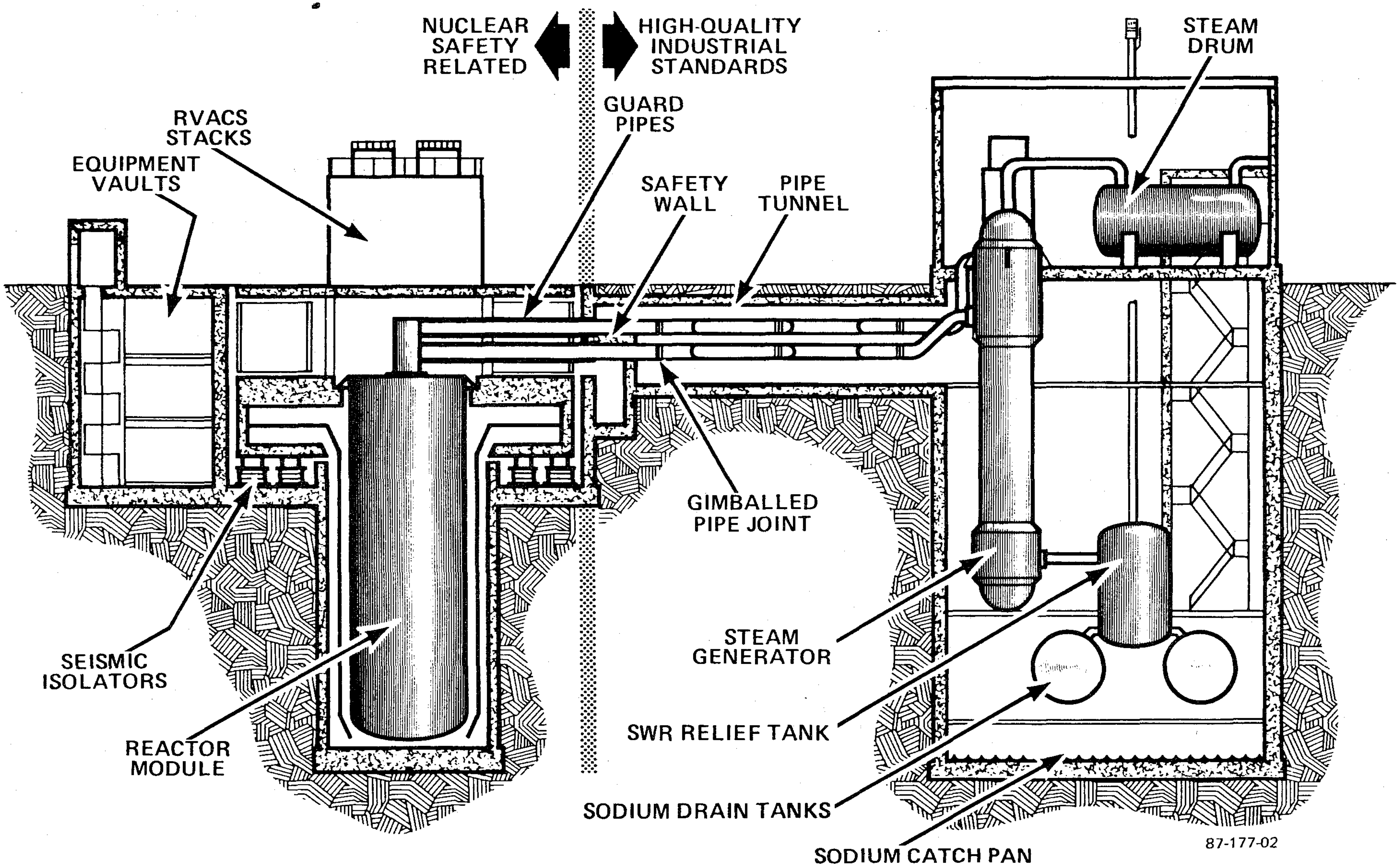
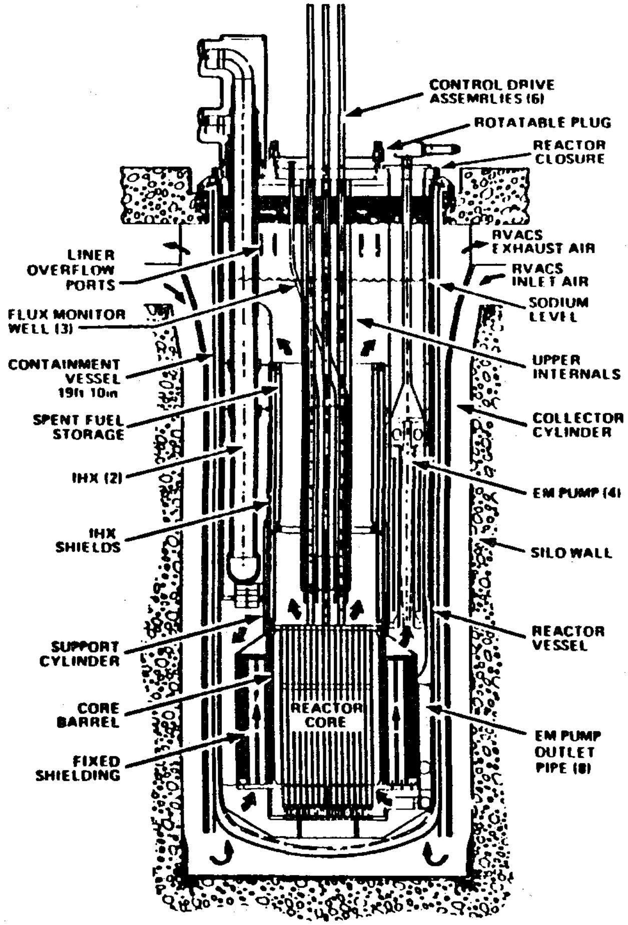
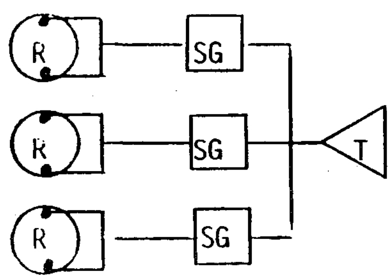


Figure 3

ADVANTAGES OF PRISM REACTOR CONFIGURATION



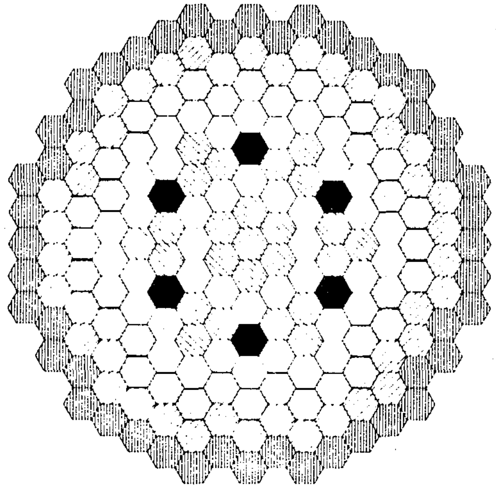


- o TALL, SLENDER DESIGN GIVES EXCELLENT INTERNAL FLOW DISTRIBUTION AND ASSURED NATURAL CIRCULATION FOR SHUTDOWN HEAT REMOVAL
- o VESSEL SIZE REQUIRED FOR INTERNAL EQUIPMENT MATCHES SIZE REQUIRED FOR RVACS WITH GOOD TEMPERATURE MARGIN (AT ~20 FT DIAMETER)
- o SEISMIC CAPABILITY ENHANCED BY HIGH VERTICAL STIFFNESS AND SMALL CORE MASS
- o SMALL CORE GIVES REDUCED ENERGY AND RADIATION RELEASE POTENTIAL FOR SEVERE ACCIDENTS
- o VESSEL DIAMETER PERMITS SIMPLE SLAB-TYPE HEAD CLOSURE
- o REACTOR SIZE ALLOWS OVERLAND SHIPMENT OF FACTORY-FABRICATED MODULE TO INLAND SITES (AT ~20 FT DIAMETER)
- o MULTIPLE PARALLEL REACTOR IHTS POWER TRAINS ENABLE CONTINUED OPERATION AT REDUCED POWER IN A POWER BLOCK DURING EQUIPMENT OUTAGES, GIVING ASSOCIATED AVAILABILITY BENEFITS

Figure 4

REFERENCE METAL & ALTERNATIVE OXIDE CORES

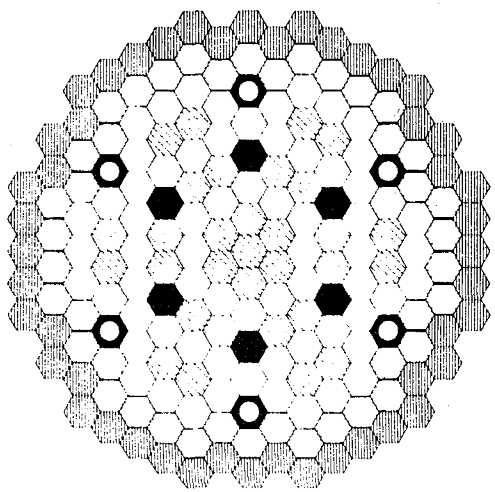
METAL CORE



FUEL	42
INTERNAL BLANKET	25
RADIAL BLANKET	36
RADIAL REFLECTOR	42
RADIAL SHIELD	48
CONTROL ELEMENT	6
TOTAL	199

THE METAL AND OXIDE CORES ARE INTERCHANGEABLE

OXIDE CORE



FUEL	66
INTERNAL BLANKET	31
RADIAL BLANKET	42
GAS EXPANSION MODULE	6
RADIAL SHIELD	48
CONTROL ELEMENT	6
TOTAL	199

	METAL	OXIDE
POWER RATING (MWt)	471	471
PEAK LINEAR POWER (kW/ft)	10.5	8.0
PEAK FUEL BURNUP (MWd/kg)	150	150
BREEDING RATIO	1.12	1.14
LIFETIME (yr) **	4.5	8
REFUELING INTERVAL (mo)	18	12
BURNUP REACTIVITY SWING, NOMINAL ($)	0.06	2.60
ONE ROD RUNOUT WORTH ($) *	0.07	0.50
SINGLE ROD SCRAM WORTH ($) *	2.60	3.80
COLD TO HOT FULL POWER REACTIVITY	2.20	2.45

* From full power at beginning of life
** With blanket shuffling

88-282-05

Figure 5

PRISM MAIN POWER SYSTEM

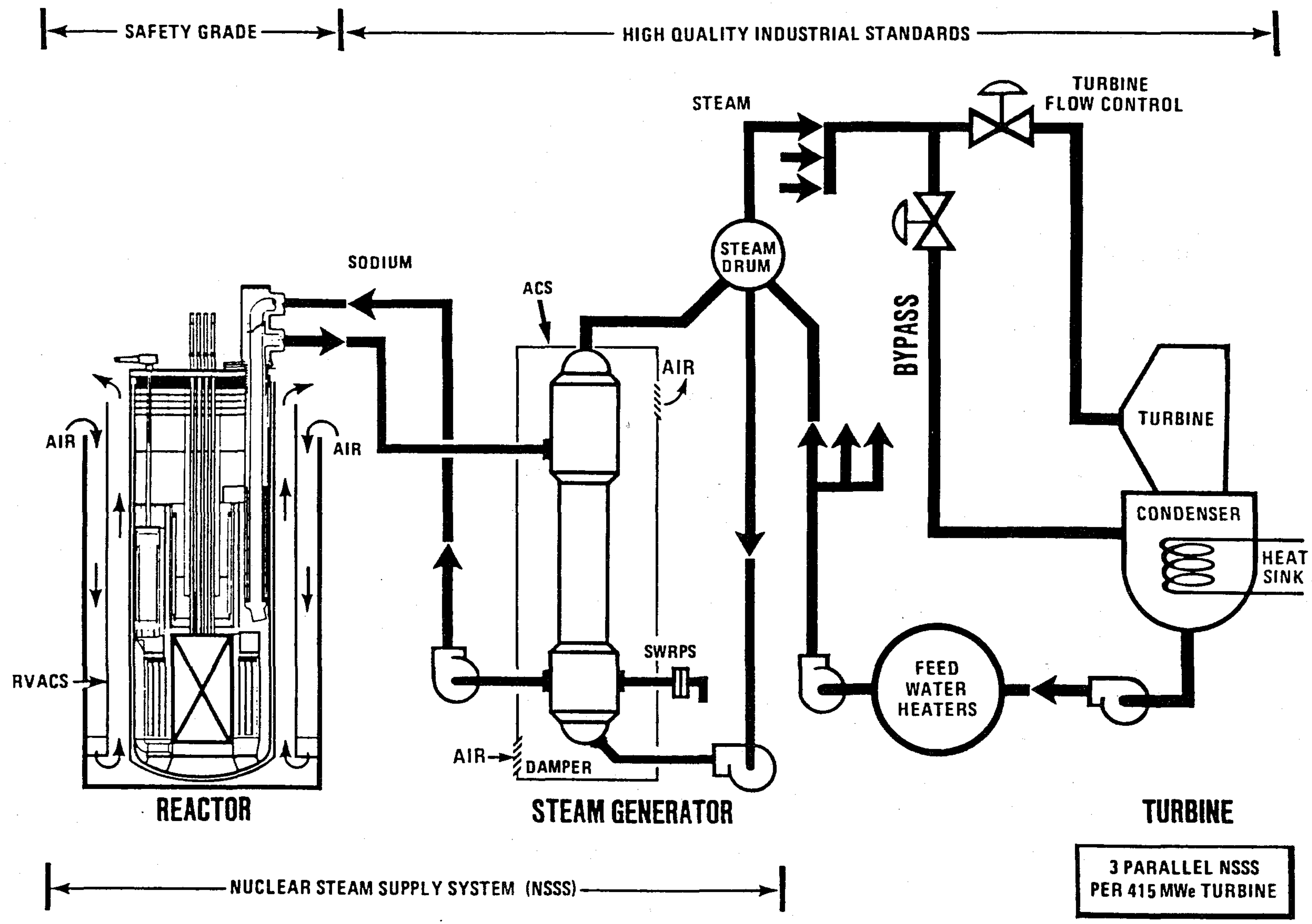
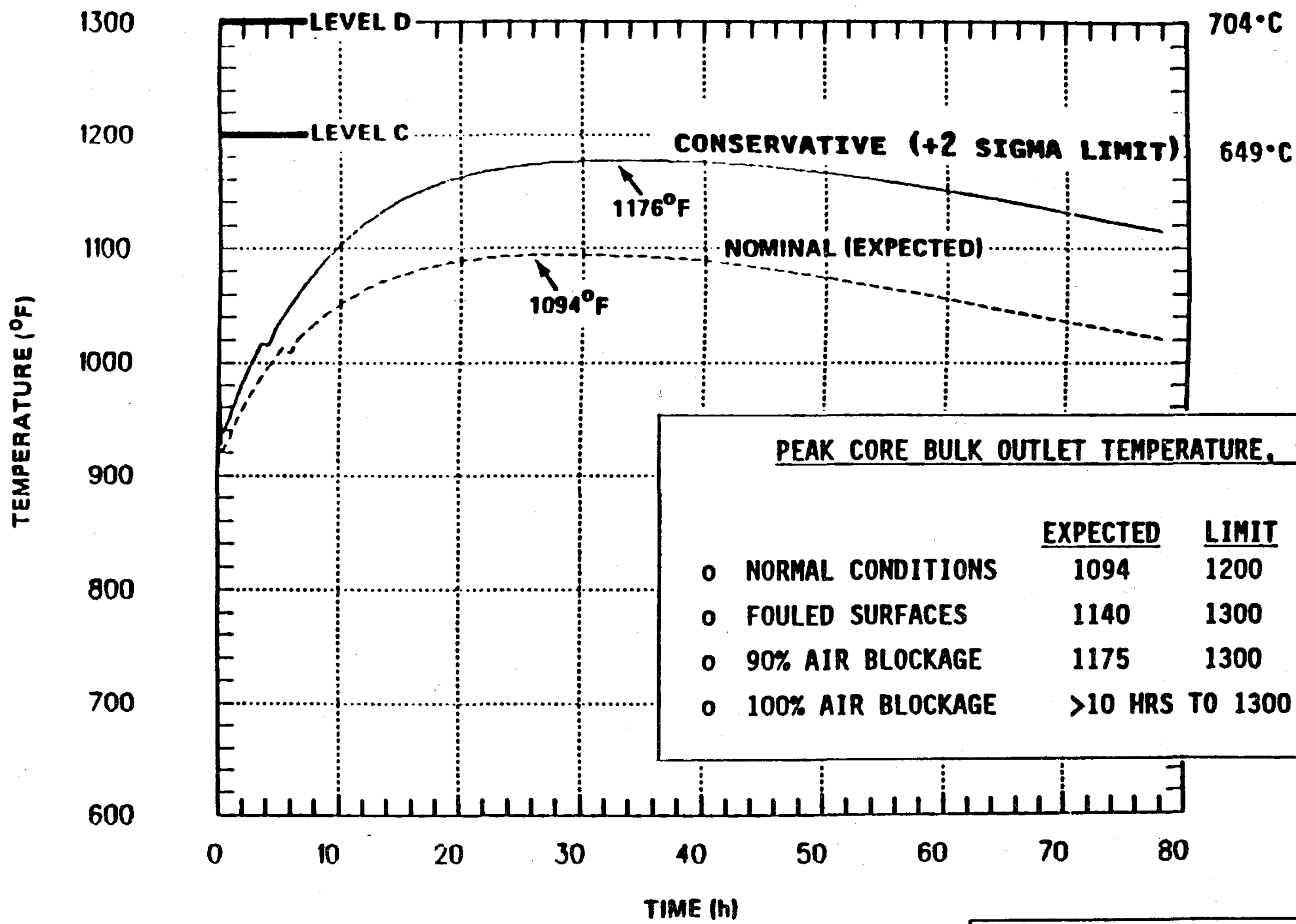


Figure 6

DECAY HEAT REMOVAL BY RVACS ONLY - CORE OUTLET TEMPERATURE

o LOSS OF PRIMARY FLOW AND IHTS COOLING WITH SCRAM



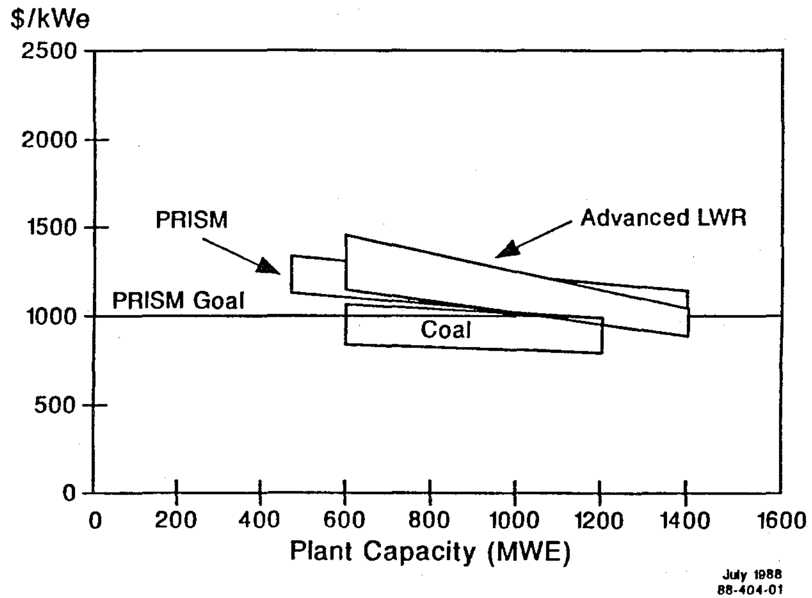
PEAK CORE BULK OUTLET TEMPERATURE, °F

	EXPECTED	LIMIT	ASME LEVEL
o NORMAL CONDITIONS	1094	1200	C
o FOULED SURFACES	1140	1300	D
o 90% AIR BLOCKAGE	1175	1300	D
o 100% AIR BLOCKAGE	>10 HRS TO 1300		

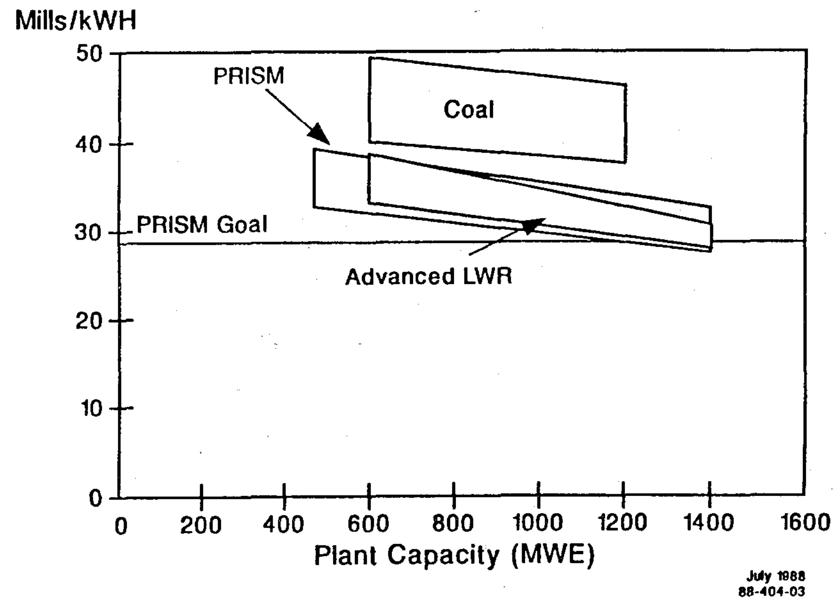
RVACS HAS LARGE MARGINS FOR FAILURE ACCOMMODATION

Figure 7

PRISM COSTS (1987 dollars)



Overnight Capital Cost



Busbar Electricity Cost

89-019-01

Figure 8

ALMR - Actinide Burning Potential

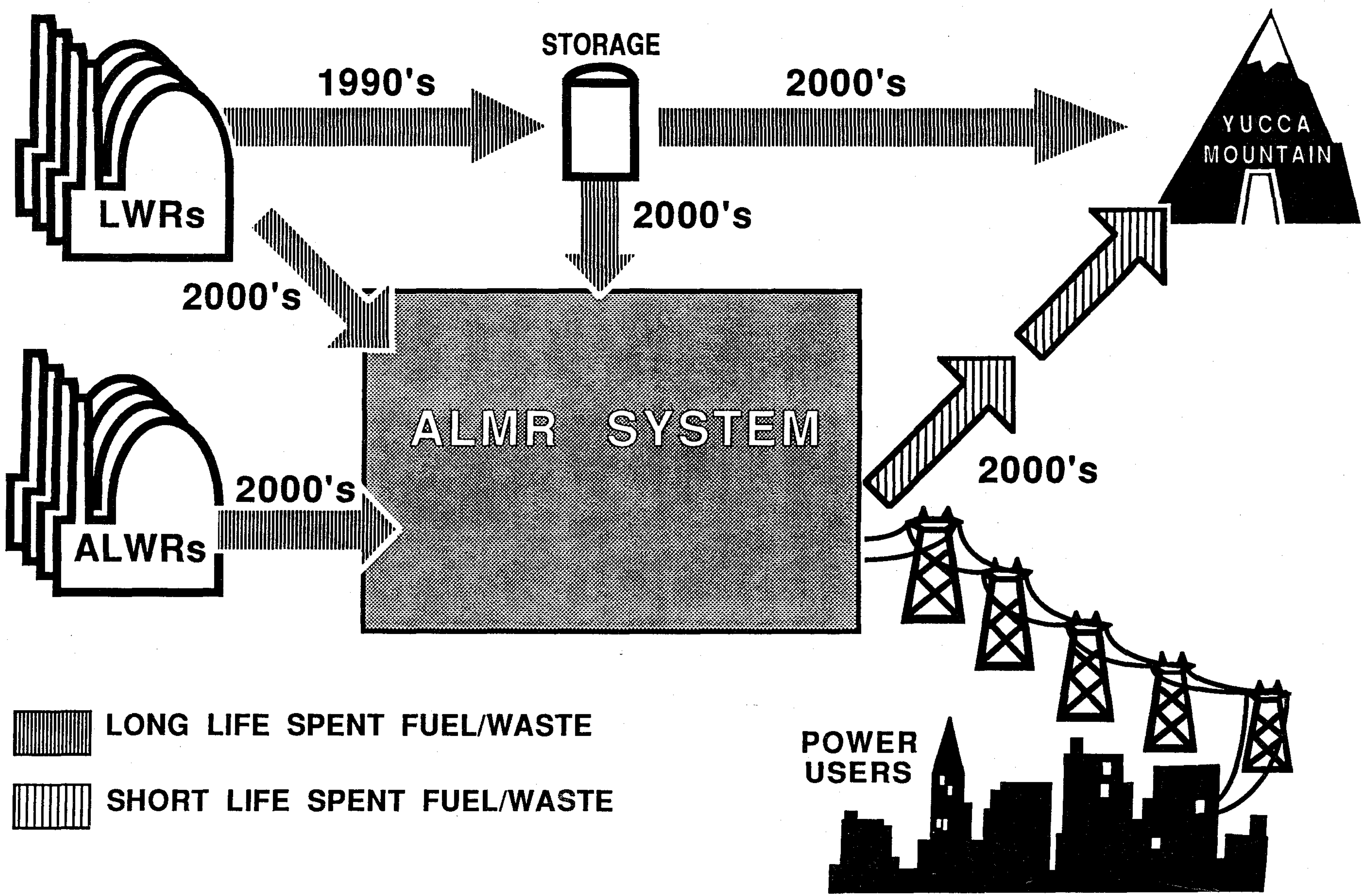


Figure 9

89-011-02

POTENTIAL ALMR PROGRAM PLAN

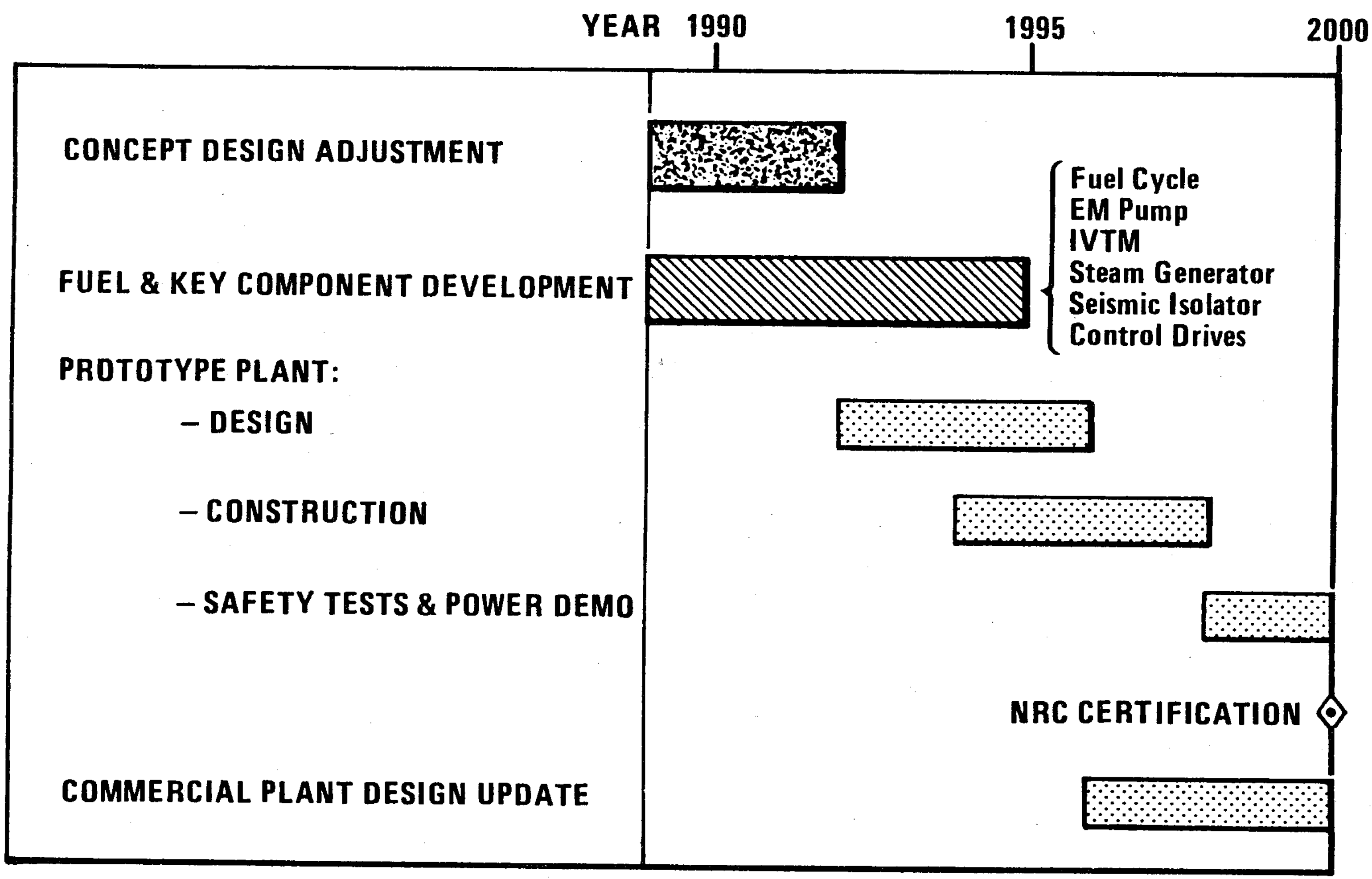


Figure 10

89-081-10

NUCLEAR MATERIALS RECYCLING, THE GREAT CHALLENGE

R. LALLEMENT, Director for Nuclear R and D programs, CEA

JP. ROUGEAU, Vice Président, COGEMA

I - INTRODUCTION

For countries like France or Japan, which have poor oil or coal as natural resources of their own, there is no alternative to the choice of nuclear energy.

In France, this choice has been made early, and maintained continuously since nearly forty years.

Today 75 % of our electricity comes from nuclear fission and oil importation has greatly decreased.

The choice of nuclear has been based on a comprehensive program, where all the steps of the nuclear cycle have been developed, from the the mining industry to the waste treatment. It must be noticed that, since the start up of nuclear electricity production in France through the gas-graphite reactors, the choice has been made to reprocess irradiated fuel.

This choice is essential and is the key point of any mature program.

We know that there are worldwide disputes about the need and the economy of reprocessing. Irradiated fuels contain plutonium, enriched uranium and fission products. It is the french conclusion that reprocessing is the safest way to handle the fission products, and it seems obvious that it is a nonsense to throw away the valuable fissile uranium and plutonium contained in the irradiated fuel.

As long as the reserves of uranium are known as limited, as long as no other method to produce electricity is known except the polluting coal and oil-routes, uranium and plutonium must remain available to mankind. Some rich countries can wait and store the fissile materials. France cannot afford this delay and has decided to utilise uranium and plutonium to produce electricity.

The great challenge of our nuclear program is to define the best strategy for uranium and plutonium utilisation leading to the cheapest cost of energy and the optimum safety of our facilities.

This is a multiparameter question, which implies the development of low cost enrichment, reprocessing, fuel fabrication and waste treatment, as well as easy to build, safe, easy to operate and cheap reactors.

The parameters are interconnected and may have adverse trends. For example it might be useless to improve the core of a reactor in the direction of better burn up and maximum utilisation of plutonium if this implies a greater complexity of the operation of the reactor and an overinvestment in reactor components or fuel fabrication plants or reprocessing.

We are going to examine the possible strategies which could be developed to meet the challenge, as well as the programs which are needed, keeping in mind the following guidelines :

1) Fission as a source of energy
2) Optimisation of energetic resources as a permanent strategic concern
3) Utilisation of uranium and plutonium as a consequence

4) Reaching the cheapest cost of KWH as a permanent goal

II - POLICY FOR PLUTONIUM AND URANIUM UTILISATION

II.1. - General comments, importance of economic evaluations

At the beginning of the french program, in the early fifties, the choices have been made on the grounds that France had to rely on natural uranium and, later on, on plutonium produced in the gas graphite reactors.

The gas graphite reactors work well and four are still in operation in France.

However, at the beginning of the seventies, a major change of line was made in France, mainly due to economic reasons. The gas cooled reactors, due to their high investment cost per kWh , could not compete with the PWR developed in the US. Fortunately the reprocessing plants prepared for the gas graphite fuel could be adapted to the new fuels ; so that the coherency of the program could be maintained.

Nowadays, all the major industrial facilities are in operation in order to support our fifty reactors, and the french decision to rely on fission as the major source of electricity is rationally fulfilled.

For the future, we explore all the ways to improve efficiency and economy of our system. We do not exclude major innovations or changes. But, everything been the same otherwise, especially in safety standards, economy will always be the criterium for the final choice. This is the case for the future of the breeders, which, despite their optimum characteristics for plutonium utilisation, will be adopted only if they are competitive with the other type of reactors.

II.2. - Short term decision and programs

The decision has been recently in France, to utilise plutonium in the existing PWR. This evidently diminishes the quantity of uranium burnt in the reactors by replacing it by the plutonium recovered from reprocessing.

However the utilisation of plutonium introduces some difficulties which have to be taken in account, resolved, and evaluated.

they are :

1) the increased neutronic complexity of the core, inducing more concern in the operation of the reactors, increasing incertainties in power density of the core and, consequently, reducing the margins for power production.

2) the degradation of the quality of plutonium after irradiation and its consequences for subsequent utilisation.

3) the overcost of fuel fabrication of "normal" and "multirecycled" mixed oxyde fuel.

4) the specific care to be taken in the reprocessing plants for MOX fuel

Those questions are the basis of the R/D program of the CEA for the next years, including the effect of burn-up increase of MOX fuels on them.

Careful estimation of the advantages and disadvantages of plutonium recycling have been made and have lead to the conclusion that plutonium utilisation in PWR was economical. The decision to do it was consequently taken by EDF. Today the industrial program is well under way :

- EDF has already introduced 8 tons of Mox fuel in St Laurent B1 in 1987, and 16 tons in 1988. A tonnage of 24 t, that is to say 3 reloads, is ordered for 1989. Five reloads (40 tons) are foreseen in 1990 and 1991, and 7 reloads (56 tons) in 1992 and 1993.

- COGEMA is launching a 120 t/year fuel fabrication plant MELOX in Marcoule, which should operate in 1993. In the interim period, BELGONUCLEAIRE and CEA will deliver the needed fuel in their facilities of Dessel (30 t/year) and Cadarache (15 t/year).

- In parallel the reprocessing facility in La Hague (UP2800) has been adapted to MOX fuel reprocessing.

II.3. - Long term decisions and programs

The long term decisions are less straightforward that the simple utilisation of Pu in existing reactors, which is an optimisation of the existing route in the frame of the to day state of the art.

For the long term decisions two main considerations have to be taken in account and made compatible. On one hand, all the possible improvements leading to decrease of the cost of kWh have to be pursued. On the other hand more strategic, considerations, in particular the possible shortage of uranium during the next century, have to be taken in account.

Some actions are easily deduced from the structure of PWR produced electricity costs, which is :

Reactor investment	~	55 %
Exploitation	~	20 %
Cycle cost	~	25 %

The main effort should be placed on reactor investment, and all the new reactors for the future should be simpler and more easy to operate. This must be the guidelines of the designers.

The cycle cost structure is :

Uranium cost	~	40 %
Conversion	~	3 %
Enrichment	~	31 %
Fabrication	~	10 %
Reprocessing	~	25 %

With those figures in mind it is more easy to give a weight to each action and to figure out the main trends.

- First of all, for a given type of reactor, it is a positive trend to try to decrease significantly the major components of the cycle costs.

a) uranium cost : Utilisation of plutonium and also of reprocessed uranium decreases the quantity of natural uranium needed to produce the same quantity of energy, and induces cost decrease.

b) enrichment cost : The significant decrease of costs foreseen through utilisation of SILVA is the main justification of the laser enrichment program.

c) Fabrication costs : The decision to utilise plutonium induces an increase of the fabrication costs. However the weight of fabrication costs is relatively small. This allows for a small increase of this cost.

d) Reprocessing costs : All the efforts have to be made and are made to decrease the costs. It has been checked that the MOX decision has no significant adverse effect on them.

On the whole, the permanent challenge to us in the next century is to decrease significantly enrichment costs, reprocessing costs and fabrication costs through technological innovation, and to reduce uranium consumption by the best utilisation of plutonium and reprocessed uranium.

- The second line of actions to be pursued in parallel to the preceeding one is to modify or change the existing reactors in order to improve the economy of the cycles costs, without of course increasing too much the investment cost of those new reactors compared to the existing PWRs.

  Three main lines are explored or developed in France :

a) The spectral shift reactors, where special control procedures of the core, and specific design features of the fuel assemblies, improve the efficiency of the nuclear reactions during irradiation, which leads to a better utilisation of uranium.

b) The reactors, where the core is made tighter in order to harden the neutron spectrum and to improve in core plutonium production which in turn diminishes uranium consumption.

c) The breeder reactors, which are well known to transform inert U 238 into fissile material, and thus to multiply enormously fissile material reserves.

II.4. - The strategic choices and plannings

In France, the main question for the long term is to decide when the breeder option has to be launched significatively and what should be the structure of the park of reactors to be built in the next century in order to obtain the best optimisation of costs and of natural resources savings.

The terms of the French problem are :

a) The French reactors have to be replaced around the year 2010, the lifetime of the French reactors beeing supposed to be of the order of forty years.

b) At that time one third of the existing PWR reactors will be loaded with MOX fuels, and two third will rely on normal uranium fuel.

c) The improved reactors (spectral shift, under moderated reactors, breeders) might then be available and adopted if they have been shown cheeper than the previous reactors. If not, the only choice, as far as uranium savings are concerned, will be to increase the capacity of MOX fuel production and to increase the number of MOX reactors.

d) If improved advanced reactors are available, the strategic question will be to manage their introduction in the park.

One must know that it takes time to introduce a 100 % Pu reactor system. As a consequence the french park of reactors will comprise several types of reactors during decades, namely PWR with uranium fuel, PWR with MOX fuel and breeders.

It will be a very delicate problem to optimise the composition of the park, taking in account plutonium availability and guessing when the uranium resources will become scarce. The immediate needs might lead to burn plutonium rather inefficiently in advanced PWR reactors instead of keeping it for the breeders. A very interesting and important strategic optimisation is ahead of us.

e) In parallel the reprocessing and fabrication industries will have to be very flexible to accept all the type of irradiated fuels which will be there. In particular they will have to accept more and more recycled plutonium with more and more higher transplutonium isotopes. Moreover, the decision will have to be made to reprocess breeder fuels in specific or in polyvalent plants.

III - THE BENEFITS OF THE NUCLEAR PROGRAMS

The french program has lead us to master very important technologies such as :

a) <u>Fabrication of uranium fuel</u>

The existing plants in Romans and Pierrelatte produces regularly the hundred of tons of fuel needed for the EDF plants. In parallel CEZUS and ZIRCOTUBE manufacture the zirconium tubes necessary for the cladding and structures of the fuel assemblies.

b) <u>Fabrication of mixed oxyde fuel</u>

A fabrication pilot plant in Cadarache (CEA) has produced more than 40 tons of plutonium fuels for PHENIX and SUPERPHENIX, showing mastery of the specific questions of handling plutonium oxide powders in clean environment, with great control of the level of irradiation of workers.

The french specialists know how to obtain safely the mixed oxyde pellets with the required diameter and density, the fuel pins with the required tightess, the fuel subassemblies according to the reactor specifications. Up to now the fraction of fuel leakage in reactors linked to fuel fabrication defects is below 10^{-5}.

c) Industrial reprocessing

It is well known that COGEMA masters all the steps of reprocessing, having to day reprocessed over 1000 tons of fuel.

This industrial know how is well supported by a very important R and D program in CEA.

One should specially note the existing R and D facilities in Marcoule, where are tested the main components of the La Hague plants (Industrial Prototype Testing Service) and where are reprocessed experimental and special fuels (in the Marcoule Pilot Plant). It is of special significance to note that more than ten tons of plutonium mixed oxide fuels have been reprocessed in France, that the Marcoule Pilot plant is reprocessing regularly tons of PHENIX fuel, and will soon reprocess several tons of MOX fuel coming from PWR plant as a rehersal of the La Hague MOX reprocessing.

d) Ability to manipulate irradiated fuel

Since the beginning of the French program, CEA has built hot cells in Saclay, Grenoble and Cadarache to destructively and non destructively examine irradiated uranium and plutonium fuels. Simultaneously chemistry hot cells and pilot plants for reprocessing irradiated fuels have been built and operated in Fontenay aux Roses, Marcoule and La Hague.

e) Fine knowledge of reactor core neutronics

Several physic facilities have been built on the Cadarache Center and are still in operation. The reactors EOLE and MASURCA have allowed the CEA to build up a wealth of data and experiments which are the base of the codes for PWR and RNR. Recently EOLE has been utilised to study the undermoderated reactors, and nowadays is devoted to MOX core problems. The question of heterogeneous cores for breeders will soon be studied in MASURCA.

f) Waste treatment

The problem of waste has been studied since the start up of the program.

In particular, high level waste treatment through incorporation of fission products in glasses has been experimented in PIVER facilities nearly twenty years ago in MARCOULE, and this technology is now incorporated in the La Hague and Thorp plants.

g) <u>Enrichment of uranium</u>

In parallel to the gaseous diffusion techniques the CEA has studied the centrifugation method, the chemical enrichment process, the molecular laser enrichment technique, and is now concentrated on the enrichment method through atomic uranium vapor laser excitation (AVLIS).

All those examples show that we, in France, master the uranium and plutonium technology and that we have already entered the plutonium age.

We have seen above that the next century challenge for natural resources savings implies more progress in all the fields of the cycle (enrichment, fabrication, reprocessing, waste treatment) as well as in the reactor design control and operation. Among the most important scientific or technological advances which have been done or will be done, we could select :

1) Mastering hostile irradiated environment which implies teleoperation, teleintervention and robotisation.

2) Mastering the collection and fast treatment of many informations which implies ultra fast measurements and computer treatment of information.

3) Establishment and demonstration of nuclear "cleanliness" which implies low irradiation rates for workers, control of effluents release, and maximum safety.

4) Safe disposal of wastes.

IV - CONCLUSION

The development of nuclear energy is a slow process which implies huge investments and must comprehend all the steps of the cycle, from mining to waste processing. All the decisions made to day will be implemented twenty years (or more) from now. The decision makers have to foresee far ahead in the future. The challenge is great and of vital importance because the energy supply for our children depends on our skill and on our will.

The french partners of the nuclear energy development are well aware of the problems and are preparing the future with confidence.

PUISSANCE NUCLEAIRE A CONSTRUIRE APRES L AN 2000

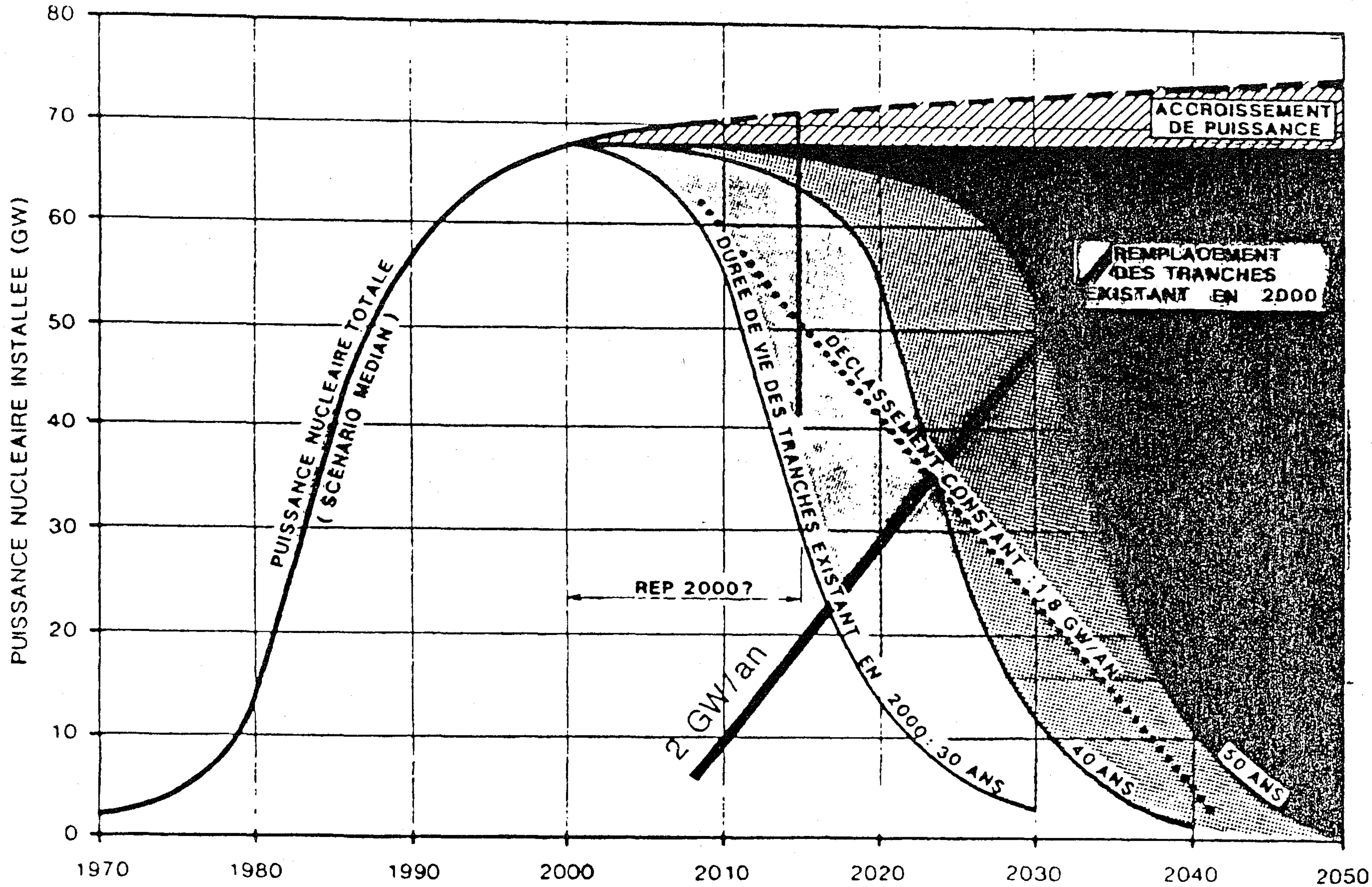


FIGURE 1

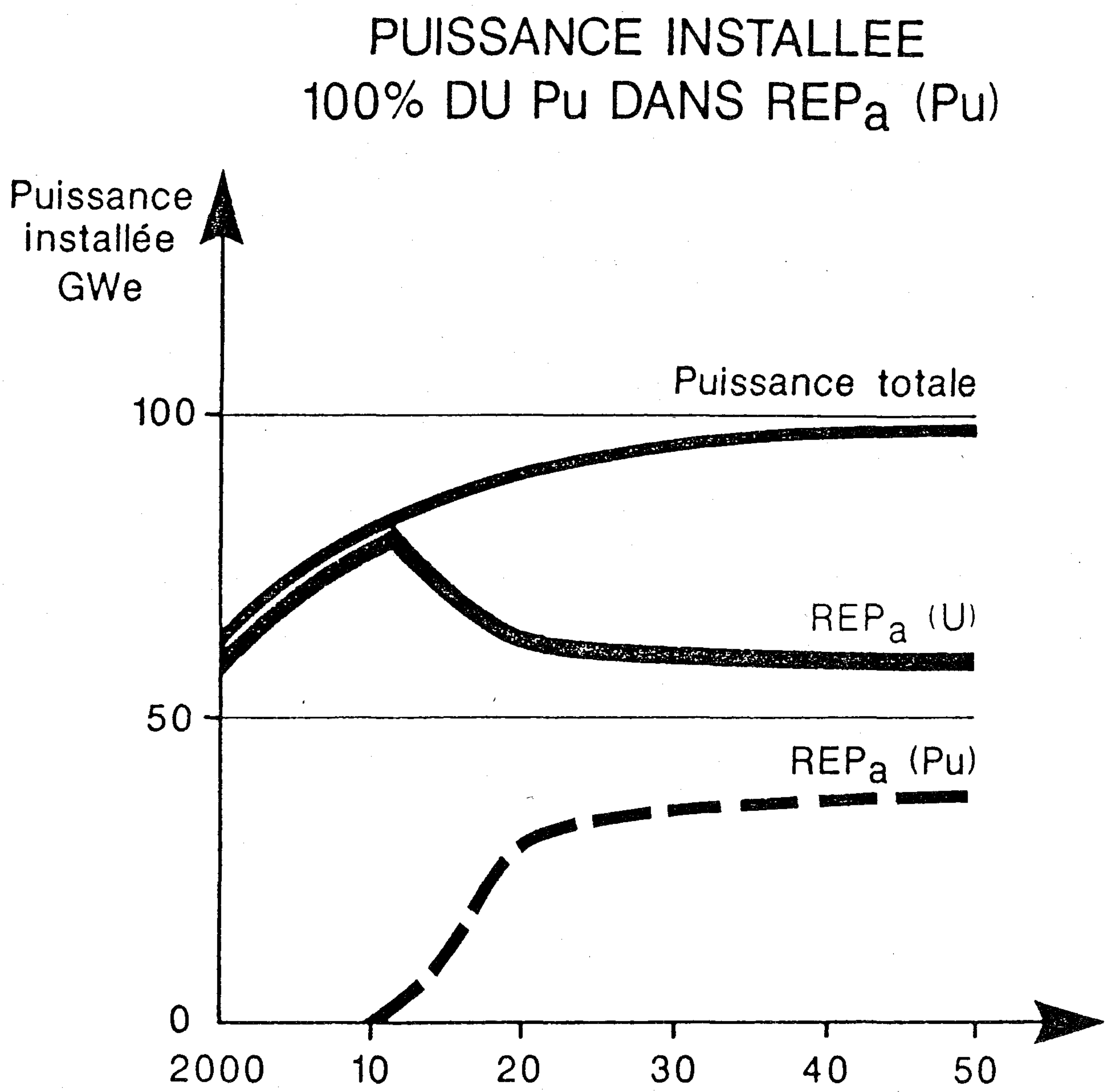
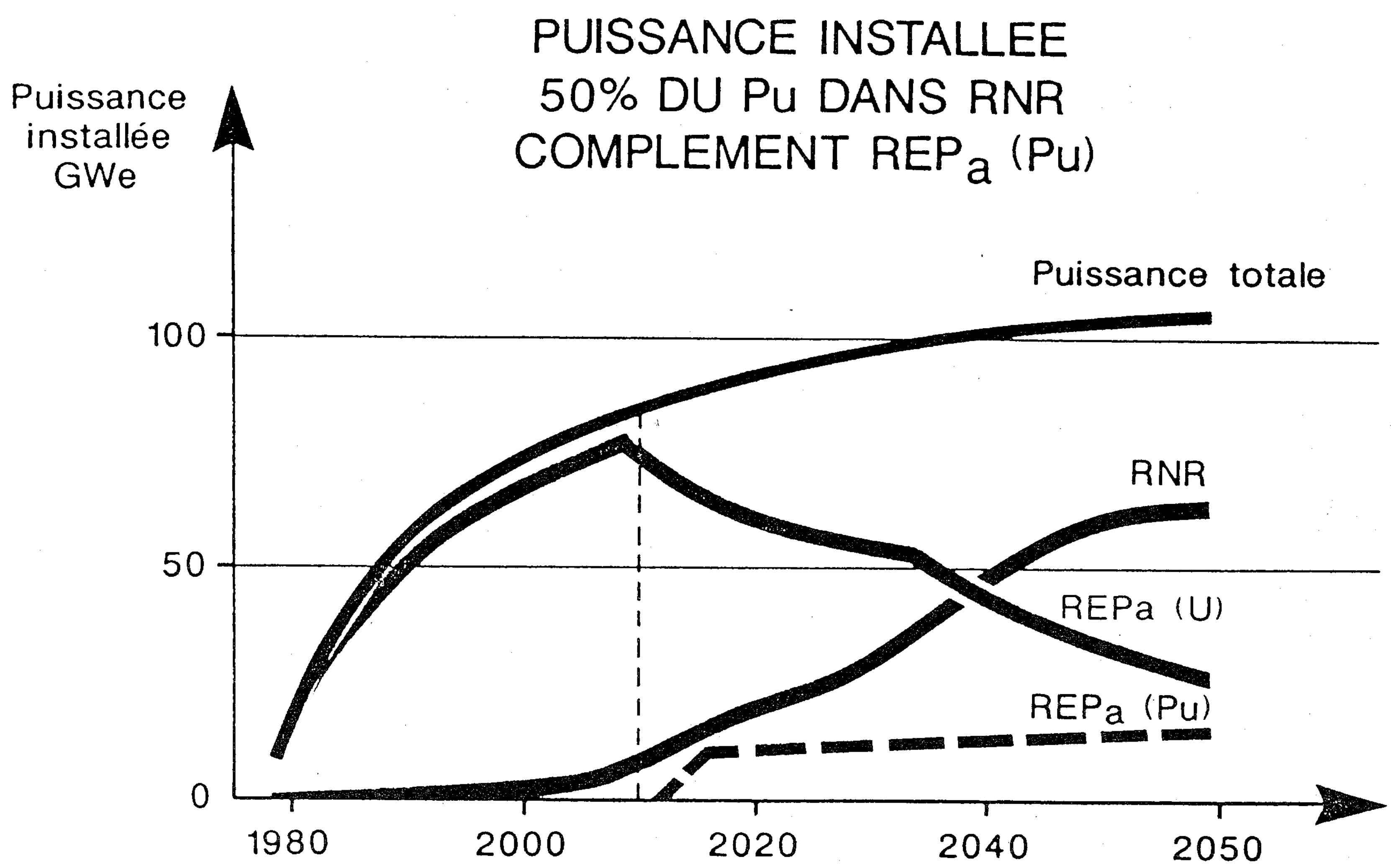

PUISSANCE INSTALLEE
100% DU Pu DANS REPa (Pu)
Puissance installée GWe
Puissance totale
100
REPa (U)
50
REPa (Pu)
0
2000
10
20
30
40
50

FIGURE 2



PUISSANCE INSTALLEE
50% DU Pu DANS RNR
COMPLEMENT REPa (Pu)
Puissance
installée
GWe
100
50
0
1980
2000
2020
2040
2050
Puissance totale
RNR
REPa (U)
REPa (Pu)

FIGURE 3

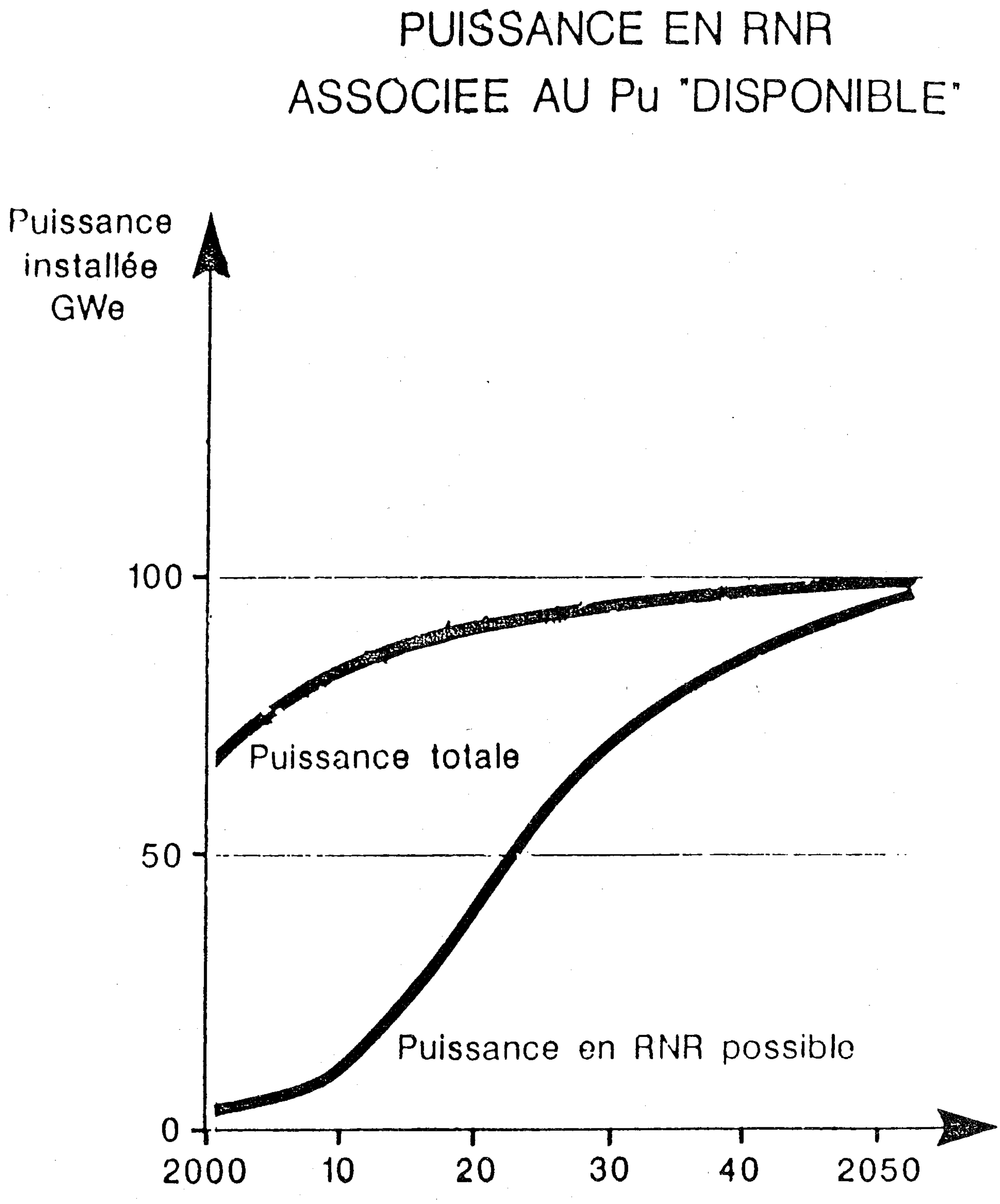

PUISSANCE EN RNR
ASSOCIEE AU Pu "DISPONIBLE"
Puissance
installée
GWe
100
50
0
Puissance totale
Puissance en RNR possible
2000
10
20
30
40
2050

FIGURE 4

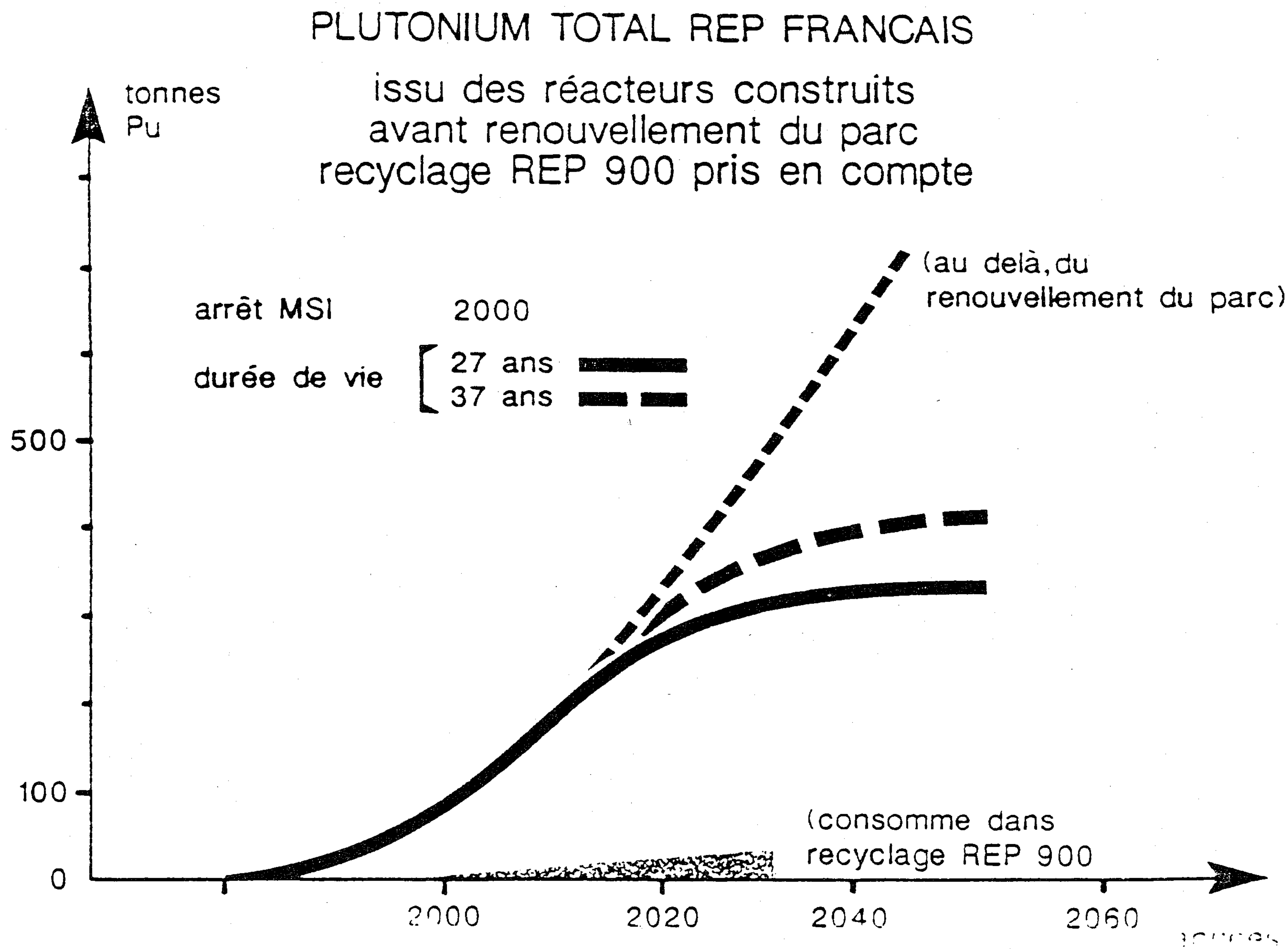
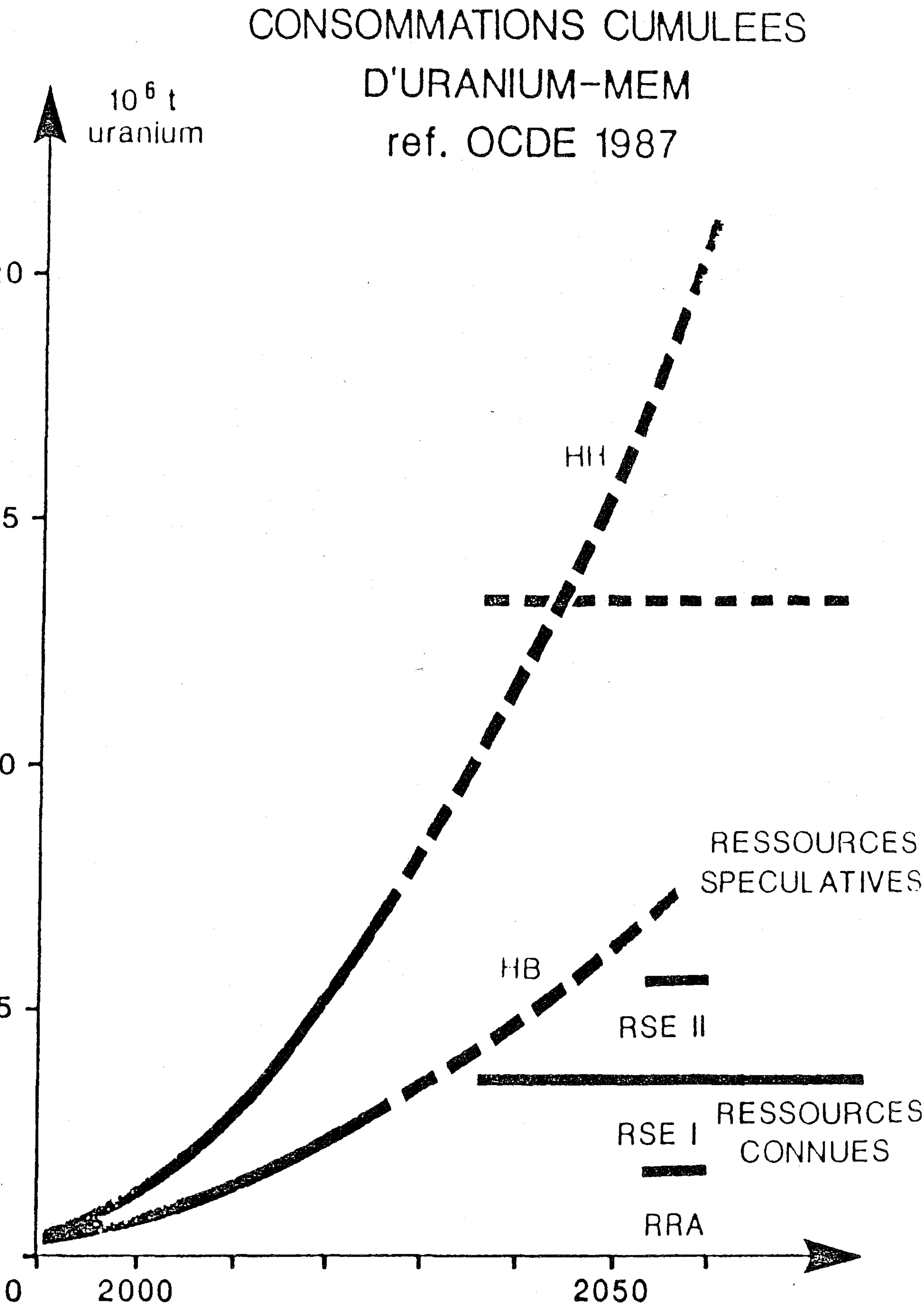

PLUTONIUM TOTAL REP FRANCAIS
issu des réacteurs construits
avant renouvellement du parc
recyclage REP 900 pris en compte
tonnes
Pu
arrêt MSI 2000
durée de vie
27 ans
37 ans
(au delà, du
renouvellement du parc)
(consomme dans
recyclage REP 900
500
100
0
2000
2020
2040
2060

FIGURE 5



CONSOMMATIONS CUMULEES
D'URANIUM-MEM
ref. OCDE 1987
10^6 t
uranium
20
15
10
5
0
2000
2050
HH
HB
RESSOURCES
SPECULATIVES
RSE II
RESSOURCES
CONNUES
RSE I
RRA

FIGURE 6

原子力ロボット

極限作業ロボット技術研究組合
技術委員会　原子力部会長　　井元一彦

スライド	スライド	
A-1	--	只今御紹介にあずかりました極限作業ロボット技術研究組合の原子力部会長をおおせつかっております井元でございます。 本日は「原子力ロボット」と題しまして、現在国の大型プロジェクトの一環としまして研究を進めております極限作業ロボットのうち原子力ロボットの内容につき紹介させて頂きます。
A-2	B-2	極限作業ロボットの内容に入る前に、日本における原子力ロボットの歴史を簡単に紹介いたします。 日本における原子力ロボットは１９７０年代に始まりました。 まず最初、主として被曝低減を目的として原子力発電所の作業を自動化する開発より始まりました。その後小型計算機の開発と相まって、現在でもその改良が進められております。 一方原子力発電所の作業をより広範囲に自動化するために多機能ロボットが必要となってまいりました。従ってその為の研究開発が１９７０年代の半ばより始まっております。これらの多機能ロボットは今まさに実用化レベルに入ろうとしている時代に来ております。しかし本当に普及化するには更に安価に、また小形化する必要があります。 他方、現在の先端ロボットの操縦は、産業用ロボットの如く予め、プレ・プログラミングされたものは別として、オペレータにとってかなり難しいものであります。従ってこのオペレータに対する負担を極力軽減するためロボット自身の知能化あるいは操縦の容易さに対する技術が求められてきております。このように知能化されたロボットの研究は大むね１９８０年代に始まっております。

		このような背景のもとに知能化ロボットのＲ＆Ｄの一環として本プロジェクトの原子力ロボットについて御説明申し上げます。
A-3	B-3	本論に入る前に極限作業ロボットの背景と目的について述べさせていただきます。 現代社会においては、安全に対する十分な防護なしでは実施しえない作業や直接アクセスできない作業が多数あります。原子力発電所における高放射線下での作業、海底石油掘削などにおける大水深下での作業、災害時などの消火救援作業などがその例ですが、これらの作業は経済社会の発展には不可欠であり、その重要性が益々増大しております。 「極限作業ロボット」プロジェクトは、このような背景を踏まえ、原子力、海洋、災害等の分野において、点検・保守・救援活動などを実行し得るロボットの開発をめざすものでありますが、このようなプロジェクトは多数の資金、長期の研究期間を必要とし、かつ多大なリスクを伴うため、ナショナルプロジェクトとして工業技術院の大型工業技術研究開発制度（通称：大プロ制度）により推進しているものであります。
A-4	B-4	このプロジェクトは１９８３年に始まり、１９９０年に終了致します。現在は本プロジェクトの最終段階になっており、後ほどお見せするロボットを２年後に完成させる予定です。 このプロジェクトの研究は基盤技術および固有要素技術の研究から始まりましてこれらの技術をとり入れて全体システムとする予定となっております。基盤技術は原子力・海洋・防災の各分野に共通な技術であり機構技術、制御技術、支援技術より構成されております。また固有技術は原子力・海洋・防災の３分野において、それぞれの分野固有のニーズを踏まえた要素技術です。

A-5	B-5	原子力ロボットの概念図です。下端にあります絵は床を移動し作業するロボットです。その特長は複雑な原子力発電所内の現場にアクセスし易いように４脚をもち、また種々な作業を行うよう双腕のマニピュレータを有しているものです。目は原子力発電所内の環境をある程度認識して自律的にロボットを運転させるよう工夫されています。 右上端にあります絵は全体制御室です。ここからロボット本体を操作しますが、人間の直接指示による遠隔操作とＡＩを使用した自律的な操作も可能となっております。そのため多くの計算機が使用されます。 左上端にあります絵は原子力発電所に多くみられるタンク類の検査を行う事を主たる目的としている壁面ロボットであります。 次にこれ迄本プロジェクトで開発された技術の一部を紹介します。
A-6	B-6-1	最初に床面を移動し作業するロボットの脚移動システムについて紹介します。原子力発電所内では平坦でない床面が多いため脚移動システムを採用しております。
同上	B-6-2	これは床面移動システムで４脚を有しており段差の昇降やせき・配管等の跨ぎ越えが可能です。脚は各関節に次に述べるアクチュエータを有しております。動きは動物の脚の動きをシミュレートしており、膝や腰の関節をうまく制御し、前進、跨ぎ越え、段差の昇降等の歩容パターンが可能となっております。
同上	B-6-3	これは脚の膝や腰の関節に使用する予定のアクチュエータです。市販品のものより大巾に軽量化されております。

A-7	B-7-1	次にマニピュレータシステムについて紹介します。マニピュレータシステムはオペレータによる遠隔操作が可能なように、オペレータの手の動きをロボット側がそのまま行えるマスター・スレーブ方式も可能になっております。
同上	B-7-2	これは双腕４本指マニピュレータです。この写真の例では、片手にナットを持ち、他方の手はボルトを持ってねじ込み作業を行っております。この例の如く双腕の特長をうまく利用し又指の器用さも使って通常人間が行っている動作に近い作業が可能となっております。
同上	B-7-3	これはマニピュレータに使用するアクチュエータです。肩用から指用まで大小の種類があります。このアクチュエータも市販品のものより大巾に軽量化されております。
同上	B-7-4	これは指につける触覚センサーです。指の皮膚に感じる力をオペレータに伝えることが出来ます。この写真は指の先端部につける触覚センサーの例で、指の丸みに沿ってセンシング出来るようになっております。
A-8	B-8-1	次に視覚情報処理システムについて紹介します。視覚はロボットと対象物の間の距離を測定すること、および対象物の認識等の目的をもっています。
同上	B-8-2	左の写真は単眼移動立体視です。単眼を移動させることにより複数の目でとり入れたのと同様な距離測定が可能となります。右側の写真は取り入れた画像より距離を測定するに至るまでの演算処理を行うためのプロセッサーです。

同上	B-8-3	これは視覚を使った認識実験の例です。テレビカメラで取り込んだシーンより目標としている対象物例えばこの例のごとく複雑な形状のバルブ等を見つけ出します。この写真ではデータベースとして持っている３次元的形状を画像上で見出し、バルブを認識した結果です。
A-9	B-9-1	次に光空間伝送システムについて紹介します。このシステムは無線で全体制御室からの指令をロボットに与えたり、ロボットからの信号を全体制御室へ伝送する目的をもっております。
同上	B-9-2	この光空間伝送システムでは、２組のレーザー発信器と受信器がお互いに常に正面を見合って通信出来るようになっています。この写真では左側が移動する台車の上に搭載された送受信器で、ロボットがどの位置に移動しても正面を向き合うようお互いの追尾機能を有しております。また、伝送経路を自動的に見出すシステムをもっています。
A-10	B-10-1	次に壁面ロボットについて紹介します。このロボットは先程述べましたようにタンク類の検査を行うことを主たる目的としておりますが、そのためタンク等の曲面上が走行可能なこと、又タンク類の壁面についております障害物の乗り越え等が可能です。
同上	B-10-2	この壁面移動ロボットは、２個の吸盤をもち壁面上を自由に移動出来ます。この写真の例ではタンク上にある障害物の乗り越えを行っている例で、このため下の吸盤で壁表面に吸着しており、上の吸盤は持ち上がっております。

A-11	B-11	その他の技術として高信頼性技術と耐放射線技術の研究を行っています。 高信頼性とは故障の予知を行ったり、一部の部品が故障しても他の部品でこの故障をカバーする技術です。 耐放射線技術とは主として電子部品等のロボットに搭載される部品、センサー類の耐放射線性を調査するものと一部の電子部品の耐放射線を向上させる研究を行っております。
A-12	—	以上極限作業としての原子力ロボットの開発状況を述べさせていただきましたが、残された２年間、これ等の技術の主要部分を搭載し、作業性を主体とした実証試験用ロボットを製作し、試験を行う予定となっております。更にはこの試験結果を踏まえ１９９０年には総合評価を行うこととなっています。 私の講演は以上で終らせていただきますが、これらの技術が近い将来先端ロボットの技術の一環として必ずや、役立つものと信じております。 御静聴有難うございました。

ADVANCED ROBOT

TECHNOLOGY FOR

NUCLEAR POWER PLANT

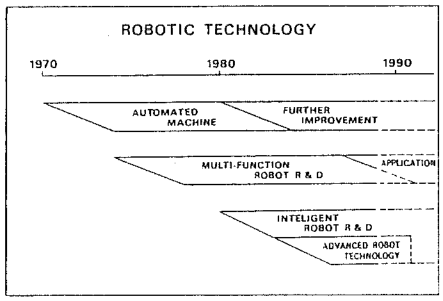
(A－1)

NUCLEAR ROBOTS

R & D TREND

IN JAPAN

(A－2)



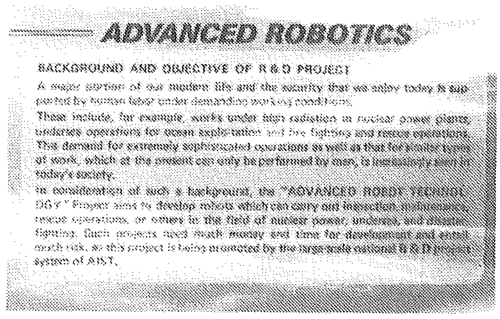
(B－2)

BACKGROUND

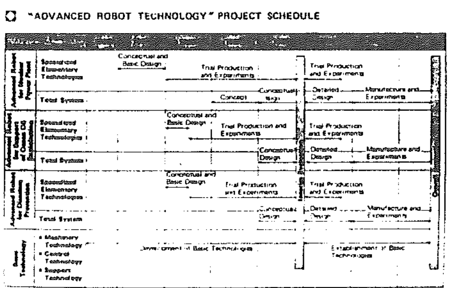
AND OBJECTIVE

OF R & D PROJECT

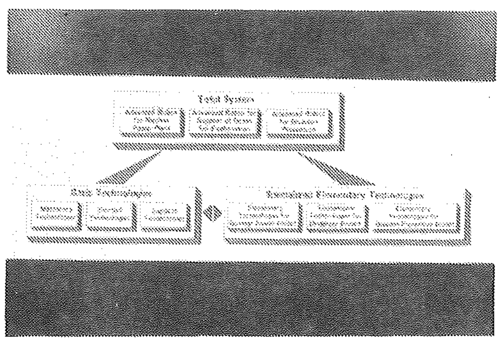
(A－3)



(B－3)



(A－4)

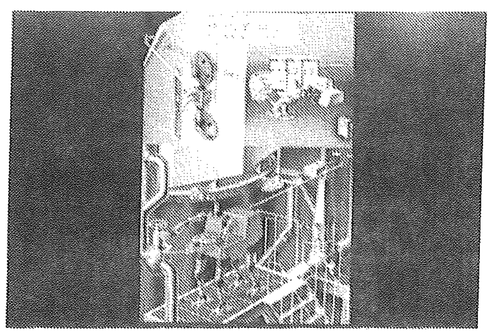


(B－4)

CONCEPT OF

NUCLEAR ROBOT

(A－5)

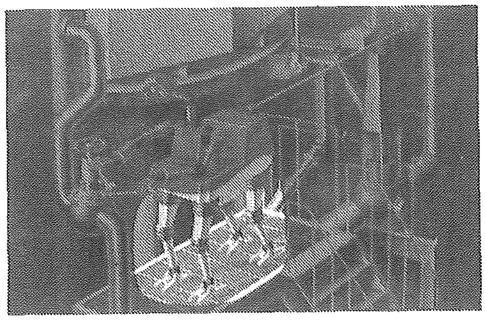


(B－5)

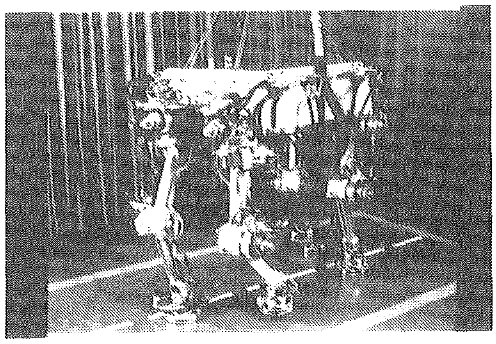
(A－6)

Moving Robot on Floors

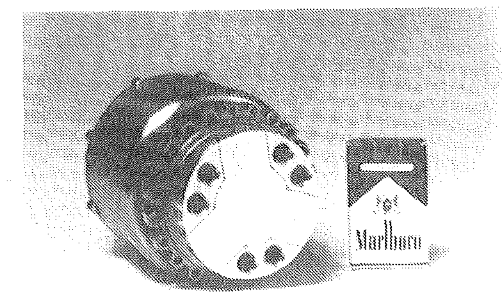
- Multi-Legged Locomotion
- Heavy Duty Actuator


(B－6－1)

同　　上


(B－6－2)

同　　上

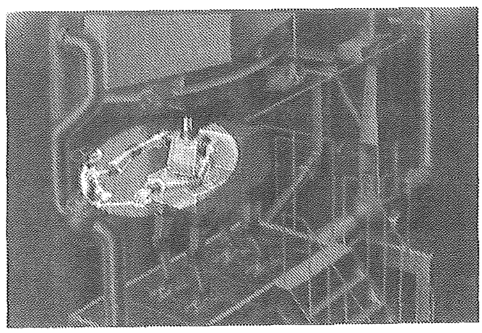


(B－6－3)

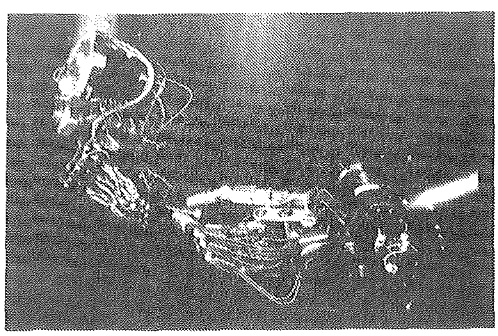
(A－7)

Manipulator

- Equipped with Two Arms and Four Sensitive Fingers
- Light Duty Actuator
- Tactile Sensor


(B－7－1)

同　　上

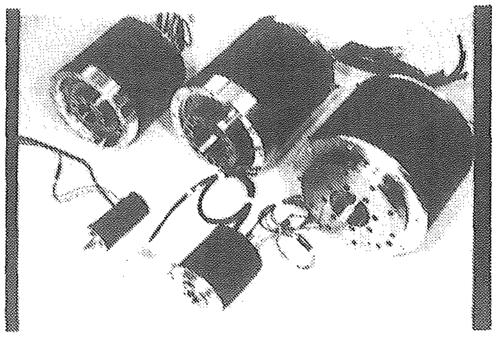

(B－7－2)

(A－7)

Manipulator

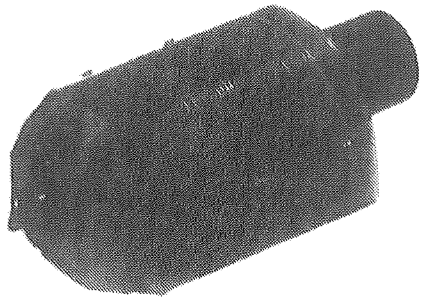
- Equipped with Two Arms and Four Sensitive Fingers
- Light Duty Actuator
- Tactile Sensor

(B－7－3)



同　　上

(B－7－4)

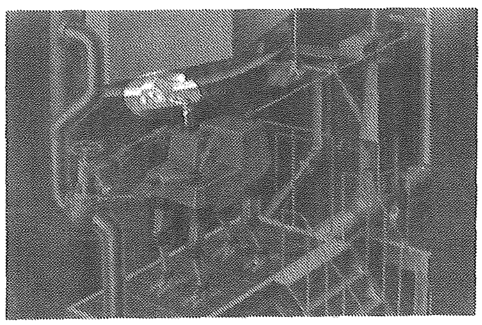


(A－8)

Vision System

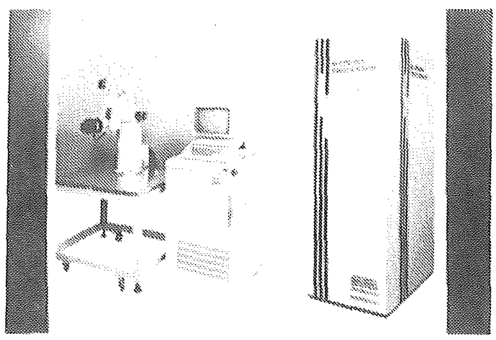
- 3-D Vision by Motion Stereo
- Visual Information Processing System (Recognition of Objects)

(B－8－1)



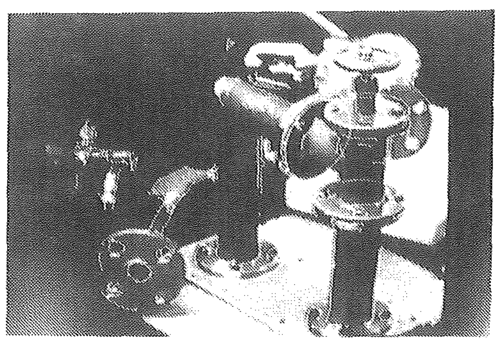
同　　上

(B－8－2)



同　　上

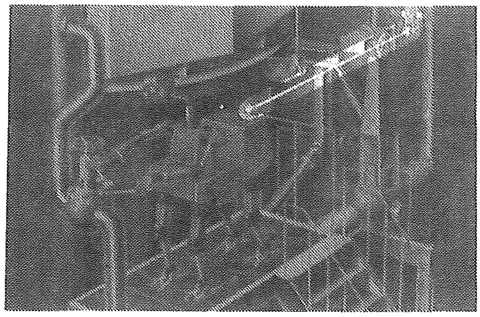
(B－8－3)



Optical Transmission

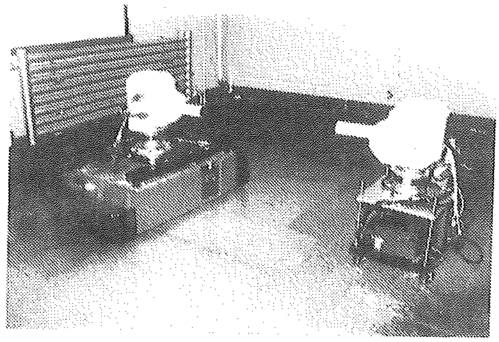
- Tracking Robot's Movement
- Determing Path of Transmission Automatically

(A－9)



(B－9－1)

同　　上

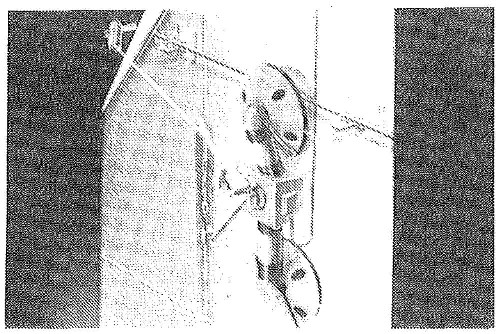


(B－9－2)

Moving Robot on Walls

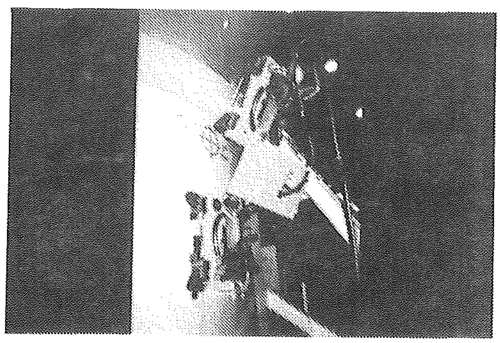
- Negative Pressure Adherence
- Compound Locomotion Mechanisms Composed of Two Adhering Disks

(A－10)



(B－10－1)

同　　上



(B－10－2)

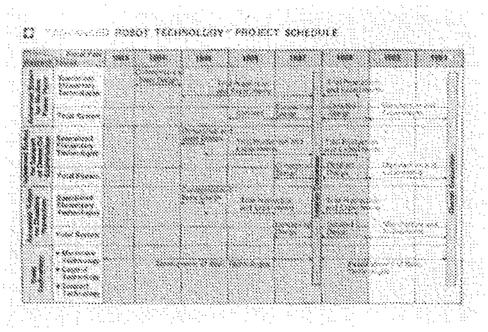
Other Technologies

(A－11)

- High Reliability
- Radiation Hardness

(B－11)

(A－１２)



セッション4
スウェーデンの脱原子力政策をめぐって

スウェーデンのエネルギー政策
スウェーデン・エネルギー庁長官
H．ローデ

産業および国際的視点からみたスウェーデンのエネルギー政策
ABBアトム社社長
L．フォーゲルシュトローム

スウェーデンのエネルギーの将来：政策ｖｓ政治
ストックホルム大学教授
T．ヤールホルム

＜パネル討論＞
米国エネルギー啓発協議会（USCEA）副理事長
B．ハリス

フランス工業省エネルギー資源庁長官
J．D．レビ

日本経済新聞論説委員
末次克彦

関西電力㈱専務取締役
秋山喜久

スウェーデン・エネルギー庁長官
H．ローデ

ABBアトム社社長
L．フォーゲルシュトローム

ストックホルム大学教授
T．ヤールホルム

＜議長まとめ＞

Statens energiverk
National Energy Administration, Sweden

Director-General,
Chairman of the Board.

1989-03-14

JAPAN ATOMIC INDUSTRIAL FORUM, APRIL 14, 1989

Speech by Mr Hans Rode, Director General, National Energy Administration, Sweden

Mr Chairman, ladies and gentlemen,

First, may I say what a very great pleasure it is for me to be here today.

I am really enjoying your wonderful city and country.

I wish to present the current Swedish energy policy in the following manner:

1. I shall start with a summary of Swedish energy policy during the fifties, sixties and seventies and its development up to the mid-eighties.

2. I shall then deal with the present energy and environmental situation in terms of supply, demand and environment.

3. This will be followed by a description of the main features of our present energy policy.

4. In conclusion, I shall describe the work we are doing at present to reach our energy and environmental goals.

Sweden's energy policy and events during the fifties, the sixties and seventies

The vulnerability of Swedish energy supplies was demonstrated twice during the fifties, first during the Korean war and then during the Suez crisis. It is no wonder that the energy policy during the first ten years after the Second World War was mostly engaged in building up strategic stocks of heating oil and petrol. Administrative preparations for rationing and for an increased utilization of domestic fuels were proceeding concurrently.

Soon, however, the future method of production of cheap electric power became the main issue. The harnessing of hydropower was likely to run into conflict with ecological interests in the near future. An alternative was required.

In the mid 50's the civilian utilization of nuclear power appeared to be a promising avenue to explore. If nuclear power could be used for electricity production and space-heating, a substantial break-through towards an energy system based on domestic resources would be within reach.

Decreasing oil prices after the Suez crisis ran counter to these plans. In a number of big cities the construction of oil-fired power plants for combined generation of electric power and heat was started. This took place simultaneously with the introduction of district-heating net-works. Electric power tariffs were lowered, which made direct use of electricity for space-heating in one-family houses feasible.

Although these years of the sixties were dominated by the launching of a nuclear programme, governmental activities were seen in other fields as well.

The oil crisis in 1973-74 suddenly changed the conditions in the energy markets. The fourfold price increase brought about heavily increased costs for oil. The crisis also emphasized new political aspects of the security of supply.

This situation called for a substantially new basis for energy planning. Prompt action was needed to handle the problems initiated by the first oil crisis. Hence, new governmental investigations and studies started and many new governmental agencies were set up.

In 1975 the Energy Management Bill presented an energy policy programme with a new attitude towards energy policy. The programme consisted of

- deliberate conservation
- comprehensive research and development
- international co-operation
- an active oil policy
- a guaranteed power supply

While the unstable situation on the international oil market continued at the end of the 70's, including a doubling of the oil prices in 1979, an intense debate whether to use nuclear power in Sweden having regard to nuclear safety and radioactive waste was going on. You could find different opinions in each political party, so it was finally decided that this debate, which engaged the whole of society, should be resolved in a nuclear referendum. As a basis for the referendum a commission was set up to study the consequences for the economy, employment and the environment if nuclear power were to be abandoned.

The referendum took place in March 1980, and the result was that 58 % of the voters favoured using all 12 reactors throughout their service life. The will to abandon nuclear power within a 20-year period and use other, preferably renewable sources of energy, was also expressed.

In order to analyze measures necessary to accomplish the phasing out of nuclear power before the year 2010 and at the same time a continous decrease in oil dependence a parliamentary committee has been set up. This committee dealt with the policy concerning electricity use and the role of coal and oil in the longterm. The committee also investigated the potential contribution from docmestic fuels and hydropower.

In the spring of 1981 an extensive new Energy Bill was presented in which the Government proposed new guidelines for energy policy up to 1990. The goal is to attain the lowest possible level of energy use compatible with social goals and economic needs. The main emphasis is laid on measures directed to saving oil and having an impact in the short and medium term.

Many of the measures and programmes that have been implemented during the 70's would be in force also in the 80's. When it comes to instruments to manage energy demand a greater emphasis than earlier is however placed on pricing policies, in particular on taxes and charges, and on information, advisory services and education.

At that time, we think, the greatest potential for saving energy is to be found in industry and in buildings. The possiblities that exist in the transport sector should also be utilized, The 10-year plan to save energy in existing buildings which was adopted by Parliament in 1978 aimed at a saving of around 30 % of the energy used in buildings existing in 1978. Today we can say that we have reached this goal.

So, in summary, except nuclear power,

The main characteristics of the trends on the energy markets in Sweden since the end of the second world war have been the same as those in the rest of the western industrialized world.

Between 1945 and 1975 energy consumption increased by approximately 4,5 % per annum.

The oil-price rises of the seventies had significant consequences for this development, expecially in the light of the fact that Sweden does not have any oil, gas or coal resources of her own.

Increased energy prices in Sweden meant, among other things, that investments in more energy-efficient equipment became profitable, and this provided incentives for technological developments.

Much effort has also been expended in Sweden on making energy utilization more efficient. Oil consumption has decreased due both to change in manufacturing processes and other things. These changes have in many cases also led to other advantages, such as decreased consumption of raw materials and reduced emissions of pollutants.

Much of the work carried out to protect the environment has been succesful. Since the mid 1970's emissions of sulphur have decreased by 70 % and those of nitrogen oxides by about 30 % in the energy sector.

Discharges of dust, hydrocarbons, mercury, cadmium and lead have also diminished sharply during the 1970's and 80's.

Sweden's energy supply, demand and environment situation year 1989.

The total amount of energy supplied is today at approximately the same level as in 1970, that is about 450 TWh/year.

As you can see from this picture we can split up our primary energy into the following.

Sweden's energy supply in 1987

	TWh
Domestic fuels	66
Coal, coke	34
Hydropower	68
Nuclear power	68
Waste heat	8
Oil	209
Natural gas	3

The electricity market

Electricity is today generated chiefly in hydroelectric and nuclear power plants, each of which accounts for about 65 TWh a year. Apart from these, electricity is also generated by fuel combustion, mainly through back-pressure. In 1988, the total generating capacity was just over 140 TWh and consumption about 133 TWh.

It is perhaps interesting to note, ladies and gentlemen, that our present electricity consumption is double that of 1970.

Low running costs of hydro and nuclear power, combined with a certain overcapacity, have kept electricity prices low. As far as electricity consumption over the next ten years is concerned, there are too many unknowns to make numerical examples worthwhile. It is, however, clear that more expensive power production will play an increased role, and that differentiated tariffs and a higher electricity price will have effects on the electricity market.

Indigenous fuels

Indigenous fuel consumption was 66 TWh in 1987. The bulk of these indigenous fuels are produced and consumed by the same firms. Only 10 % was bought or sold before being used, which means that only a very minor part is available on the market.

These fuels are used mainly in three fields:

- the woodworking industry
- small houses with on-site access to wood
- district-heating plants

The first two categories account for about 90 % of total consumption.

Oil products

The consumption of oil products has decreased rapidly in Sweden, especially since 1979.

It is chiefly the consumption of fuel oils which has been reduced. These have been replaced by electricity and solid fuels for heating purposes. In this context, local authorities' conversions to boiler plants and the expansion of electric heating for single-family housing have played a central role.

Energy conservation has also contributed to the decreased consumption of heating oil.

What has increased, however, is petrol consumption, and this increase has been 10 % in the last ten years.

District heating

Today there are over 200 district-heating plants in Sweden. Last year they delivered 36 TWh of heating. Over half of this went to multi-family accommodation.

Final consumption areas

As may be seen from this figure, our total final energy consumption in 1988 was 384 TWh.

Industry consumed	140.8 TWh
Housing, office and services	163.0 TWh
Transport	80.5 TWh

Environmental situation

The consumption of energy affects the environment.

As I mentioned, work on the reduction of emissions of sulphur and nitrogen oxides since the seventies has given good results.

Our present situation as regards sulphur dioxide is that from emissions of 750 000 tonnes a year in 1975, Swedish enery production and industrial plants have reduced their emissions to 220 000 tonnes a year in 1987.

The emission load to which Sweden is subject, on the other hand, is considerably greater, due to emissions from other countries. This brings the total load on Sweden up to 300 000 tonnes expressed as sulphur, so that 85-90 per cent of Sweden's sulphur load comes from other countries.

Emissions of nitrogen oxides today amount of 300 000 tonnes. This is a reduction in emissions of 18 000 tonnes or 5 per cent since 1980.

Of the total load on Sweden, 85-90 per cent comes from abroad, which amounts to 90 000 tonnes, expressed as nitrogen. A further load of about 70 000 tonnes N comes from reduced nitrogen compounds. About 75 per cent of this sum come· from abroad agricultural sources.

As regards Swedish emissions today, it is above all the transport sector that is disquieting. Petrol consumptuion has grown by 10 per cent in 10 years, and this increase alone has resulted in 250 000 tonnes more of emissions.

In 1986, traffic produced about 70 % of nitrogen oxide emissions, energy production about 25 % and industrial processes about 5 %.

More rigorous demands on petrol driven motor vehicles have been introduced for all cars as of 1989 models. This is to be achieved by catalysers and is expected to reduce emissions of nitrogen oxides.

Our emissions of carbon-dioxide amount to roughly 80 million tonnes a year.

This, ladies and gentlemen, completes the picture of the present situation. It is also the starting point for what may, in the light of energy-policy decisions, lie ahead.

Current energy policy

In the spring of 1988, the government presented its proposals as to the main tasks of our energy policy for the nineties. The resulting energy Bill was passed by Parliament on the seventh of June 1988.

The main task of the energy policy of the Nineties is the creation of the preconditions necessary to achieve the adjustments in the energy system prescribed in the energy-policy decisions of 1985, that is, nuclear power is to be phased out by the year 2010 and the targets set up in relation to issues such as the environment, our emergency capacity and our security should be reached at the lowest possible cost to society.

The plan of action includes the following:

1. A first reactor is to be closed down in 1995 and a second in 1996 - both of them on the west coast of Sweden. The selection of reactor and of the order of closure is to be made in 1990.

2. Environmental controls on heating and electricity generation plants are to be tightened successively during the nineties.

Sulphur emissions are to be reduced by 80 % from 1980 to the year 2000, and must not increase thereafter.

Similarly, the emission of nitrogen oxides is to be reduced by 30 % from 1980 to 1995, and must not increase thereafter.

Emissions of carbon dioxide must not increase in a long term period.

3. Electricity conservation programmes have started. The necessary resources are estimated to be around SEK 400 million over a five-year period.

The programme aims to:

- utilize the potential for greater electricity efficiency and electricity substitution that is economically feasible from now until 1997.

Parliament has recently, on the suggestion of the government, approved a plan of action.

The government is of the opinion that a functioning electricity market would facilitate a phase-out. It is important that higher production costs are gradually allowed to affect electricity prices. Only then can the necessary adjustments be made by households, business and other electricity users, and these adjustments are a precondition for the phase-out of nuclear power.

The measures included in this plan of action should be followed and adjusted to the prevailing situation. The aims are:

- to promote and retain flexibility in electricity consumption and prevent an increase in electricity consumption in areas where such a rise is not economically justified

- to take advantage of long-term opportunities to make electricity consumption more efficient and to replace electricity with other energy types, chiefly in the heating area and in electricity-intensive industry.

4.combined heat and power plants and industrial back-pressure are to be expanded as much as is economically reasonable

- hydroelectric power is to be expanded from 64.5 TWh to 66 TWh, with attention paid to environmental aspects

- alternative forms of electricity generation are to be developed, such as:

  fuel cells
  wind power

- fuel-based electricity-generation techniques satisfying high environmental standards should be developed, especially with natural gas.

5. An energy-technology fund has been set up to encourage the development and demonstration of new energy technology with high environmental standards. The fund has access to SEK 100 million a year.

6. The electricity-distribution system is to be further developed. The additions and improvements to the grid, necessary for a nuclear phase-out, are to be carried out.

7. The government is to follow trends in electricity demand, electricity prices and the investment plans of the power companies. Electricity consumption is to be monitored continuously and conservation programmes, as well as supply-planning measures, are to be followed and revised as necessary.

A first evaluation of this plan will be made in 1990. Issues concerning the future shape of energy taxes should also have been clarified by this time.

This plan of action will be carried out on an economically correct basis. This means that the demand for new electricity-generation capacity will entail higher costs to society and that these will be allowed to affect the price level.

One characteristic of the Swedish electricity market is the absence of government price regulations. This Swedish model is to continue, and no regulation or interventions are at present expected from the government.

Summing up the present distribution of tasks and responsibilities in the face of the coming adjustment, one may say that the government and parliament formulate both long-term and short-term goals, as well as the framework of what may be done and the guidelines for what must be done.

This is achieved by imposing requirements to be met by the Swedish energy system as far as environment, security and emergency capacity are concerned.

Within this distribution of tasks and responsibilities, the power companies, local authorities, business and individuals are given the responsibility of finding a solution which harmonizes with their demands and needs and with the local situation.

The government's role in this work is, on the one hand, to determine what demands society is to make on the energy system, and, on the other, to develop new technology and new systems for demonstration and commercial introduction, through work on research and support to technological development.

In view of the parliamentary decision, we are now using both a short-term and a long-term perspective. Where the long-term perspective is concerned, we are now going to work on environmentally adapted energy scenarios, in order to test how and at what rate the change-over to the long-term goals defined for the year 2015 can be effected.

In this work, the changeover will, undoubtedly and unavoidably, affect large sectors of society and it is, to some extent, measures at local and regional level that can create scope for new production facilities.

Naturally, it is primarily the more efficient use of energy that we are now engaged in, both through government inputs and through changes in attitude and organization on the part of our energy companies.

Regarding the short-term perspective - up to the mid-1990s - we are now, in our programme to develop energy technology, devoting money to projects in the following areas:

a) small-scale combined heat and power plants, wind-power and hydropower plants

b) solar heating and heat storage, heat pumps, natural-gas distribution and storage

c) simultaneous elimination of sulphur and nitrogen oxides

d) gasification of biofuels and coal

e) waste incineration and reactor digestion of waste

f) indigenous fuels, e.g. improved techniques of harvesting energy forests.

When it comes to our governmental programme for more efficient use of electricity, we consider there are opportunities to raise efficiency in the following areas:

1. industrial electricity use for ventilation, pumps and fans (14 TWh)

2. indoor lighting and ventilation

3. electrically heated houses (21 TWh).

We are therefore becoming engaged in projects such as:

a) rotation-speed regulation in industrial fans and pumps

b) partial conversion of electrically heated houses, control opportunities

c) establishment of full-scale/demonstration systems in, for example, large housing enterprises, institutions, hospitals, offices, etc.

When it comes to long-term activities, it is also our task, in co-operation with the government, to define the targets and framework concerning environmental, security and emergency requirements, and thereby give agents in the energy and industrial sector, in conjunction with research and technical development, a stable base for their work.

Our work is both stimulating and a challenge to us in Sweden. However, at the same time we know that neither environmental nor energy issues are merely national ones. They are global, and co-operation between countries is therefore essential if together we are to succeed in attaining our goals.

22nd JAIF Annual Conference
12-14 April 1989

Lennart Fogelström, President, ABB Atom:

The Swedish energy policy in an industrial and international context.

Summary.

The Swedish nuclear programme is a success excepting public acceptance. However, there are reasons to believe that the public opinion will change and with the opinion eventually the energy policy.

Nuclear power was developed to complement hydro power. Several goals were set up. Nuclear energy had to be economically competitive, safe, environmentally benign and a low burden for the trade balance. Looking at the result nuclear energy has fulfilled most, if not all, of these demands.

The Swedish technology has never depended on foreign licenses. Safety has been kept in the forefront. All Swedish plants have filters which make the use of surrounding land possible even after an unlikely core melt accident. Sweden also has a very comprehensive programme for the final treatment of nuclear waste. This makes nuclear power basically a closed system and thus nuclear energy from environmental and safety point of view is matching hydro power.

Further, plant construction schedules have been short, operational reliability is excellent and the average radiation dose to nuclear plant personnel is very low. Together these factors make the Swedish nuclear power programme a formidable economical success.

The development of nuclear power hasn't stopped neither in Sweden nor abroad. As a matter of fact Sweden was pioneering the development of inherently safe reactors in the 1970ies which since then have gained an increasing international interest. Decisions taken ten years ago have little to do with the current and even less with the technology of the coming decades.

The Swedish industry is concerned not only over the future cost of electricity. The current energy policy also creates a lack of confidence in the future production capacity. The alternatives for producing electricity have one by one been politically eliminated, hydro, nuclear, coal and, as the Parliament in 1988 set a limit for the release of carbondioxide, even natural gas can be looked upon with doubt.

The energy consuming industries contribute strongly to an improvement of the balance of trade. The net export income from the pulp&paper industry is thus

three times that of the automotive industry. The population trend is towards an increasing number of retirees and a decreasing number of active employees. The percentage in non-industrial work has been increasing over the years. It is of strategic importance for the industry in the coming decades to get qualified personnel in sufficient numbers. The current energy policy makes this problem more difficult on a national basis. The Swedish labour unions are becoming more and more concerned over these related problems.

There are further objections against the current energy policy. How does it comply with the ambition to have a close relation to the inner European market after 1992? Should developed nations choose an energy policy which increases their dependence on fossil fuels which should be saved for lesser developed countries? Should nations with an advanced technological infrastructure make an energy choice which will increase the burden on the global environment?

Introduction.

The official energy policy in Sweden has developed step by step influenced by external events like TMI and Chernobyl and by the political force exercised by various pressure groups.

In the referendum of March 23, 1980, the two winning alternatives stipulated that the nuclear power plants which were under construction were to be completed and taken into operation. After this, the totally twelve nuclear power units were to be closed down at a rate consistent with the need for electricity to maintain employment and welfare. Further conditions were that nuclear power should not be substituted with oil or coal and that the twelve plants were to be operated pending the availability of renewable energy sources. Figure 1.

Shortly after the referendum the Parliament interpreted the result into a decision which stipulated that nuclear power should be phased out by the year 2010.

The accident in Chernobyl initiated an assessment of the safety standard of the Swedish nuclear reactors. The main question asked was if Chernobyl gave any reason to reevaluate the energy policy because of nuclear reactor safety. The result arrived at by the Nuclear Reactor Inspectorate was that Chernobyl did not give any cause to change the opinion about the safety of the reactors in Sweden. Figure 2.

In spite of this, the Government made in 1988 a proposition to the Parliament to speed up the nuclear phase out, two units should be taken out of operation already about 1995. In 1990 the Parliament will decide if the material which the government will then present is sufficiently credible for the Parliament to endorse the closing of two nuclear power plants in 1995 to 1996.

Mr Hans Rode, Director General of the Swedish National Energy Administration, and Dr Tor Ragnar Gerholm, Physics Professor at the University of Stockholm, present today their views on the current energy policy in Sweden. I shall give some further facts which together with their speeches gives you a base for an independent decision.

The question is, is the current energy policy of the Swedish Government credible or not?

The nuclear power programme, production reliability and working environment.

One reason which could support the governments policy would be if the Swedish nuclear power programme had failed to reach its objectives but this is certainly not the case.

On the countrary the programme has been extremely successful. As the only country in the western world outside the U.S.A., Sweden has developed its own LWR design without dependence on any license agreements. This is even more of an achievement if one takes a look at the operational results. Figure 3.

Compared with the world average, reactors of the Swedish design have year after year reached very competitive capacity factors indeed. As was stated in Nucleonics Week's issue of February 2, 1989, ABB Atom was the supplier who in 1988 reached the highest average capacity factor of all. Lacking operational reliability can thus not be the cause behind the governments ambition to phase out the nuclear power plants.

Neither is a bad working environment for the staff for operation and maintenance a reason. As you all know most nuclear power plants in the world fulfil very high requirements on internal working environment and as you can see from the figure the NPPs in Sweden can well stand a comparison. Figure 4.

Nuclear safety.

Could it be that there is reason to question the safety of the nuclear power plants?

Sweden is naturally participating in the international safety development and the trends which are valid internationally are valid also for Swedish reactors. But after TMI the Swedish Government went further in its demands on nuclear safety than the governments of most other countries.

It was stipulated that all NPPs in Sweden should be equipped with reactor containment venting filters by 1988. Figure 6. The requirement on the filters was that even in case of a reactor core melt accident, the radioactive material should be contained in the containment and in the filters so that the release to the environment is limited to a maximum of 0.01 percent of the core inventory. Expressed in another way this means that no limitation on the use of the surrounding land would be necessary after a core melt accident. It also implies there would not be any acute deaths nor radiation sickness due to the accident.

This programme has been implemented. Barsebäck's two units were equipped with a filter in 1985 and the installation of FILTRA/MVSS filters in the remaining units was completed in 1988.

Thus, from safety point of view there should be little reason to phase out nuclear power in Sweden.

This has also been supported by the Minister of Environment and Energy who frequently has said that the decision to phase out nuclear power in Sweden is not based on a lack of faith in the safety of the plants.

The reason is that the Swedish people is deeply concerned over nuclear power and as a politician the Minister feels obliged to let the concern of the people decide the direction of the energy policy. In order to set this concern into a proper setting I shall describe some of the views the Swedish people has about nuclear power.

Some figures on the public opinion.

As I just have discussed nuclear safety it can be appropriate to start with a look at how many Swedes believe we can operate the Swedish nuclear power plants without accidents. Figure 7. As you can see there is a very high confidence in the safety.

More important for the political decisions however, has been the percentage who feel deeply or rather deeply concerned over nuclear power. Figure 8. As you can see close to 30 percent confess to this and among women even more.

Could it be that this concern is caused by lacking information? The answer to the question "is radiation always a risk or does it vanish with time" perhaps gives an indication. Figure 9. About as many believe radiation is always a risk as those who believe radiation is reduced with time.

Most probably this misbelief also has a strong influence on the opinion about the safe disposal of radioactive waste. Figure 10. It is still a long way to go before the public gives the waste programme the recognition it truly deserves.

The nuclear waste.

Because looking at the nuclear waste programme of the Swedish utilities, one sees a very comprehensive one which is about to be fully implemented in commercial installations. Figure 11. There is a system in operation for transportation of all types of waste. A final depository for low and medium level waste was inaugurated in 1988. The results from an extensive research programme, covering both the final deposition of reprocessed high level waste and direct deposition of spent nuclear fuel, have been examined in an extensive mundane peer review. The response from the international expertise has been that the spent nuclear fuel, reprocessed or not, can be disposed of in a way which is safe for the environment. Further demonstrations will be made starting in 1992 when a laboratory at 500 meters depth in the bed-rock will be finished.

Sweden's current policy is that the spent fuel shall not be reprocessed. There is plenty of time for reconsideration, however, since the fuel will be stored for about forty years in the away from reactor storage of spent nuclear fuel, CLAB, which has been in operation since 1985.

Considering these facts, the waste should not be an valid argument against nuclear power. On the countrary the relatively small amounts of waste and the methods developed to take care of the waste should be an argument for nuclear power.

Facts a threat to the phase out.

Voices have been raised in the Parliament that the Government should not only talk about recognizing the concern of the people but also do something to meet this concern. Thus party colleagues of the energy minister have twice motioned that it should be a Government responsibility to bring the general public factual information about radiation and nuclear power.

Twice the Parliament has turned the motion down and among the arguments against it one from the anti-nuclear communist party is characteristic: if information of the kind which has been asked for in the motion is brought to the people the nuclear phase out would be threatened. Figure 12. For some facts is a threat, for nuclear power facts will in the long run win the case.

The economy of the nuclear alternative.

It has frequently been said that nuclear power can't carry its waste costs and still be competitive. Also this argument has proved to be false. The costs for the backend of the fuel cycle as well as the costs for decommissioning are accumulated in a fund in proportion to the kWhs produced.

For each kwh produced is currently 3.5 U.S. mills set aside for waste and decommissioning. Including this cost the average cost in 1988 for the twelve NPPs in Sweden was 25 mills per kWh. Depending on the year of commissioning the cost varies from unit to unit in the range 20 to 44 mills per kWh. Figure 13. This sets nuclear power in a very good position in almost any comparison.

Considering that the investment in the twelve NPPs is already made every competing alternative which is constructed solely to replace the NPPs, should compete with its total cost against the running cost the NPPs. From economical point of view this of course gives no alternative to the already operating NPPs.

Perhaps the alternatives would stand a better chance if one compares new investment with new investment? In such a comparison one prefers to use real interest and a fixed depreciation time, lets say 6 percent and 25 years. Figure

14. If new nuclear capacity was considered the cost would be about 37.5 mills per kWh which can be compared with new hydro 37.5 mills per kWh, new coal in a condensing plant 48.5 mills per Kwh, new coal in cogeneration 37.5 mills per kWh, new natural gas combi plant (heat and electricity) 48.5 mills per kWh and wind power 70 mills per kWh. In this comparison the cost for power transmission has been included.

The price of oil is now about double of what it was when it quite recently was at its lowest. Over the past fifteen years we have learned how unpredictable the price on fossil fuels can be and how suddenly the price can double. Besides the estimated cost, sensitivity to fuel cost increase should thus be taken into consideration. Figure 15. As we all know nuclear has a tremendous advantage over coal, oil and natural gas from this aspect.

If there were no other factors to consider than economy, the choice would be between hydro and nuclear. A problem for the Swedish energy future is that too many alternatives have been eliminated in the political process. Figure 16. Hydro construction was stopped already during the 1970ies and definitely in a decision by the Parliament in 1986. Nuclear power was eliminated by a Parliament decision after the referendum in 1980. Finally in 1988 the Parliament took a decision according to which the release of carbon dioxide from Swedish facilities must not be increased. If taken verbatim this eliminates oil, coal, natural gas and peat. The decision gives, however, some room for increased use of natural gas as substitute for coal and oil.

The conclusion is that those who are to make the decisions about the Swedish energy future are quite efficiently fenced in. New openings must be created. According to the minister of energy the nuclear option is totally out. Not even to use the existing units over their total technical lifetime is considered acceptable.

Instead the Socialdemocratic party who is in Government, recently published an energy programme which declares that nuclear energy shall be substituted with fossil fuels with natural gas as the main alternative. This declaration is made while the price negotiations with the Norwegian and Soviet suppliers of natural gas are still not wrapped up. If the programme comes true, the Swedish balance of current account will roughly go from the present deficit of about 2.5 billion USD to close to 4 billion USD which will increase the already heavy burden on the economy.

Nuclear power in Sweden has expanded after the referendum.

However, one must give the Government credit for very sound decisions when it comes to increasing the power in existing nuclear power plants. Due to among other measures, introduction of the more efficient SVEA BWR fuel design, it has been technically possible to increase the power production from the Swedish reactors. Since the referendum the output of the existing units have been increased with close to 500 MW, corresponding to one medium sized NPP. Forsmark 3 and Oskarshamn 3 received their permit to increase power as late as last month. Figure 17.

Nuclear power has only started its production.

Looking at how much nuclear energy has been produced in the existing NPPs, how much is left until 2010 and how much more could be produced it is difficult to comprehend that the decisions in the future would not be taken with the same open mind as the decisions about power uprating. Figure 18. The economic benefits which can be gained from 900 TWh of at that time extremely cheap power must be an irresistible temptation for any ministers of energy and finance after the turn of the century. But my conviction is that a revision of the current policy must take place long before that.

Nuclear technology hasn't stopped to develop.

From what I have said so far it is clear that much has changed since the Swedish referendum and the development continues at an accelerating pace.

Based on the vast experience of LWR technology, more advanced LWRs will be offered the future customers. The existing designs are developed further to reach plants with an even higher degree of safety, simplified licensing, shorter construction time, and more rational operation and maintenance etc, all to bring forward even more competitive NPPs. Figure 19. In parallel more evolutionary LWRs are developed, LWRs which safety is inherent or based on passive systems. Figure 20.

ABB Atom follows both these lines of development. The BWR90, which is developed in close cooperation with Finnish utilities, is the very advanced BWR for the next century and PIUS is the evolutionary concept. What this proves is that technological development didn't halt at the time of TMI.

The decisions made in 1980 were made on a different base of knowledge than the decisions made today and the difference will be even greater in the 1990ies. Not only the technological base for decisions will be different, so will the constituency and to a large extent also the Parliament. I can assure you I have hope for the future.

Sweden's supply of electricity.

Sweden is using close to 140 TWh of electricity including losses in transmission and distribution. Figure 21. Hydro and nuclear produce about half of this each. According to the official policy part of the nuclear production is to be compensated for by conservation. The distribution among consumers is described by the figure. Let's take a look at each of these user categories.

Transportation takes a very small part of the consumption but the political ambition is to transfer more of the transportation work from road to rail. A possible future option which could have an influence is an increased use of electrical cars. The air pollution of most major cities can lead to an accelerated development of this so far not very successful technology.

The household consumption is separated in two parts, general consumption and electric heating. It is quite safe to claim that the general consumption will be increasing. This estimate is based on an evaluation of the penetration of labour saving and other appliances in homes and it is supported by the opinion of the public. In a poll the people were asked if they expected to use less, equal or more electricity in the year 2000 than today. Only 6 percent expected to use less, 25 percent an equal amount and 68 percent more than today.

The public and service sectors have been expanding over the years. So has the electricity consuming equipment used in these sectors. Even if the expansion, at least in the public sector, most likely has slowed down, it's not very likely that the consumption of electricity can be reduced from the present level. Most probably there will instead be a slight increase. An indication supporting this is that in the U.S., computers consume more electricity today than the steel industry.

Electrical heating has been a very competitive alternative which has survived continuous political efforts to limit its use. 27 TWh is a considerable amount of electrical energy which could compensate for almost half of the nuclear generation if a substitution was possible.

The problem is that there are about 800000 homes totally heated with electricity. 500000 of these houses have no other alternative. In addition 350000 homes have a combination of electric heating and oil or wood burning, in some cases utilizing heat pumps, which until very recently were enthusiastically supported by most politicians.

To substitute electricity with some other source for heating would require a considerable investment by the houseowner. This constitutes a political problem per Se but furthermore, to make economy a sufficient motivation for the houseowner to invest in an alternative form of heating would require a very substantial increase of the price of electricity, so substantial that not only all household consumers could become a political problem for the party politically responsible, the industry would also be in serious trouble.

The industry's consumption is just above 50 TWh. Of these 50 TWh about 37 is consumed by industries for which energy and especially electricity is a major production factor. The mining industry, iron and steel industry, part of the chemical industry, the pulp and paper industry etc belong to this category.

It has frequently been claimed that Sweden should transfer from these traditional branches into mechanical, electronics and service industries. This is a proposed method to reduce the electrical consumption of the industry.

The problem for Sweden is that this energy consuming industry which is presumed to be substituted, is extremely important for the economy. Just as an example the net export income from the pulp&paper industry is three times that of the automotive industry. The net export income in the pulp&paper industry is 8 billion USD, in iron&steel it is almost 3 billion USD, in mining close to 1 billion and in the heavy chemicals industry 1.5 billion USD. Figure 22. An energy policy which threatens the supply of electricity is a direct threat against these industries and, thus also against the economy of Sweden.

It is a low risk prediction to claim that the energy consuming industry will continue to be extremely important for the Swedish economy and thus a factor which is hard to neglect in future decisions about the energy policy.

This is enhanced by the fact that the industry has a lack of employees already today. To substitute high energy consuming industries with high production per employee with low energy consuming but more labour intensive industry hardly seems the right way to go. This problem is increased year by year as those employees reaching retirement age grow in number while the young, professionally active are decreasing.

Sweden and Europe.

The Swedish situation must be seen in an international context. If the Swedish industry shall stay competitive Sweden can not deviate in its policies too much from other countries. If one compares the development in Sweden with the average trends in Europe during the last 15 years one can see an obvious similarity. Figure 23. The consumption of non-electric energy has been kept constant or even been slightly reduced while the consumption of electricity has gone up.

If one instead looks at the forecasts for the remaining years of this century one finds an astonishing difference. Figure 24. One can wonder which strange forces shall make it possible for Sweden to pursue such an odd course.?

There are no such forces. The industry has realised this and is mobilising to influence the Government to change to a more realistic direction.

The unions are concerned.

It has also become more and more evident that the labour unions don't support the current energy policy. There is reason for the unions' opposition. According to a study made by the National Energy Administration last year, Sweden can expect to be up to 160000 jobs shorter by 2010 with the present policy. Many of these jobs will be lost in parts of Sweden which already have problems with unemployment. Also this will become an increasingly important factor for the future decisions in Sweden.

Conclusion

If the current Government policy would be realised, Sweden would certainly be out of, but still surrounded with nuclear power plants in increasing numbers. Figure 25.

Looking at this situation it is worth to notice that other nations which have decided not to go nuclear or to halt their nuclear development, as a rule have come into a situation in which they import electricity from their neighbours. It is even more ironic that this electricity usually is produced in nuclear power plants.

While the Swedish energy debate goes on the number of reactors is increasing in the world. New nuclear power plants have been ordered in Japan, Korea, France and Great Britain who like Finland is considering to go further in the coming years.

Since TMI, the number of reactors in operation world-wide has increased to over 400. The accumulated experience from nuclear power plant operation is now some 4000 reactor-years. The experience of nuclear operation is rapidly increasing.

I have been told that Sweden is used by anti-nuclear groups in Japan as if Sweden had a solution how to phase out nuclear power. This is clearly not true. We have a political decision to phase out and we are trying to find the means do so, but, it is proving to be very difficult and very costly both from environmental and economic point of view.

All the factors I have brought up support a change of the current energy policy in Sweden. Internationally nuclear power has come to stay as an increasingly important alternative for energy production. It would be very surprising if an advanced industrialised country such as Sweden were to distance itself from this international development at a for the Swedish economy and environment very costly price.

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ASEA BROWN BOVERI

The Swedish Energy Policy in an Industrial and International Context

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Conditions for Nuclear Phase Out

- Welfare maintained
- Employment maintained
- No increase of oil or coal
- Renewables available

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SKI - The Nuclear Power Inspectorate

"Chernobyl no cause to change
the opinion about the safety
in Swedish NPPs."

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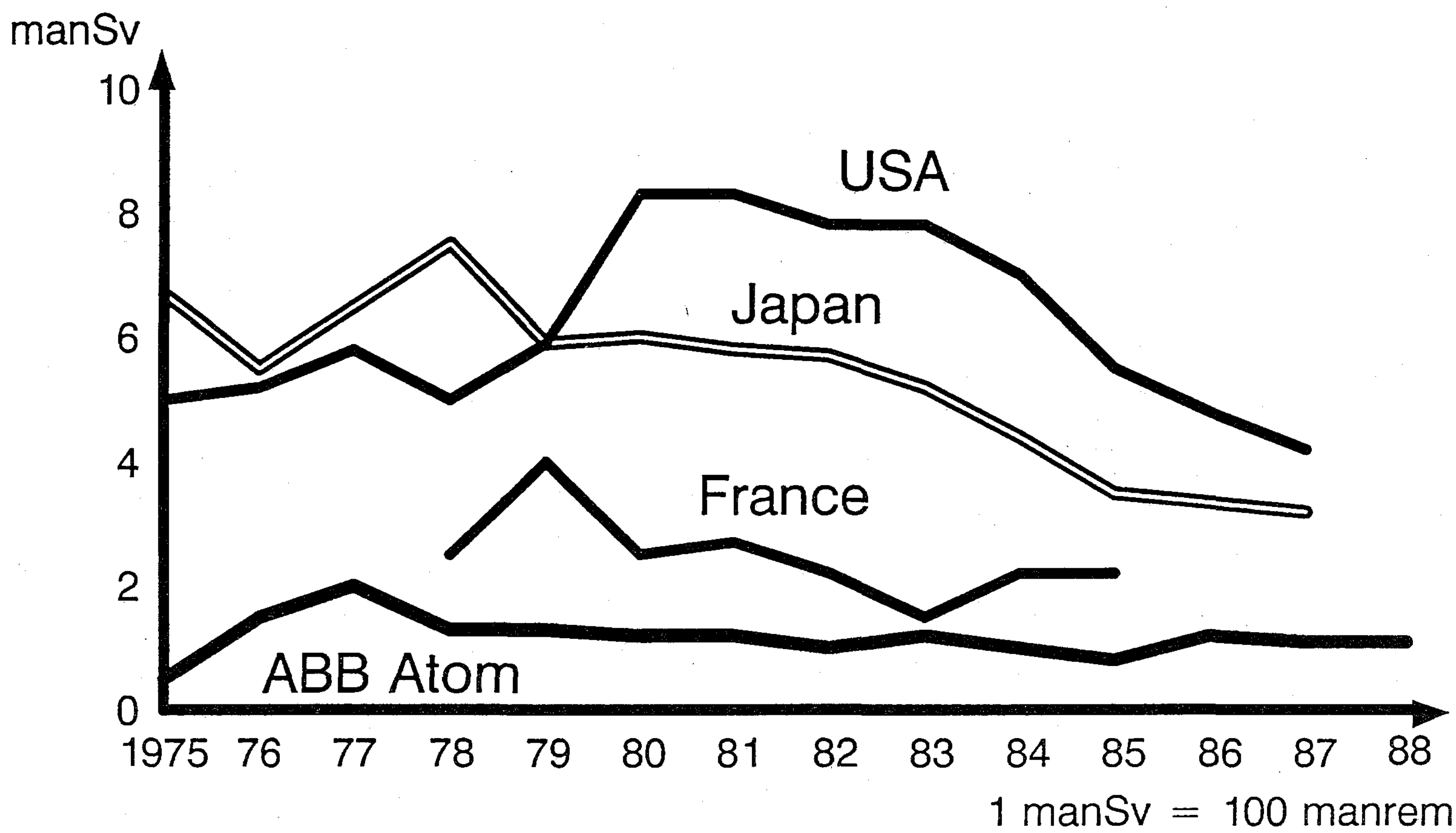
Radiation Exposure



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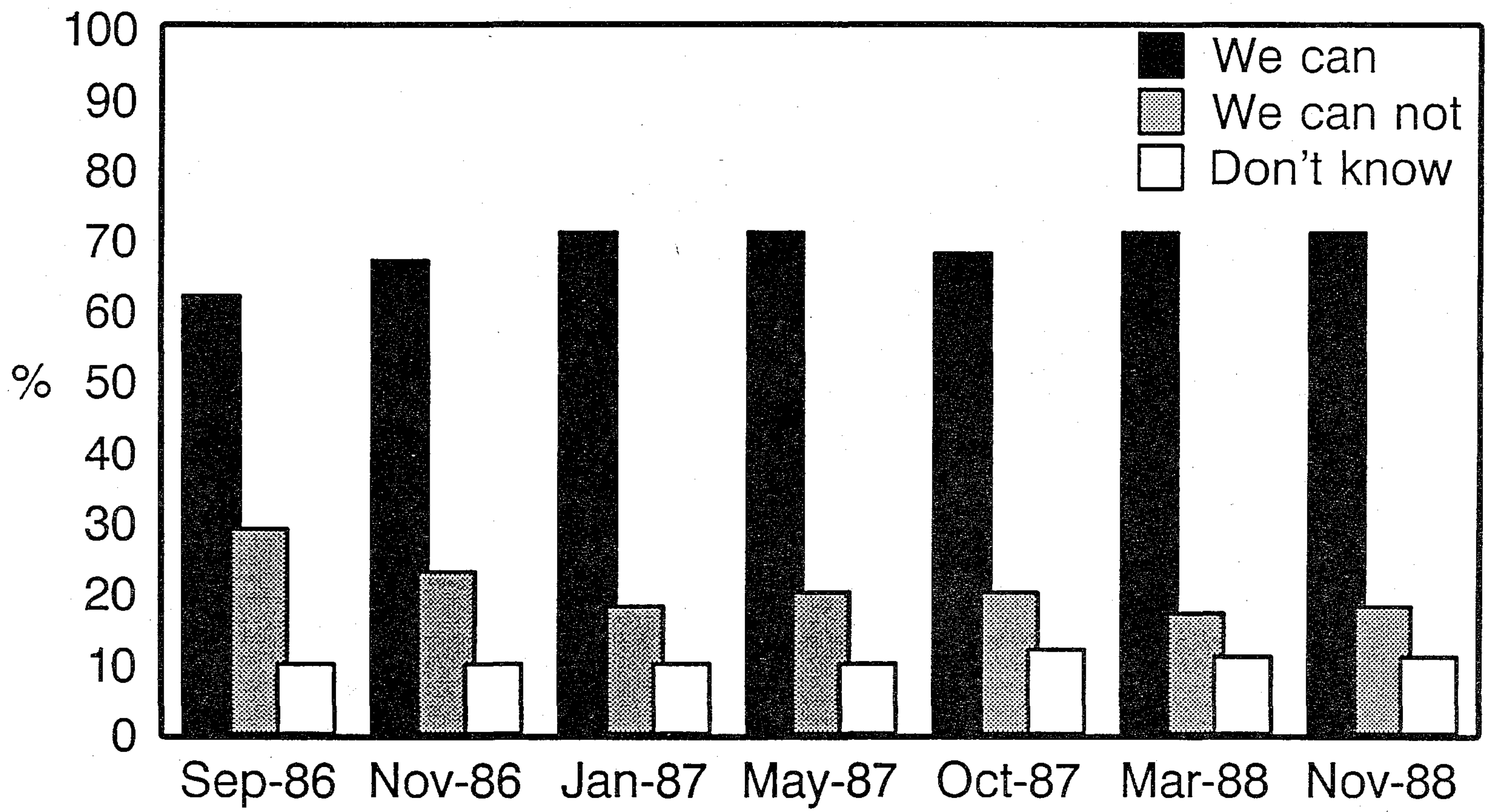
Sweden: Do you believe we can operate our NPP's without severe accidents?



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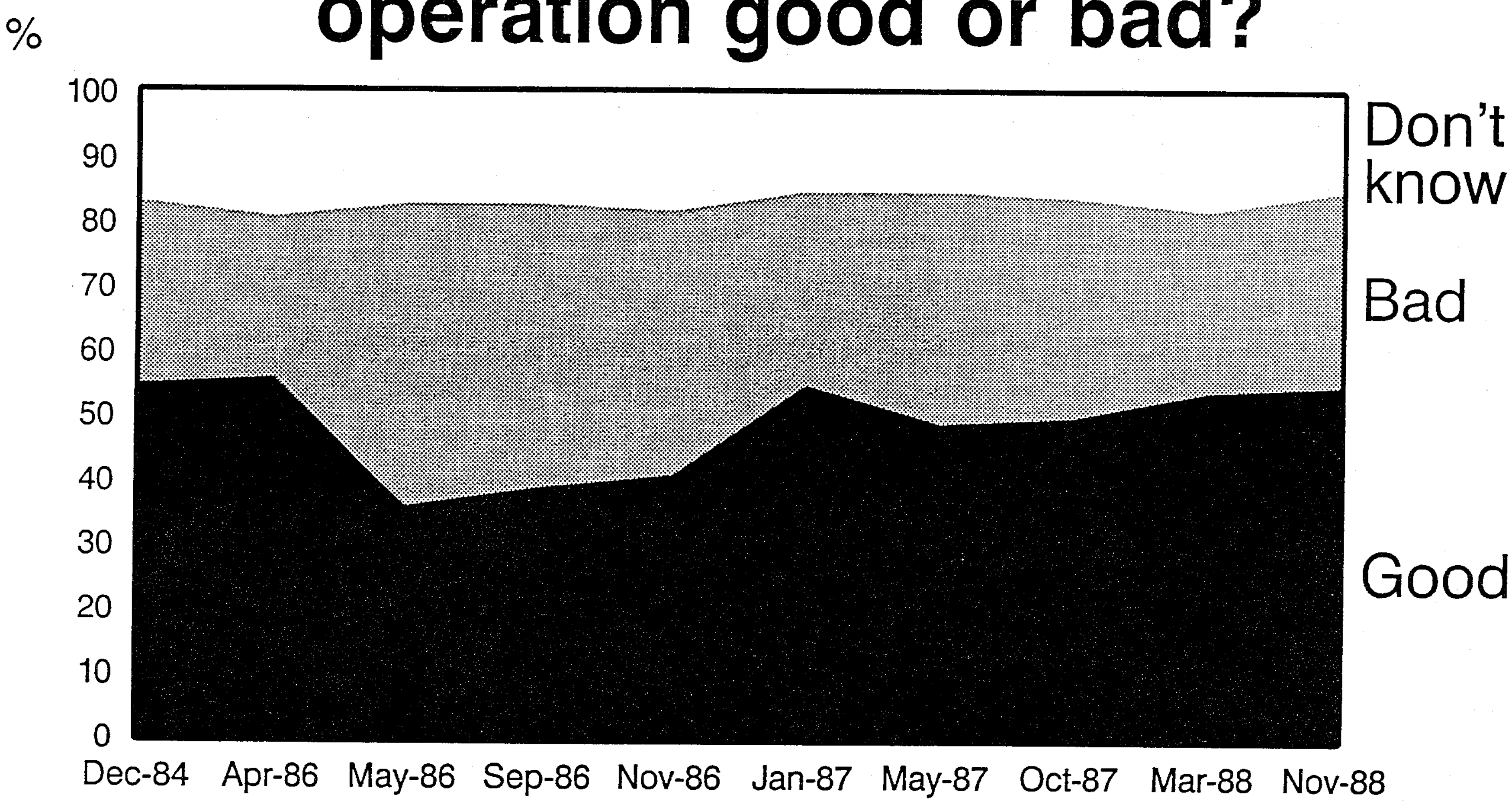
Sweden: Is the experience from NPP operation good or bad?



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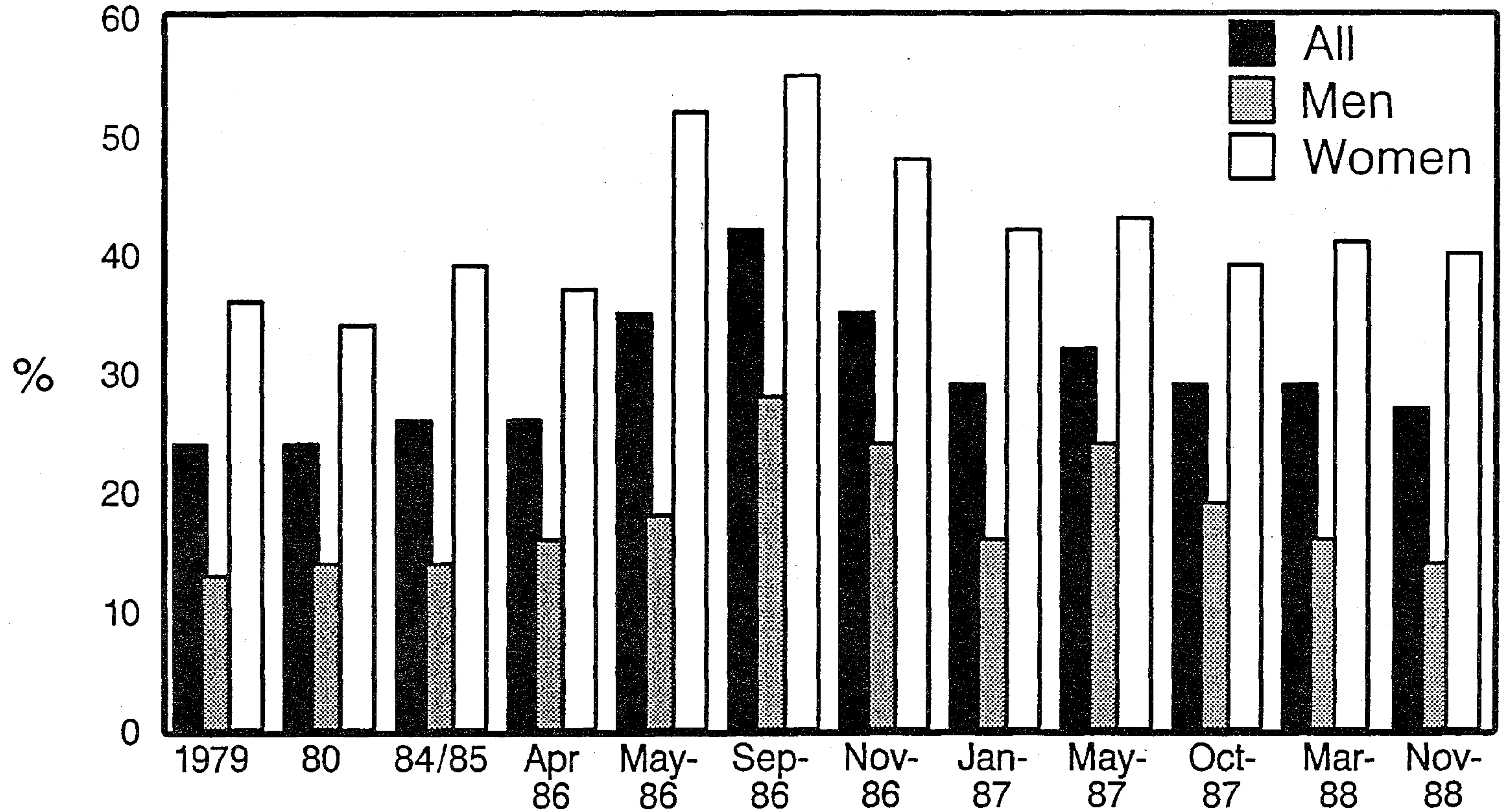
Sweden: Percentage deeply or rather deeply concerned over nuclear power



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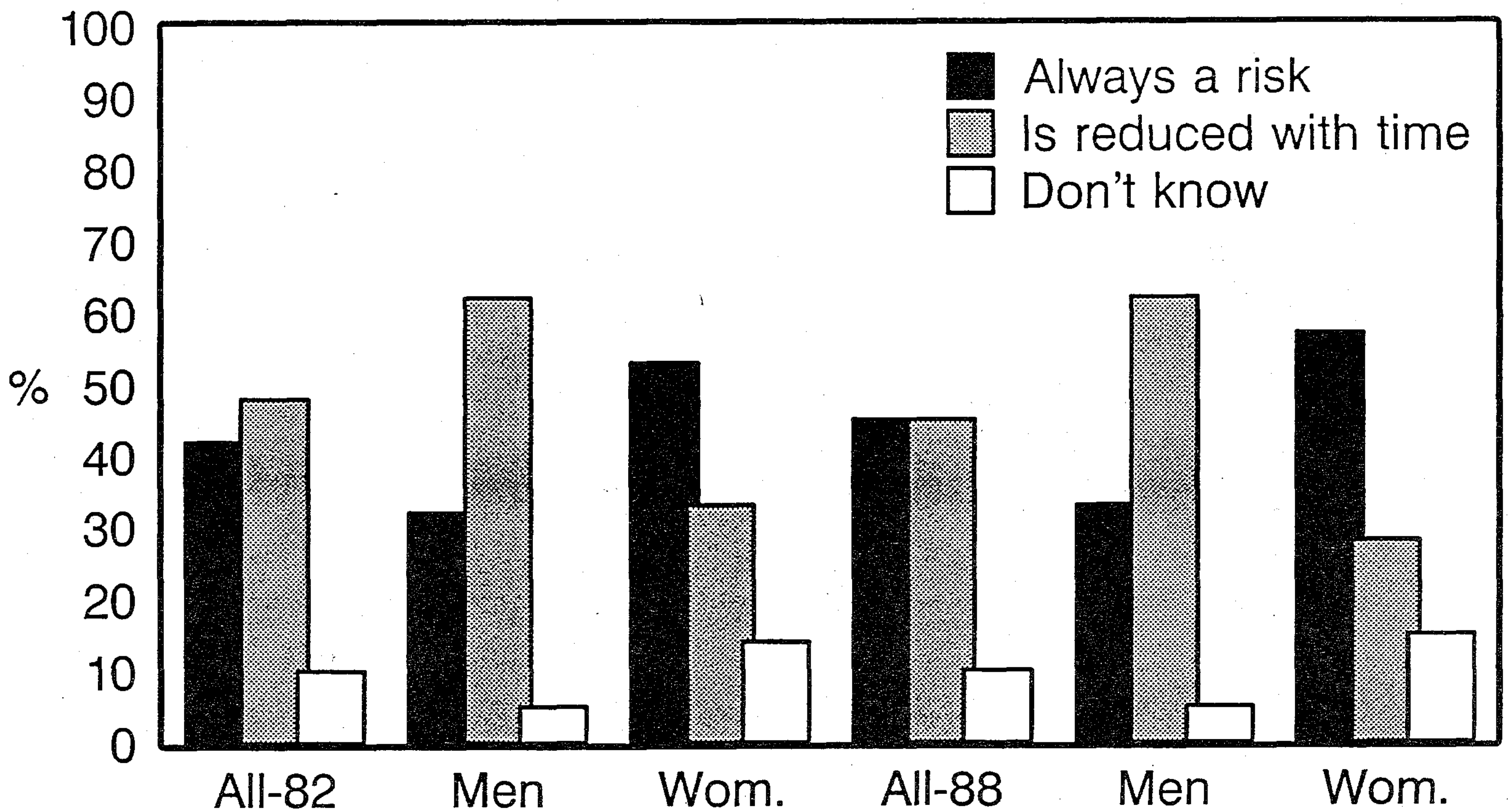
Sweden: Is radiation always a risk or does it vanish with time?



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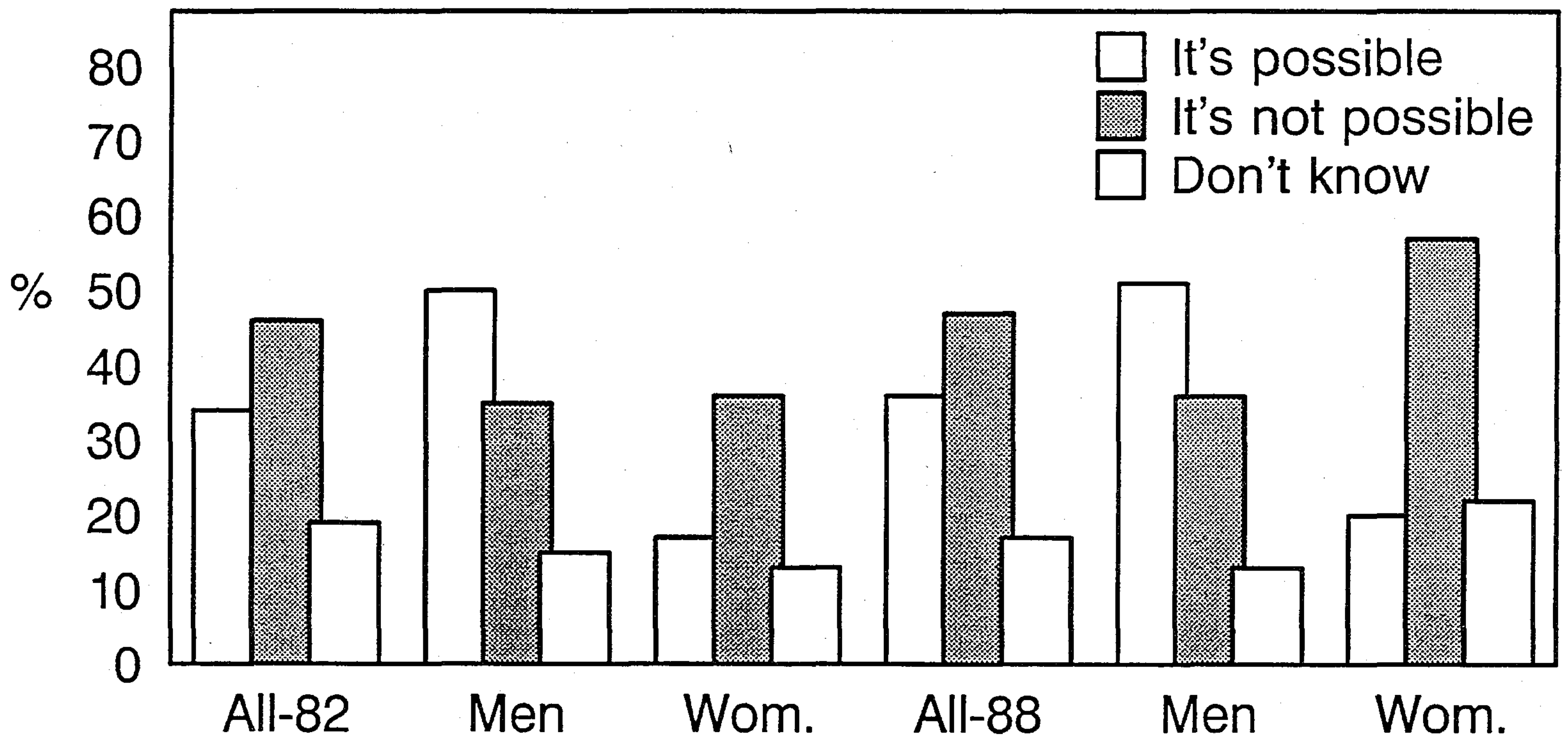
Sweden: Considering that radioactivity is reduced with time, is it possible or not to arrange a safe disposal of the nuclear waste?



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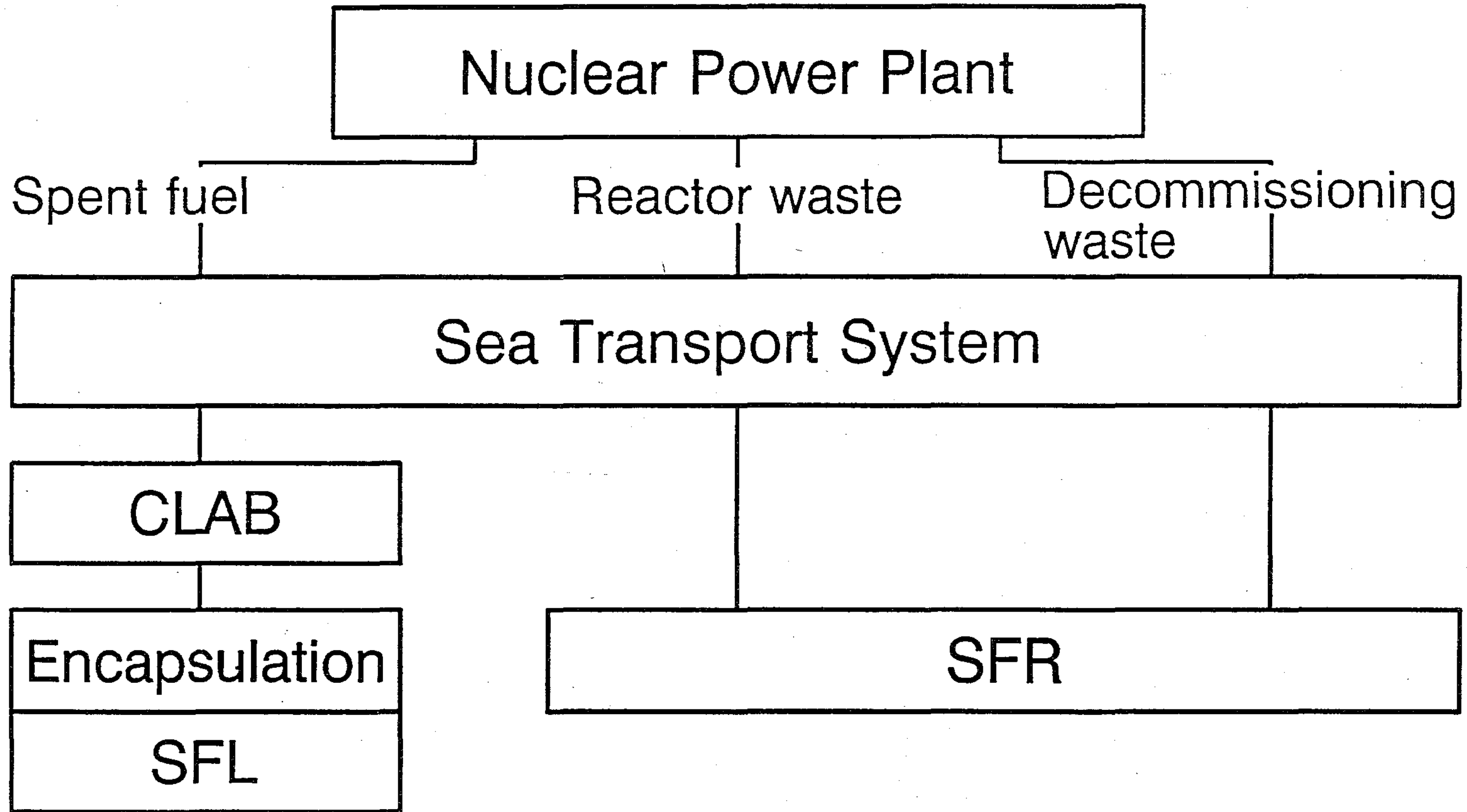
Nuclear Fuel Cycle Back End in Sweden



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Facts about Nuclear

A threat to
the nuclear phase out

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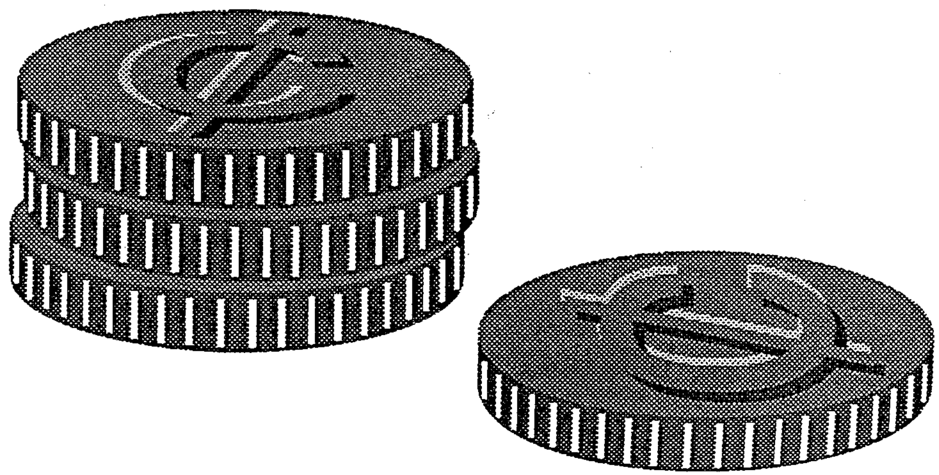
Swedish Nuclear Cost

2.0 - 4.4 US¢/kWh



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Sweden
New Electric Capacity

	US ¢/kWh
Nuclear	3.7
Hydro	3.4
Coal	4.8
Coal, cogeneration	3.7
Natural gas, comb	4.8
Wind	7.0

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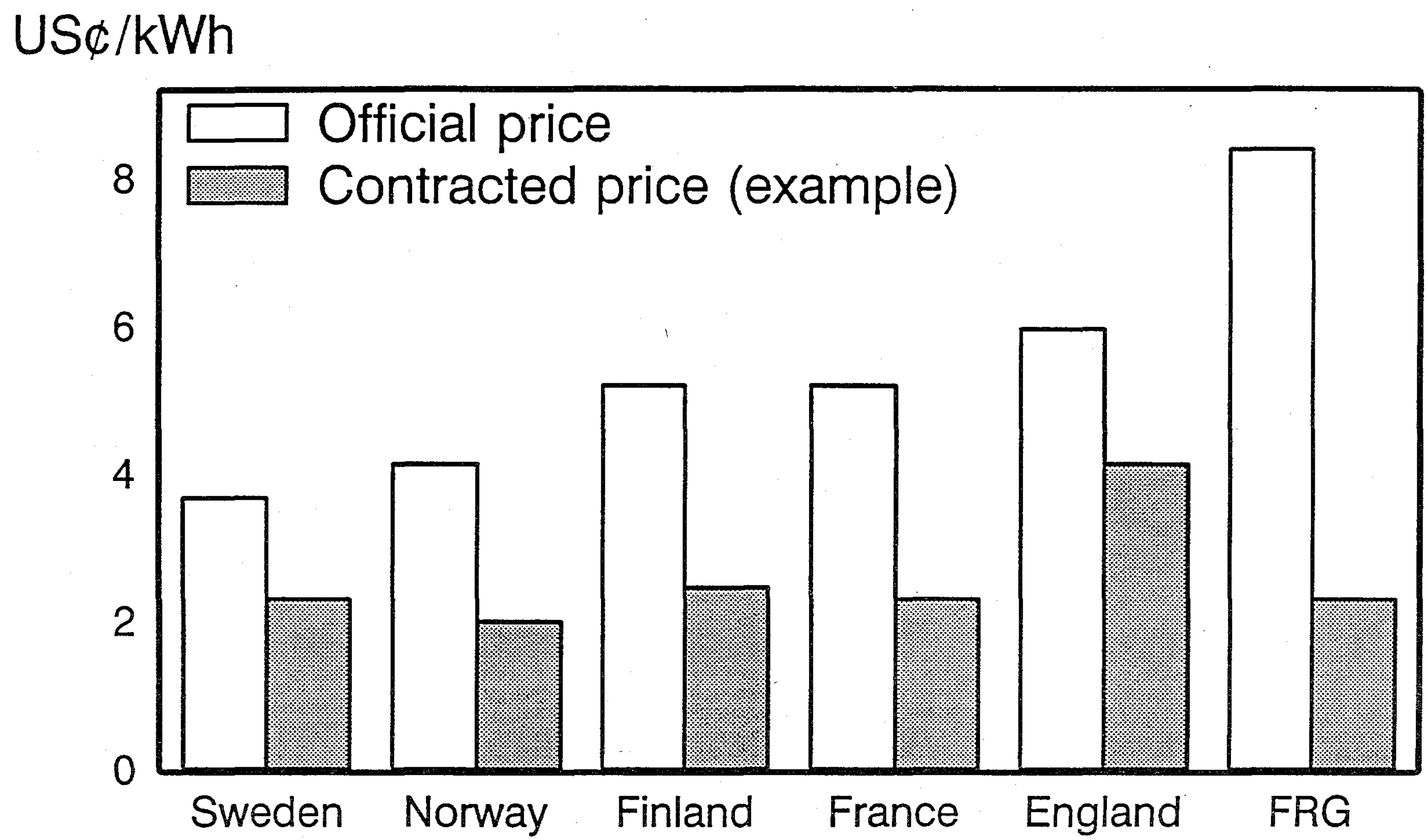
Price of Electrical Power



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(Source: Industriförbundet)

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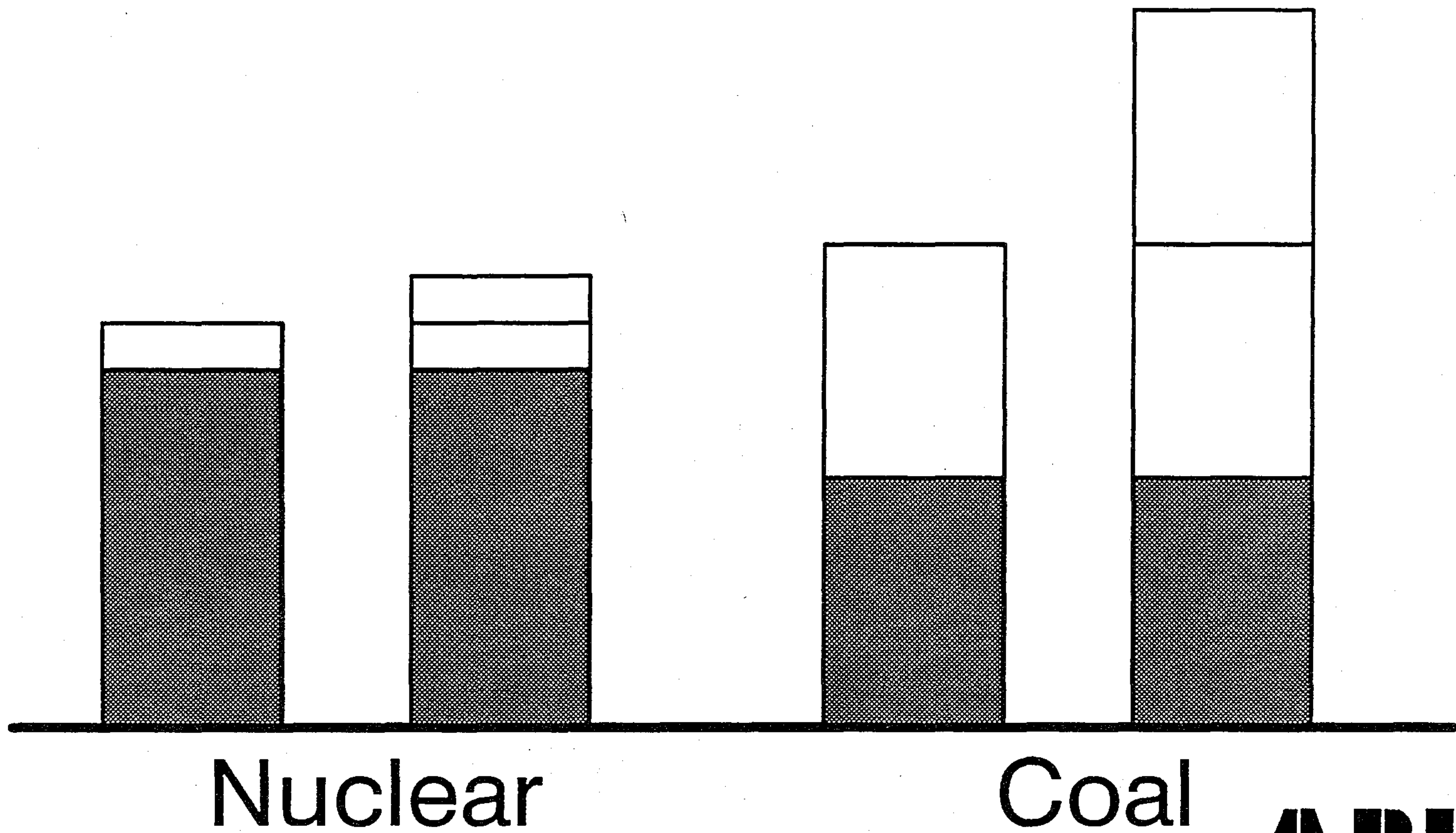
Coal vs. Nuclear
100% Increase in Fuel Cost



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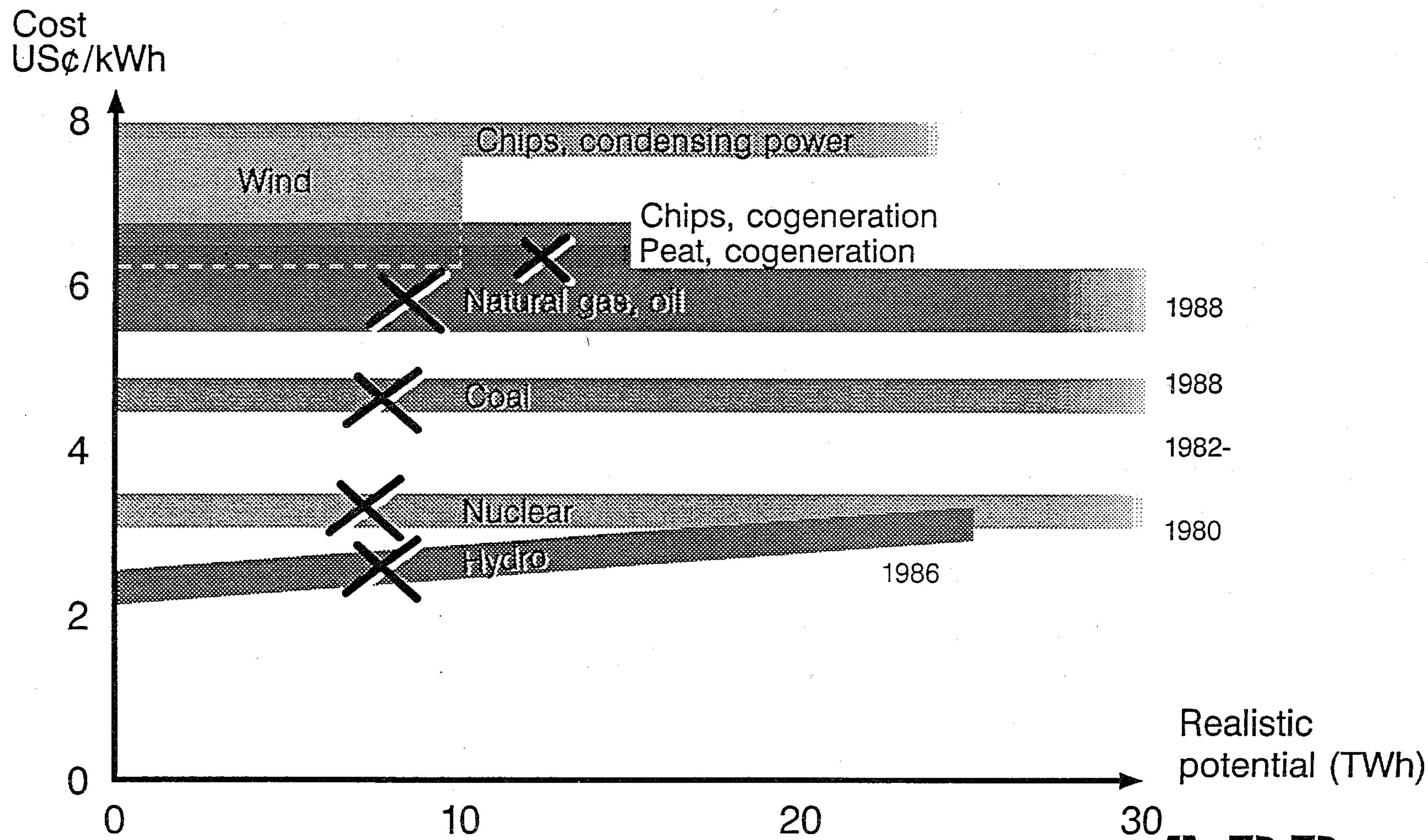
The Eliminated Alternatives



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Uprating Nuclear Power Plants

Plant	Rated power MWe net	Power uprate %	Power uprate MWe	Mechanical changes in	In operation
Oskarshamn 2	570	106	34	T, RS	1982
Barsebäck 1	570	106	34	T, RS	1985
Barsebäck 2	570	106	34	T, RS	1985
Forsmark 1	900	108	70	T, RS, SS	1986
Forsmark 2	900	108	70	T, RS, SS	1986
Ringhals 1	750	110	75	T, HS	1988
TVO I	660	108	50	T,RS,SS	1984
TVO II	660	108	50	T, RS,SS	1984
Forsmark 3	1060	109	96	s	1989
Oskarshamn 3	1060	109	96	s	1989

T - Turbine
SS - Steam separators
s - Study going on
RS - Relief system
HS - Hydralic scram system

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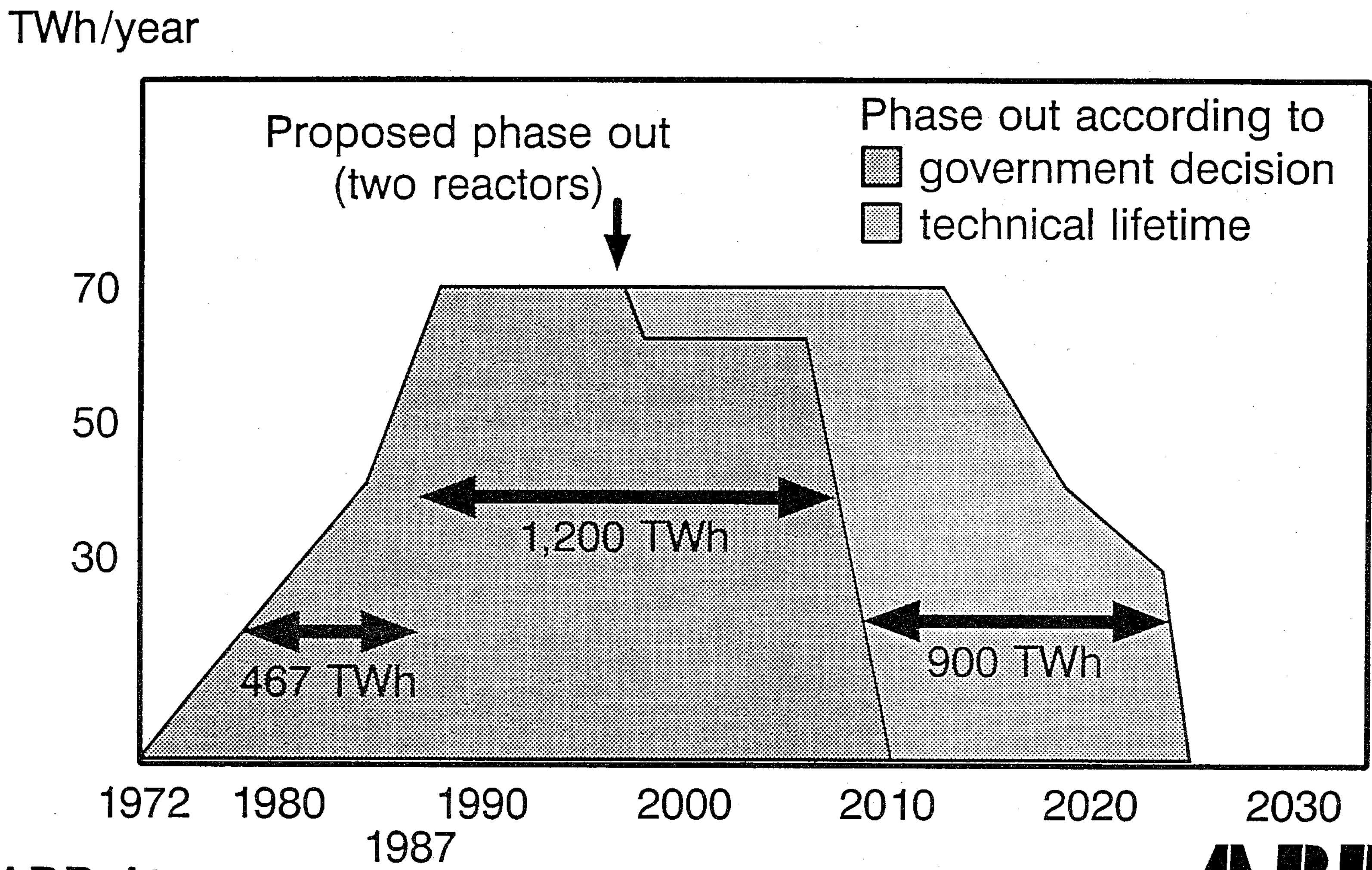
Nuclear Power Generation



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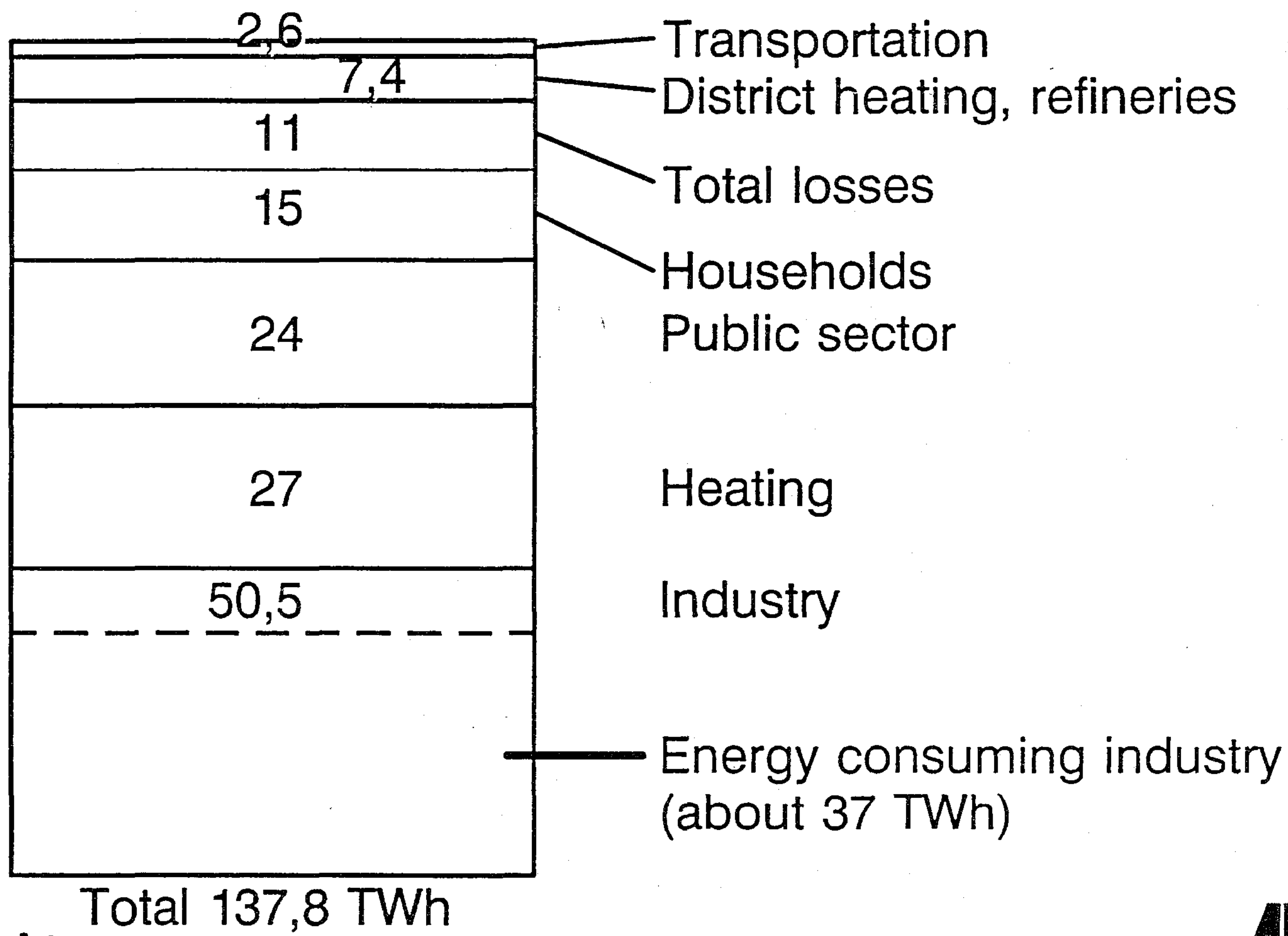
Electricity Consumption 1987



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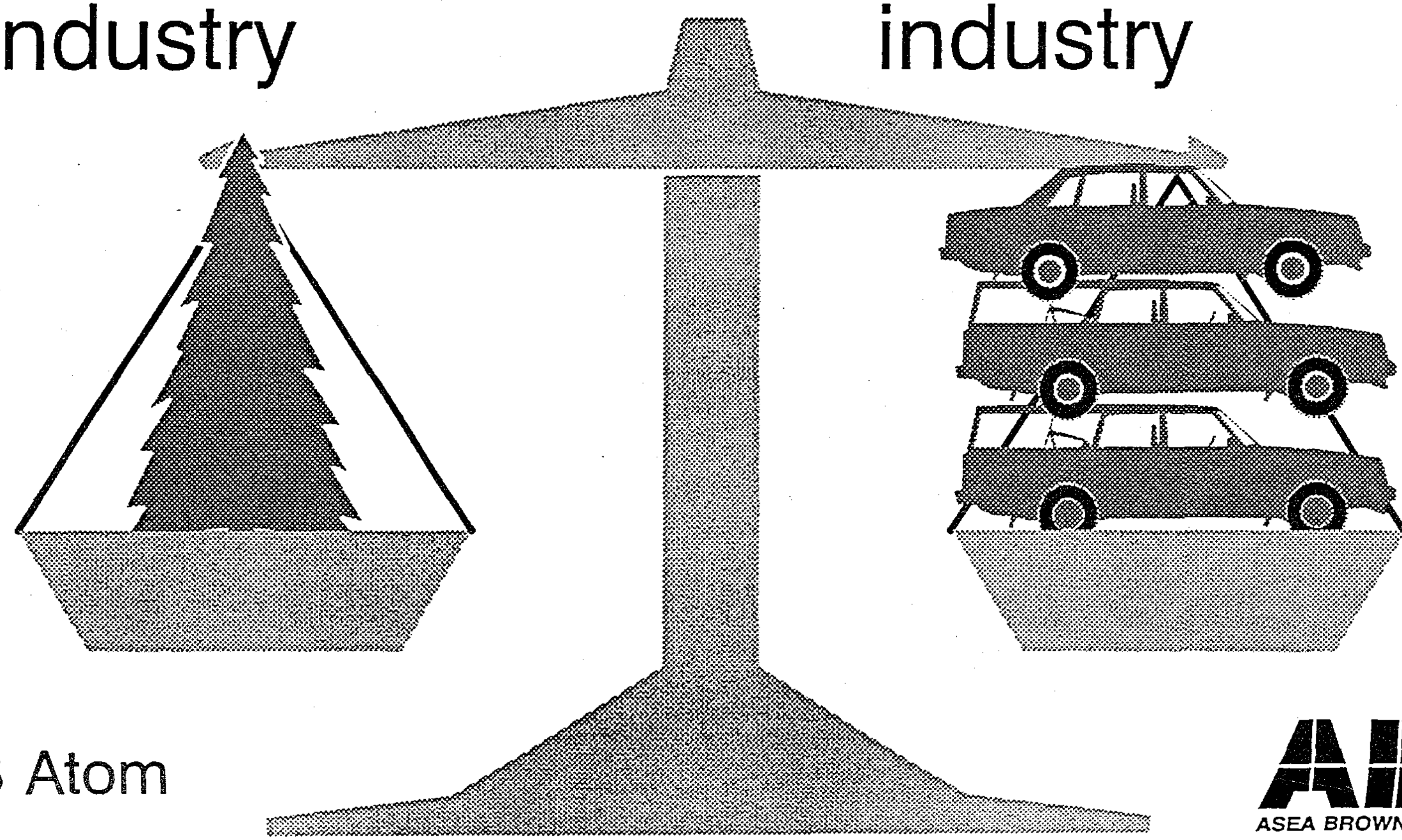
Sweden
Net Export Income:

Pulp & paper industry = 3 X automotive industry



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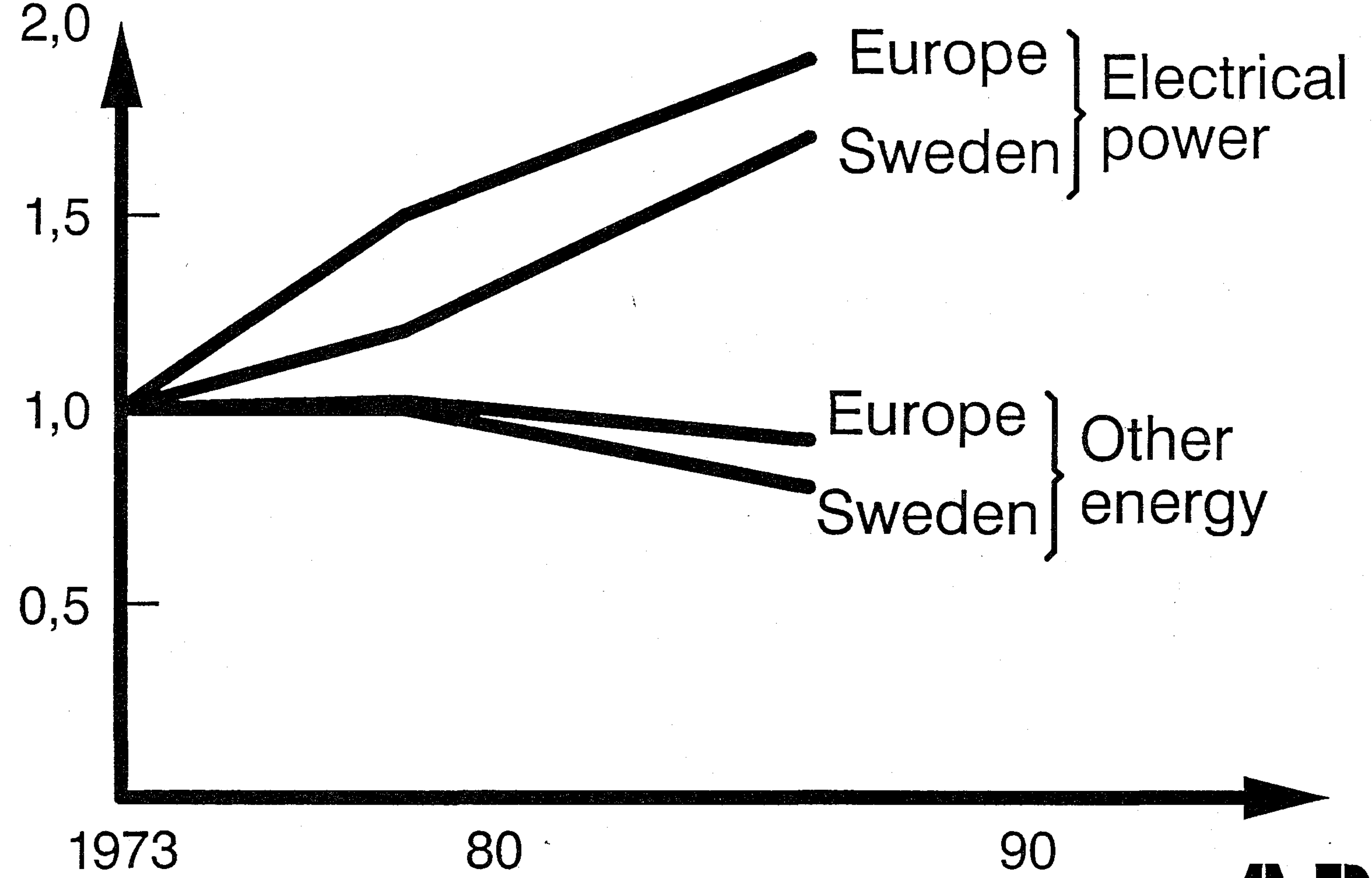
Energy Sweden - Europe



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(Source IEA 1988)

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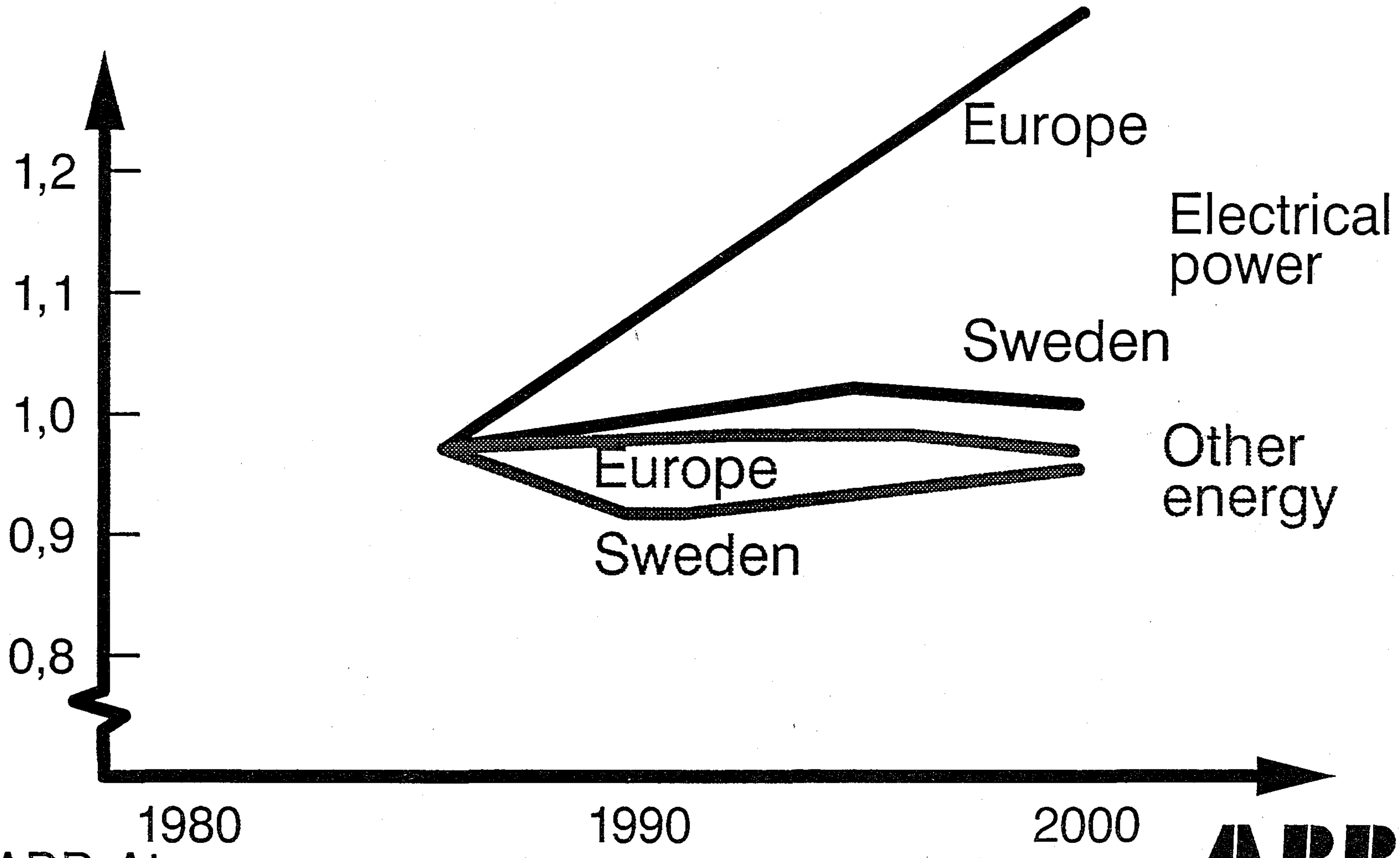
Energy Sweden - Europe



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(Source: IEA 1988)

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Europe - Summary

- The electrical power share increases strongly
- The importance of nuclear power remains
- Open power market within EC

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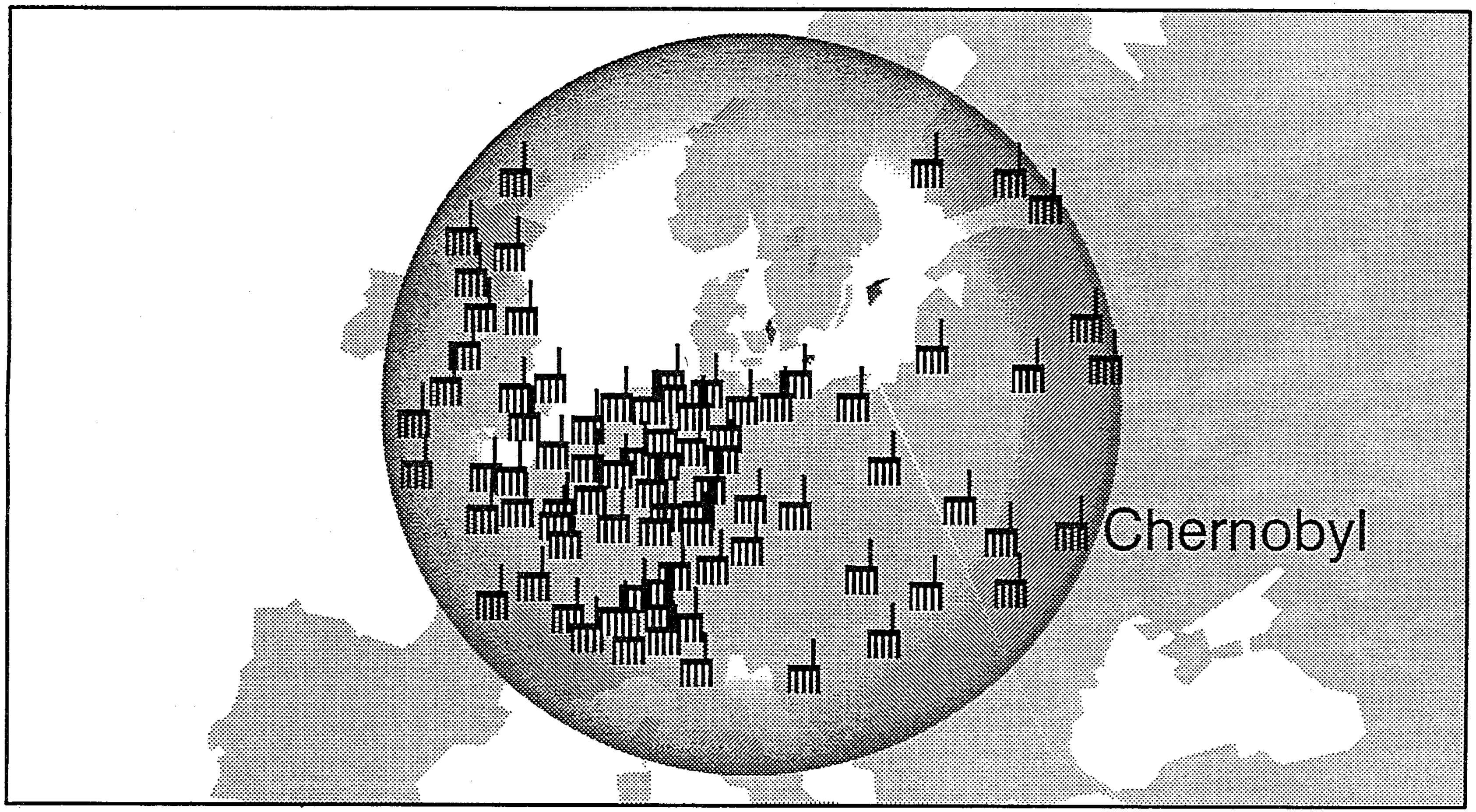
Is Sweden Safer without Nuclear Power?



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SWEDEN's ENERGY FUTURE

Policy vs politics

by

Tor Ragnar Gerholm

Professor of Physics, University of Stockholm

Abstract

Hydroelectric power played a major role in the industrialization of Sweden. But by the late 50s environmental resistance essentially foreclosed further hydroelectric development projects. Nuclear power was therefore enthusiastically seized upon as a viable new alternative. Sweden embarked upon an ambitious nuclear effort which finally met with striking success. Half of the electricity now generated in Sweden comes from our 12 nuclear reactors. Of these 10 have been made by ASEA-ATOM (now ABB-ATOM).

But in the 60s nuclear power was not yet ready for use. Petroleum served as a bridge to the nuclear future. Oil was imported to Sweden in ever increasing amounts, not only for power production, but also for industrial and domestic heat and for the fueling of a rapidly growing fleet of motor vehicles. In the early 70s Sweden's per capita consumption of petroleum was higher than in any other industrialized country.

The oil price shock in 1973 probably hit Sweden harder than other OECD countries. Energy conservation, efficient energy use and - in particular - oil substitution became top priority goals.

Unfortunately public debate took a weird turn: energy use rather than oil substitution was seen as the main problem. Nuclear energy, just about ready to be called upon as a major means for oil substitution, was singled out as the culprit. After Three Mile Island the political parties reluctantly agreed to a nuclear referendum. The outcome of this spectacle was somehow interpreted to mean that all nuclear power plants should be phased out by the year 2010 at the latest. These events silenced the debate completely.

In the wake of the referendum and in the absence of public debate nuclear power was massively introduced as a substitute for oil.

Renewable and domestic sources of energy were supported on an ambitious RD & D level but with meagre and disappointing results. Meanwhile public opinion changed slowly but steadily towards a more pronuclear attitude.

Chernobyl called the bluff. It was felt that something had to be done to make the promised nuclear phase out appear more credible. The Government proposed a premature decommissioning of two, out of the twelve, nuclear power reactors.

This seemed like a modest proposal in particular since the nuclear contribution to the Swedish energy balance is systematically undervalued by a deceptive accounting method used in Sweden but hardly anywhere else. But it is now becoming abundantly clear that in economic, ecological and political terms a heavy price will have to be paid for the forsaken reactors. Furthermore the immediate impact of the Chernobyl accident has already worn off and the environmental movement is now turning against all realistic alternatives to nuclear power.

Since we find ourselves caught in a blind alley the nuclear phase out is not likely to occur. However the current breed of energy politicians will certainly be phased out as time goes by.

In other words: the key to the understanding of Sweden's energy future is not to be found in policy but in politics.

Introduction

A century ago Sweden was one of the poorest countries in Europe and perhaps in the whole world. Our industrial revolution was slow in coming, probably for the simple reason that significant amounts of fossil fuel have never been found in Sweden. The one and only domestic source of energy available in large quantities was embodied in our great river's freely flowing water. We had to wait until technology could tell us how to harness these hydraulic forces and to make them instantaneously available over large distances through the intermediary of electricity.

By the early 30s engineering was ready. Electric power in ever increasing amounts began to flow from the hydraulic powerplants up in the north to the major population centers in the southern third of our stretched out country. Sweden embarked upon an accelerated pace of industrialization, propelling itself out of its so far unyielding poverty. In half a century she emerged as one of the wealthiest nations of the world.

The important point is that welfare is a fairly recent phenomenon in our country. Many of us - and the present author is one of them - can still vividly recall how hard and cruel life could be in the old pre-electric days. To us a "low energy" future has few attractions to offer.

From success to failure

However, at the end of the 50s the bottom of the hydroelectric potential was already in sight. At the same time environmental resistance to new hydroelectric projects had risen to politically intolerable levels. With hydraulic power foreclosed alternate forms of primary energy had to be found to meet the rising demands for electric power.

Scientific research and technological development held a fascinating new source of energy in prospect: nuclear. A seemingly endless supply of domestic fuel appeared to be almost within reach. Our huge reserves of low grade uranium ore could conceivably be turned into nuclear power.

Sweden courageously decided to make a nuclear effort all by itself. After a false start and many major mistakes the development project finally met with a striking success. Today Sweden is one of the very few countries that are able to offer turn key nuclear plants. Moreover, the reactors built by Swedish company ASEA-ATOM (now ABB-ATOM) have in practice proven to be among the very best in the world in terms of efficiency, reliability and availability.

Half of the electricity now generated in Sweden comes from our nuclear power plants. These are used for base load, while the remainder, essentially hydro, has been turned into capacity regulation matching the large daily and annual fluctuations in demand.

All of this is operated within NORDEL, an interscandinavian cooperation scheme, which presents an almost unbeatable system for efficient and reliable production and delivery of electric energy.

But in the 50s this belonged to the future. Nuclear technology was far from mature and could not be relied upon for some time to come. Petroleum offered itself as a convenient bridge to the nuclear future. Cheap petroleum was readily available in seemingly boundless quantities at the world market.

We imported oil and oil products in ever increasing amounts. It is symptomatic that Sweden pioneered in supertanker production. The imported petroleum was used not only for electricity generation, but also for industrial processes and domestic heat and, of course, for powering the rapidly growing fleet of motor vehicles. In the early 70s Sweden's per capita consumption of petroleum, was the highest of all industrialized countries'. All of this oil was imported. Most of it came from the Middle East!

Sweden was probably harder hit by the oil price shock than any other OECD country. At any rate its, through oil import acquired, vulnerability was most effectively demonstrated when a handsome surplus in trade balance suddenly turned into a most depressing deficit (fig 1), a deficit which stayed over the years, piling up to a substantial foreign debt. In 1984, to give an example, the debt service accounted for as much as the total expenditure for Sweden's military defense.

It took us some time to measure the magnitude of the damage done to our economy and fully comprehend its political implications. In the meantime public debate took a weird turn: energy use rather than oil consumption was seen as the main problem. Energy conservation was advocated rather than oil substitution. Nuclear energy, just about ready to be called upon as our only major means for reducing oil dependence, was singled out as the main culprit. An almost insane energy debate took off from reality to become its own goal and purpose.

In spite of internal opposition the socialdemocrats under Olof Palme staunchly defended their nuclear policy against the vigorous assaults launched by the anti-nuclear opposition led by the popular leader of the center party: Thorbjörn Fälldin. The industrial community, anxious to see Palme ousted for quite different reasons, kept a low profile. Palme lost power in the 1976 election and concluded that the defense of nuclear power was not a winning strategy.

After Three Mile Island it became an impossible one. In an astounding display of political trickery Olof Palme turned his party around 180 degrees and agreed to the nuclear referendum he previously had been dead set against. In spite of, or perhaps precisely because of, this Palme failed to regain power in the 1979 election. After a scandalous campaign the Swedish people was lured into saying both yes and no to nuclear power at the same time.

Three options, three "lines", were offered to choose among. All three pledged that further nuclear power plants should not be built in Sweden. All three lines were also committed to the ultimate phasing out of nuclear power as an energy source. The wording of the ballots was decided by the Parliament. The "people" had no say.

All three ballots began with a statement that Sweden currently had six reactors in service, four ready for service, and two under construction. The first paragraph of lines 1 and 2 read:

> Existing nuclear power plants are to be closed down at a rate consistent with the need for electricity to maintain employment and welfare. In order to, among other things, reduce dependence on oil, and pending the availability of renewable energy sources, only the twelve reactors now operating, completed, or under construction will be used. There will be no further expansion of nuclear energy. Safety considerations will determine the order in which reactors are taken out of service.

Since these two lines carried identically phrased ballots they were, with their combined 58 percent of the votes casted, together considered victorious. But in addition to the common pledge on the reverse side of the ballot, line 2 also promised that:

> Energy conservation will be vigorously promoted and further stimulated. The weakest groups in the community will be protected. Steps will be taken to steer electricity consumption, partly to prevent the heating of new, permanent buildings by electricity. Research and development concerning renewable energy resources will be accelerated under government auspices. Environmental and safety improvements will be made at nuclear plants. A special safety study will be made for each reactor. To inform the general public, a safety committee drawn from local inhabitants will be set up for each nuclear plant. Electricity production from oil- and coal-plants will be avoided. The main responsibility for producing and distributing electricity must be in public hands. Nuclear plants and any other future installations of any importance for elec-

tricity production must be owned by the state and the municipalities. Excess profits from hydroelectric production will be absorbed by taxation.

Line 2, with 39.1 percent of the votes, not only found considerably more public support than the 18.9 percent line 1 managed to mobilize. But line 2 also outweighted the antinuclear opposition - line 3 turned out second with 38.7 percent of the votes.

There is no doubt therefore, that the moral and political responsibility for Sweden's energy future rests with the two parties that were associated with line 2 and strongly supported it during the campaign. These are the liberals (folkpartiet) and the socialdemocrats. The socialdemocrats got back in power in 1982 and the party has governed since then. It is therefore up to the socialdemocrats to work out an energy policy in accordance with farfetched promises made on the back of their ballot.

Since the question put was not a simple yes or no to nuclear power there was plenty of room for manoeuvering. It was commonly understood that the Swedish people had said yes to the nuclear power plants already in use and under construction and no to any further nuclear reactors. By some incomprehensible act of political logic the Parliament concluded that this implied the phasing out of all nuclear power plants by the year 2010 at the latest. This silenced the energy debate completely.

The second oil price shock in 1979 finally led to the realization that what really mattered was oil substitution, not energy conservation. Since nuclear power could not be called upon as a long term solution alternative forms of energy "preferrably renewable and domestic" had to be found.

Like Avis we tried harder. On a per capita basis Sweden invested three times as much on energy R & D as any other country (fig 2). Most of the money went to exotic forms of energy such as solar (!), wind and biomass (fig 3). It is by now quite clear, and not questioned by any serious analyst, that none of these sources of energy will play but a minor role in the foreseeable future, except for biomass which is and since long has been an important fuel for the paper and pulp industry where it is a byproduct of the industrial process itself.

Important measures were taken to improve the safety of the nuclear powerplants and in particular to reduce the environmental impact in the event of a major nuclear accident.

But aside from this next to nothing was done in order to implement the pledges made. The route to the non-nuclear future remained unchartered while the nuclear generating capacity increased as never before. (fig 4) The new Palme government formed in 1982 promoted the use of cheap nuclear generated electricity as a substitute for oil. Sweden topped the list of nuclear countries and electricity demand increased rapidly. Public opinion changed, slowly but steadily, towards a more pro-nuclear attitude. In the beginning of 1986 attempts* were made to prepare the ground for a removal of the "latter mark of the (nuclear) parenthesis", i.e. to allow the nuclear era to stretch out beyond the year 2010.

Then came Chernobyl. The bluff was called. Chernobyl was no doubt a major nuclear disaster. Some people were killed many others got hurt. Russian property was destroyed and fertile soil was contaminated, perhaps forever. The reputation of nuclear power was seriously damaged and its public acceptance was set back by a decade or more. For the first time a civilian nuclear power plant failed to contain its radioactive content of longlived fission products. Massive amounts of radioactivity was released to the atmosphere.

The first external territory to be hit by the radioactive cloud from Chernobyl was Sweden, and Sweden was also the first nation to respond to this unexpected environmental insult.

Media coverage was enormous and it was generally expected that the dormant anti-nuclear giant would wake up with a roar and rise to more towering proportions than ever before. The political leadership anxiously prepared itself for the coming outburst of anti-nuclear sentiments.

But to everybody's surprise the giant was gone! There was a great deal of distress, anxiety and fear, but there was no uproar, not much of demonstration and agitation. Why ?

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* This "attempts" were not made by the Government, but by various representatives of the Swedish industry.

It was the wrong reactor, in the wrong place and at the wrong time.

It was the wrong reactor because it was soon concluded by nuclear experts in various countries that for physical reasons can a Chernobyl type of accident never occur in any of the nuclear power plants now used in the western world. The Swedish Nuclear Inspectorate, appointed by the Government, concluded officially that the Chernobyl accident has no direct bearing on the safety evaluation of the Swedish nuclear power plants.

It was the wrong place because to many Swedes it appeared as if the major nuclear threat was posed, not by the Swedish nuclear power plants afterall, but by the much unsafer reactors on the other side of the Baltic, not very far away but far beyond our jurisdiction and control. Moreover the Swedish communist party (vpk) which in its shameless opportunism eagerly exploited the anti-nuclear sentiments after Three Mile Island, found it somewhat difficult to take advantage of similar feelings following the Chernobyl disaster. Even if nobody got hurt TMI had been the ideal symbol of the inherent lack of safety in a profit oriented society. But the Chernobyl disaster was undeniably the result of grave mismanagement and negligence in a centrally planned economy and damage done was immeasurably much greater than it had been at TMI.

It was also the wrong time. The accident took place at 01.23 on April 26. In Sweden public debate slows down in June and comes to an almost complete stand still in July and most of August when everybody is on vacation. After the summer most of the Chernobyl effect had already worn off. In September a public opinion poll showed that although the support for nuclear power had diminished, 40 percent of those polled preferred to stick to the original pre-Chernobyl policy and keep the Swedish nuclear power plants running until 2010. Since then public support for nuclear power has grown. As shown in Table 1 nine months after Chernobyl public opinion was already back to its pre-Chernobyl position.

Meanwhile the political machinery worked. The new socialdemocratic government under Ingvar Carlsson made an ardent attempt to rally all democratic parties behind a new nuclear policy by suggesting that the non-nuclear commitment would be moved a bit closer in time than the somewhat hazy future of 2010. But these efforts failed completely. Internal debate almost paralyzed the socialdemocrats. When a compromise solution was finally hammered out it was vague and unconvincing. Of the twelve reactors now in use one will be phased out in the 1993-95 period and another in the 1995-96 period. The precise meaning of the pledge is unclear. It is said that the decommissioning of the two reactors presupposes installation of a corresponding generating capacity based on some alternate source of primary energy, which in practise means hydro, coal or natural gas. But a major hydraulic development project is hardly realistic given the strength of today´s environmental movements. Public resistance to coal is large and rising and so far there has been no long term price agreement on gas import from Norway or from the Soviet Union. It is also clear that a premature decommissioning of two nuclear reactors represent a massive destruction of capital and an otherwise unnecessary rise in the cost of electricity of some 25 to 40 percent by the year 1995.

In a recent study some 500 professors in the Swedish universities´ natural science and technology departments were asked about their opinion on the current nuclear policy. Of the 85 percent that responded 7 out of 10 felt that nuclear power ought to be used even after 2010 and only 1 out of 10 thought that the decommissioning should start immediately. It is also interesting to note that 65 percent of the professors polled declared that their opinions had not been altered in any essential way by the Chernobyl accident.

Reasons for failure

> The best laid schemes o´mice an´ men
> Gang aft a-gley

But why? How could Sweden, known as the "middle-way country", deeply committed to its parliamentary democracy and generally recognized for efficient management and rational desicionmaking, how could Sweden suddenly find itself as the one country out? The one and only in the whole world which is committed to an anti-nuclear policy. How can Sweden deliberately throw away its hardwon excellency in nuclear engineering and deliberately accept a huge destruction of capital? How can Sweden prematurely decommission a whole dozen of highly efficient, profitable, safe and environmentally benign nuclear power reactors? How can the Swedish parliament do all of this against the will of the majority of the people and against an even stronger majority of its intellectual leaders?

Future historians can possibly tell. Today we have to do with what few clues to understanding that are available to us. Some of these have already been alluded to in the foregoing. To these belong the unfortunate craveing for social engineering and the inherent tendency to political overreactions. A tendency which is amplified by the media with their coverage of dramatic events and which is skillfully exploited by various splinter groups. But behind these obvious factors reside more subtle but probably decisive causes for the failure of Swedish energy politics. Two of these deserve some additional elaboration. These are a deceitful statistical accounting method inherited from the past and a common misinterpretation of causal relations in the field of energy economics.

A statistical rope trick

From 1973 to 1987 Sweden reduced her energy consumption by a few percent, from 463 TWh to 456 TWh (fig 5), and her oil dependence from 73 percent to 46 percent. A determined effort at energy conservation and the promotion of new and renewable sources of energy, such as hydro, peat and biomass, together with some supplementary coal and nuclear, can do the trick.

Or so it seems. But the sad fact is that this outstanding energy performance is hardly more than statistical black magic. For unlike international organizations - such as UN and IEA - and almost all other countries, Sweden officially counts the electric energy delivered from her hydroelectric and nuclear power plants in terms of its thermal equivalent. In other words, in Sweden - but hardly anywhere else - 1 TWh of electric energy out from a nuclear power station equals 1 TWh of oil in under the boilers in a thermoelectric power plant.

According to the laws of nature it takes - at least - 2.6 TWh of oil to produce 1 TWh of electricity. Therefore, in most countries the amount of electric energy produced, and consumed, is accounted for in terms of the amount of oil it takes, or would have taken, to produce that much of electric energy. Thus, while in Sweden 1 TWh (el) = = 1 TWh (oil), in international statistics the corresponding relations reads: 1 TWh (el) = = 2.6 TWh (oil). This means that if Sweden were to use international statistical standards her energy consumption has increased just as it has in almost all other countries. In Sweden the increase is from 551 TWh in 1973 to 661 TWh in 1987 or by almost 10 percent (fig 6). This equals the average OECD performance.

It may even be argued that Sweden did worse than most other OECD countries. The Swedish economy grew quite a bit less in the 1973-83 period than the OECD economy in general. If we compare the energy intensities, i.e. energy input per unit of BNP, rather than the figures for primary energy consumption (regardless of economic performance) the Swedish reduction of 6 percent in this period is less than the 19 percent achieved by OECD as a whole.* (1)

So much for energy conservation. But the fact remains that Sweden has been exceptionally successful in cutting back on her oil consumption. In 1973 Sweden used 331 TWh of imported crude and petroleum products. In 1987 this figure had been reduced to 201 TWh. This is quite impressive. How come?

The explanation is again quite simple. Since 1973 Sweden has implemented a massive nuclear energy program. Eleven of Sweden's twelve nuclear units commenced commercial operation between 1973 and 1987. Together with France and Finland, Sweden tops the list of percentage nuclear generated electricity. In 1973 merely 2 TWh of electric energy was delivered from the first Swedish nuclear plant - Oskarshamn 1. In 1987 the nuclear contribution had grown to as much as 68 TWh. Of these 10 TWh have been used to replace the power previously produced in oil fired plants. These are now idle and maintained only as a standby capacity to be used in case of emergencies.

But since it takes 26 TWh of oil to produce 10 TWh of electricity and since Sweden insists on counting electric energy as if it was of the same quality as low grade heat, she has not only replaced the 26 TWh of oil with nuclear power; she has also, according to her strange statistical reckoning, managed to "conserve" 26-10 = 16 TWh of "energy"! And this, mind you, without any sacrifice whatsoever to energy consumers. This is Sweden's new version of the ancient Indian rope trick.

The remainder of the nuclear generated electricity added since 1972 - 56 TWh - has been used to substitute for oil at the consumers' end of the line. As a consequence electric energy has increased its share of final energy consumption from 17 percent in 1973 to 32 percent in 1987.

In all fairness it should be said that the international relation: 1 unit of electricity equals 2.6 units of oil, overestimates the value of electricity in Sweden's final energy

* Similar figures apply to what is sometimes referred to as final energy use: 22 percent for OECD vs 18 percent for Sweden.

mix. A value of 2.2 is more correct. (2) This means that of the 130 TWh (331 - 201) of oil saved, nuclear generated electricity accounts for 26 TWh on the production side and about 123 TWh (2.2 x 56) in consumption. Almost nothing has been conserved, or substituted for by other means. (Table 2)

The dramatic impact of Sweden's electrification program on her industry's energy mix may be illustrated by what has become known as a "boomerang curve". To avoid the fallacy of adding apples and pears, of adding TWh of electricity and TWh of oil, we may plot electricity consumption versus oil consumption (fig 7). As seen in the figure the steady increase in both oil and electricity during the 1955-1970 period was dramatically reversed in the early 70s. From then on the trend is strongly towards reduced oil dependence leading to an almost all-electric Swedish industry according to the projections made for 1990.

Exactly the same development is seen in the domestic sector (excluding transports) (fig 8). But here oil substitution has been accompanied by an overall increased energy consumption.

The close correlation between the volume of industrial production and the consumption of electric energy (fig 9) can hardly be fortuitous and supports the notion that electrification is not merely used as a means for oil substitution. The process of electrification is driven by more compelling forces.

Steering by price?

The statistical accounting method used in Sweden, but hardly anywhere else, seemed natural when practically all of the electricity in Sweden was generated in hydro-electric power plants. In those days electric energy was counted in TWh and fuels in cubic meters and tonnes. Since there was no need to add them up into an "energy balance" it made little sense to figure out what it would have taken to produce the equivalent amount of electric energy in a thermoelectric power plant fueled by oil or by coal.

Unfortunately the Swedish convention was retained when first oil and later nuclear energy came to play an increasingly important role for the generation of power in Sweden. As a result the Swedish people and their political leaders are living with a seriously distorted picture of what has actually taken place.

By Swedish statistical standards the total energy consumption has decreased slightly (cf fig 5) in spite of a 14 percent increase in production. Oil dependence has been reduced from 75 percent in 1973 to less than 50 percent in 1987. The nuclear contribution is significant, but after all modest. Nuclear is comparable to the net increase in the role played by the renewables. Together these provide twice as much energy as we get from all of our twelve nuclear power reactors.

If a substantial, but after all manageable, oil price increase could bring such a change about in only 15 years, what could not an increased electricity price do for our consumption of electric energy in the 21 years left till 2010? Would not the price itself be sufficient to bring about a substantial cut back in consumption making room for alternatives to the nuclear energy we have agreed to abandon?

When faced with the figures provided by the Swedish statistical reckoning (fig 5) these seem like legitimate expectations. But, as has been explained above, what has actually happened is something quite different (fig 6 and table 2).

Among the renewables the dominant contribution comes from hydroelectricity. The net increase recorded is mainly due to an increased yield of byproducts, used for fuel, in the flourishing paper and pulp industry. The nuclear contribution is considerable, 90 percent of what is attributed to oil.

Contrary to common belief the price increases have not markedly altered the pattern of energy conservation. As fig 10 shows in the United States there has been a continous trend towards more efficient use of energy extending over most of this century. The drastic price increase beginning in 1973 has not changed the long term development in any noticeable way. In other words: energy conservation was not discovered in 1973 and certainly not in Sweden.

I am, of course, not suggesting that prices and price increases are no avail. Economic factors are decisive for energy production and for the use of energy. But "economic" must be understood in a broad context. The market forces play over the whole field of innovation, technological development, industrial application, structural change and national economy.

A complete understanding on the complex interrelations between energy and economy is far from having been achieved. Econometric studies of price elasticities have given conflicting and confusing results. Structural changes in the economy may or may not be related to energy price fluctuations. A shift from the industrial to commercial sector reduces the energy intensity of the economy as a whole. But this shift may have taken place for other reasons than energy price increases. A simple "macroeconomic" analysis may therefore give erroneous results.

Historical evidence suggests that new forms of secondary energy have been sources of innovation and technical change. In an important study Energy and the American Economy 1850-1975: Its History and Prospects by S. Schurr and coworkers (3) (1960) it was pointed out that the simultaneous decline of energy and labor intensities in the American economy ruled out the possibility of explaining the growth in productivity by the substitution of cheap energy for expensive labor.

It was therefore suggested that "the unusual characteristics of electricity had made it possible to perform tasks in altogether different ways than if those fuels had to be used directly". This transition, which has been aptly termed "from shafts to wires"(4), has greatly improved energy productivity.

A series of very careful studies by Jorgenson and others has recently been reviewed(5) by a committee appointed by the US National Research Council (NRC). The committee concludes: "electricity plays a very important role in productivity growth".

It transpires that the process of electrification is driven by socioeconomic and technological factors quite independently of wide variations in prices and price ratios, availability of supplies and of energy policies.

These observations confirm a widespread feeling in the power industry that the consumers' demand for electricity is growing more rapidly - or declining more slowly - than their demand for fuel. In order to analyze this problem in more quantitative terms one may use a simple "electricity/fuel ratio" defined as (fig 11)

$$\frac{\text{Electricity}}{\text{Fuel}} = \frac{E_N/E_1}{B_N/B_1}$$

where E_N and B_N represent the consumptions of electric energy and all forms of commercial fuels in the year N, respectively. E_1 and B_1 are the corresponding figures for the reference year (year 1). This dimensionless number immediately shows how electricity competes with fuel. If the ratio is larger than one electricity has increased its share of the final energy market.

By way of illustration let us compare the Nordic countries which in many respects are quite similar. But when it comes to energy supplies - and prices - they are very different indeed. Sweden and Finland are both rich in hydroelectric power and have both implemented ambitious nuclear energy programs.

Their el/fuel ratios are high 1.1 - 1.7 for the 60s and 70s (6). In other words in these two countries there has been a rapid change to electricity during the last 20 years. This hardly comes as a surprise.

But what about Denmark, lacking all sources of domestic energy whatsoever, until fairly recently when offshore gas has been landed in that country? The surprising fact is that electrification has been even faster in Denmark than in Sweden or Finland. The Danish el/fuel ratio was 1.5 in the 60s and as high as 1.7 in the 70s. Norway, rich in oil and hydro recorded 1.2 in the 70s.

Sweden´s energy future

The key to the understanding of Sweden´s energy future is not to be found in policy but in politics. In this paper I have tried to show that our energy politics is at odds with reality. It is based on misinterpretation of facts and of causal connections, it lacks parliamentary support and is not considered trustworthy by the majority of the Swedish people. But unfortunately there is currently no viable alternative in sight.

This is the true measure of our dilemma!

Democracy is more valuable to us than any energy policy. As long as the Parliamentary decision stands we will abide by the law and loyally plan as if the last nuclear power plant will be shut down on December 31, 2009.

But this will not happen. Given our geographical constraints: a stretched out country, with long, cool and dark winters, given our lack of alternative supplies and the current

state of art in energy technology, the conclusion seem unavoidable - to me at least - nuclear power will not be phased out. "Reality", as Olof Palme once put it, "is the socialdemocrats´ worst enemy".
Sweden is, and is likely to remain, an energy intensive, highly industrialized society. In Sweden electricity plays an especially important role as the main energy vector. The potential for hydroelectric development projects is under all circumstances limited. There are no major domestic sources of primary energy available.

The sought for "preferrably renewable and domestic sources of energy" have not been found. Energy conservation and more efficient use of energy will be pursued - as it has been in the past - but cannot realistically be expected to solve our energy needs within the next decade or two.

There is a world outside Sweden to which we have to adjust, a world where the degree of electrifications continues to grow everywhere. With its current 32 percent share of electricity in final energy demand Sweden is second only to Norway and Canada in terms of electrification. Can Sweden really do it alone? Can Sweden de-electrify? Can any society for that matter?

The Parliament rules in sovereignty. But not for long! Its grandeur is of fleeting durance, never more than three years. It is a comforting thought that what politicians have decided can always be corrected by politicians.

By the year 2010 the Swedish Parliament - and its electorate - will be made up of quite different people than those in charge today. Certainly by then the grown up members of the Swedish society, who were not even born at the time of the nuclear referendum in 1980, would like to have some influence on their own society and its future.

Who knows? I have a hunch that they will think and decide differently from those who happen to be in power today.

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2. Sveriges Elektroindustriförening 1984.

3. Schurr, S., and B.C. Netschert, with V.E. Eliasberg, J. Lerner and H.H. Landsberg 1960. Energy in the American Economy 1850-1975: Its History and Prospects Baltimore: John Hopkins University Press for Resources for the Future.

4. Devine, W.D. Jr. From Shafts to Wires: Historical Perspective on Electrification. The Journal of Economic History. Vol. X L III (1983) p 347-372.

5. Electricity in Economic Growth. A report prepared by the Committee on Electricity in Economic Growth. Energy Engineering Board, Commission on Engineering and Technical Systems. National Research Council. National Academy Press. Washington D.C. 1986.

6. Kraftsam PM 1983:37.

TABLES

FIGURES

SWEDISH PUBLIC OPINION POLLS

Question: With the experience we now have do you think it was good or bad for the country to invest in nuclear power?

	Good	Bad	Uncertain Don't know	
December -84 -January -85	55	28	17	100
Before Chernobyl 16-24 April -86	56	25	19	100
After Chernobyl 7-16 May -86	36	47	17	100
September -86	40	43	17	100
November -86	42	40	18	100
January -87	55	30	15	100
May -87	49	36	15	100
October -87	50	34	16	100
March -88	54	30	16	100
November -88	55	30	15	100

Source: SIFO 84050, 85003, 86017/020, 86038/039, 86046/048, 87004/005, 87020/021, 87042/044, 88012/082, 88047/049

Table 1

OIL SUBSTITUTION IN SWEDEN
1973 - 1987

Oil consumption was reduced by 130 TWh (th)
Nuclear generated electricity increased by 66 TWh (el)

10 TWh (el) substituted for 2.6 x 10 = 26 TWh (th) in power generation
56 TWh (el) substituted for 2.2 x 56 = 123 TWh in consumption

---

66 TWh (el) substituted for a total of 149 TWh (th) of fuel

Source: CDL, KRAFTSAM Elkraftförsörjningen i Sverige,
Sveriges Elektroindustriförening 1984

Table 2

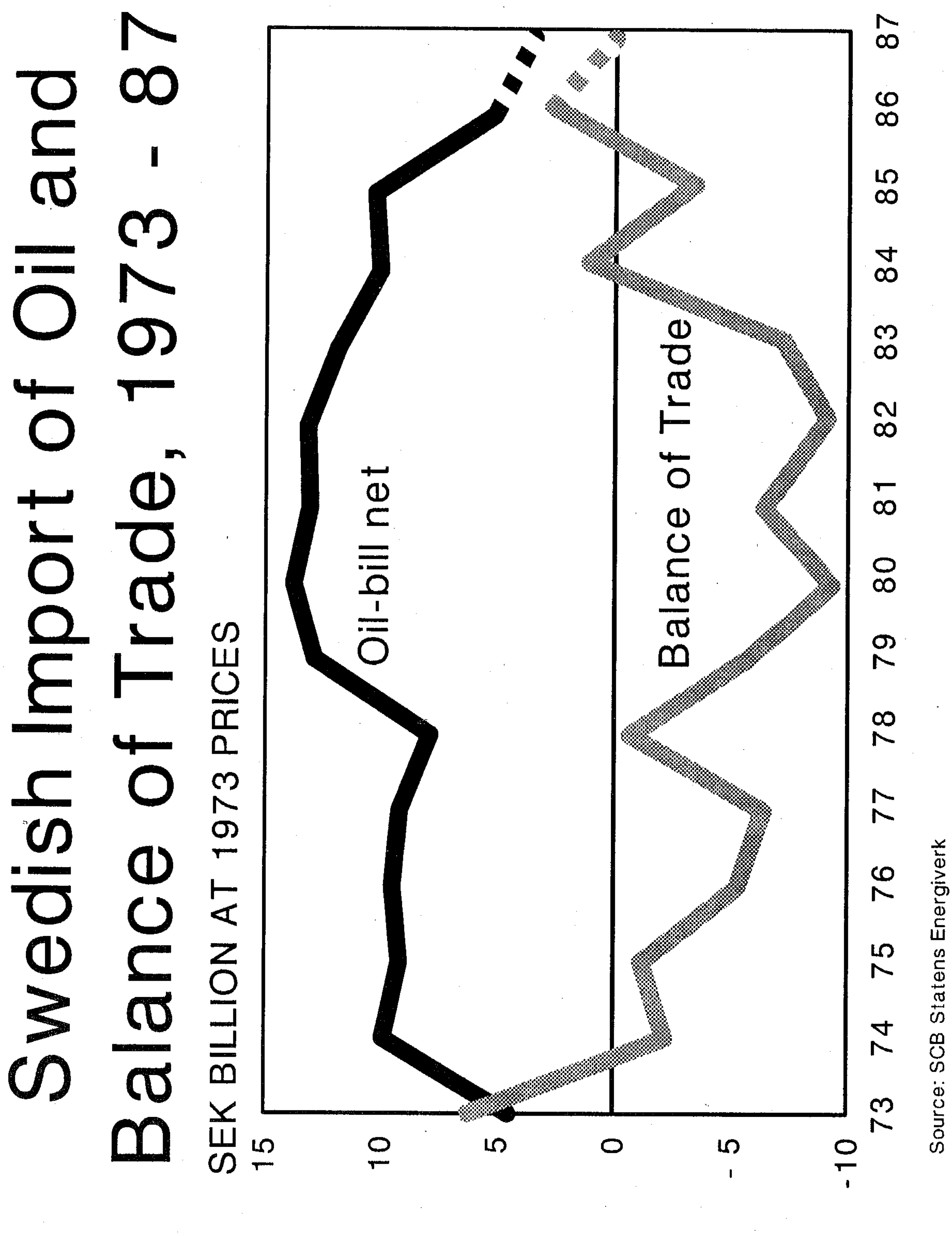

Swedish Import of Oil and
Balance of Trade, 1973 - 87
SEK BILLION AT 1973 PRICES
15
10
5
0
- 5
-10
Oil-bill net
Balance of Trade
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
Source: SCB Statens Energiverk

Fig 1

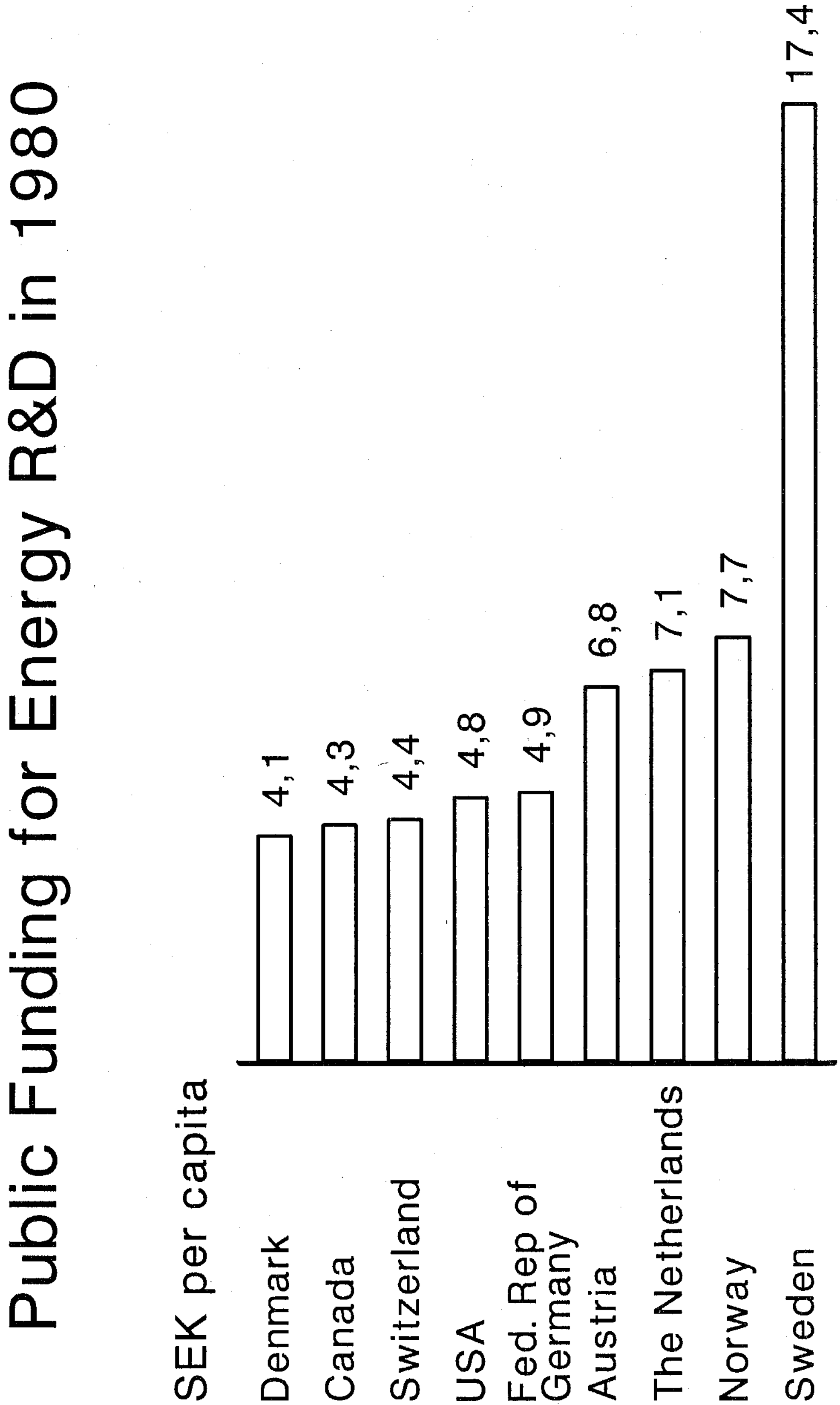

Public Funding for Energy R&D in 1980
SEK per capita
Denmark
4,1
Canada
4,3
Switzerland
4,4
USA
4,8
Fed. Rep of Germany
4,9
Austria
6,8
The Netherlands
7,1
Norway
7,7
Sweden
17,4

Fig 2

Public Funding to Energy R&D in Sweden 1980
SEK per Capita

Solar Energy

Sweden	9,4
USA	2,9
Switzerland	2,6
The Netherlands	2,6
Canada	2,4
Belgium	2,1

Windpower

Sweden	4,1
The Netherlands	1,7
Fed. Rep of Germany	1,6
Denmark	1,3
USA	1,2

Biomass

Sweden	8,4
Canada	2,1
New Zealand	1,5
Switzerland	1,3
Austria	1,2
USA	1,1

Fig 3

The Swedish Nuclear Power Program

Nuclear unit	In commercial operation	Net power MW
Oskarshamn 1	1972	450
Oskarshamn 2	1975	570
Barsebäck 1	1975	570
Ringhals 2	1975	800
Ringhals 1	1976	750
Barsebäck 2	1977	570
Forsmark 1	1980	900
Ringhals 3	1981	915
Forsmark 2	1981	900
Ringhals 4	1982	915
Forsmark 3	1985	1 060
Oskarshamn 3	1986	1 060

Source: Riktlinjer för energipolitiken, Industridepartementet 1981.

Fig 4

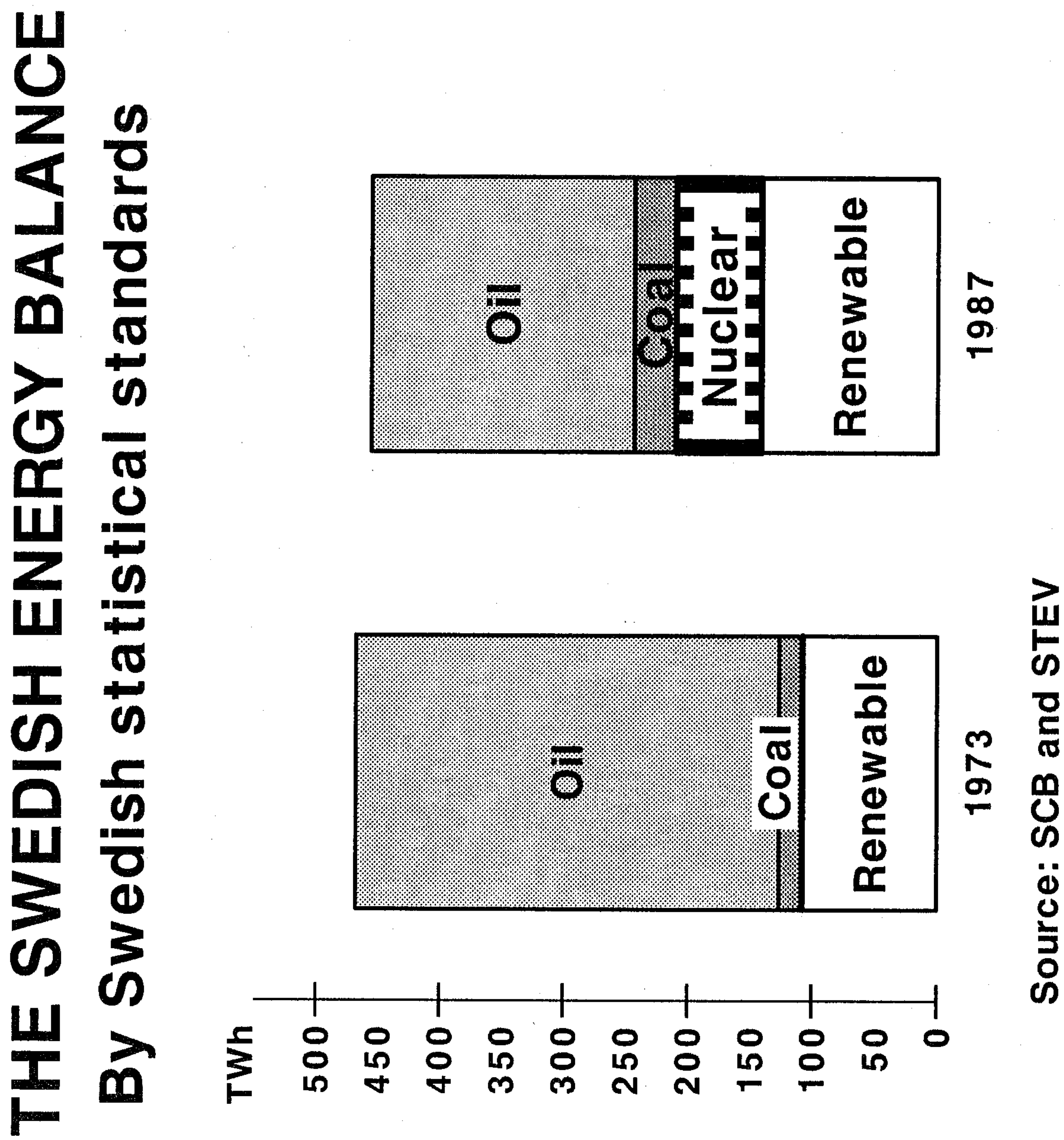
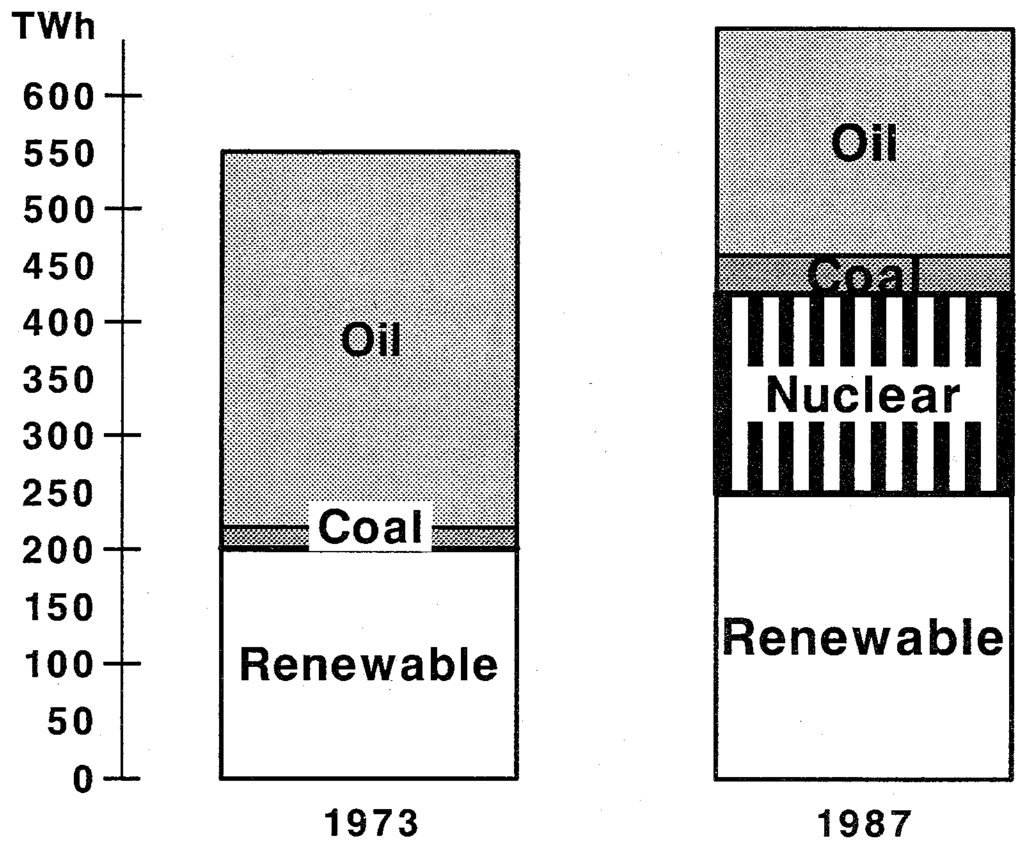

THE SWEDISH ENERGY BALANCE
By Swedish statistical standards
TWh
500
450
400
350
300
250
200
150
100
50
0
Oil
Coal
Renewable
1973
Oil
Coal
Nuclear
Renewable
1987
Source: SCB and STEV

Fig 5

THE SWEDISH ENERGY BALANCE
By international standards



Source: SCB and STEV

Fig 6

The Swedish industry's consumption of fuel oil and electricity 1955 - 1987

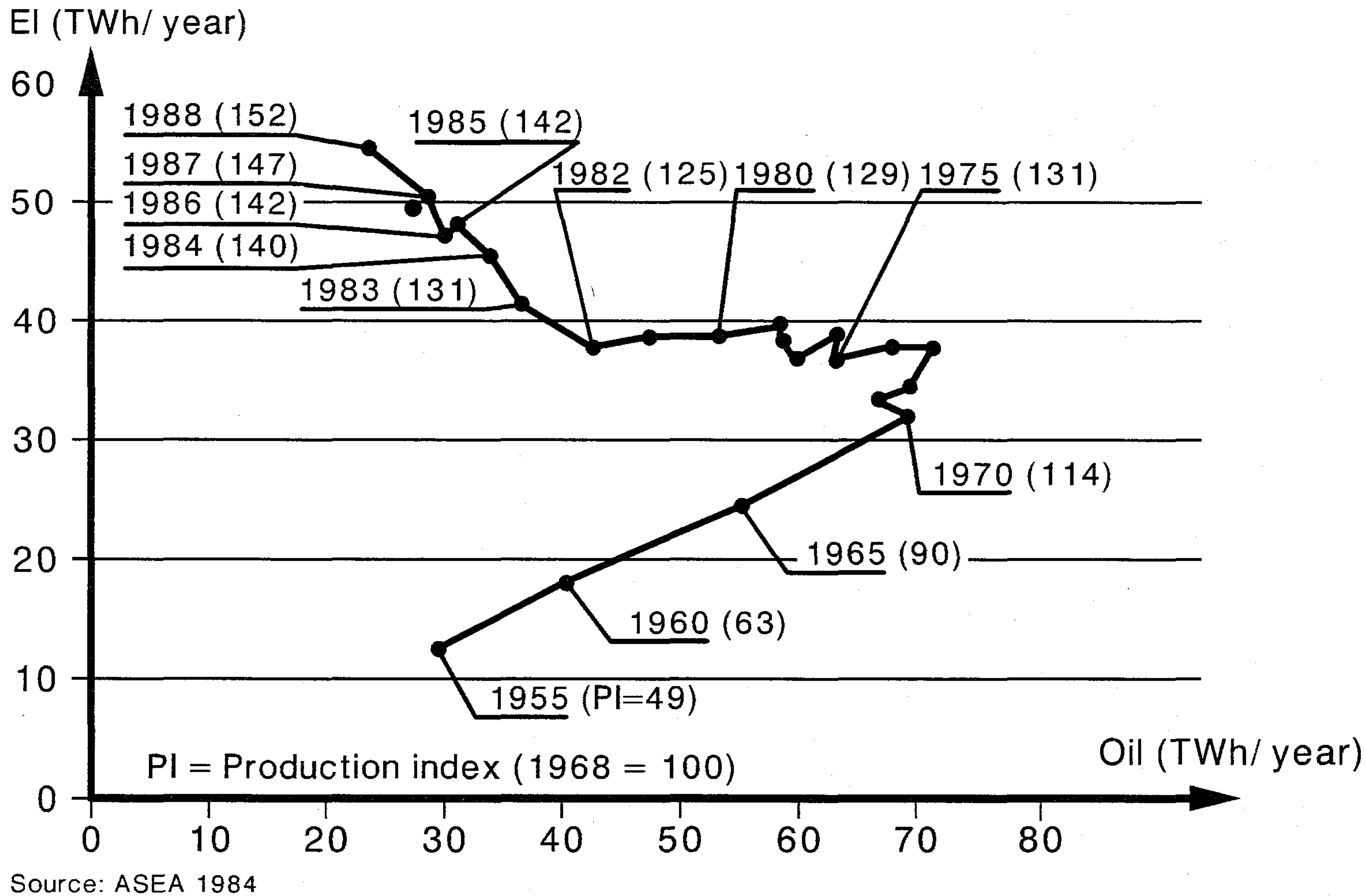
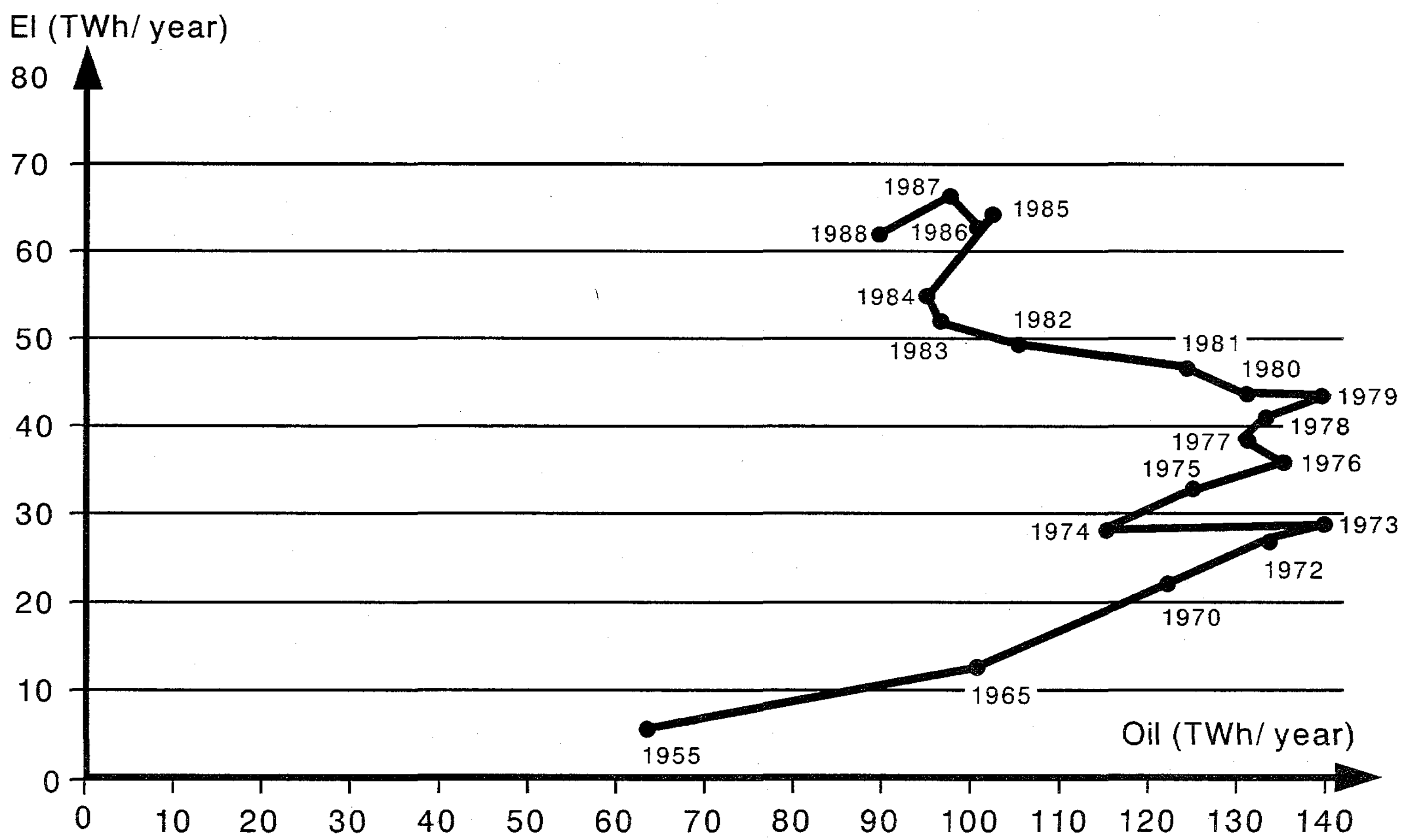


Fig 7

Consumption of fuel oil and electricity in Sweden. Household/ commercial sector (excl transports) 1955 - 1987



Source: ASEA 1984

Fig 8

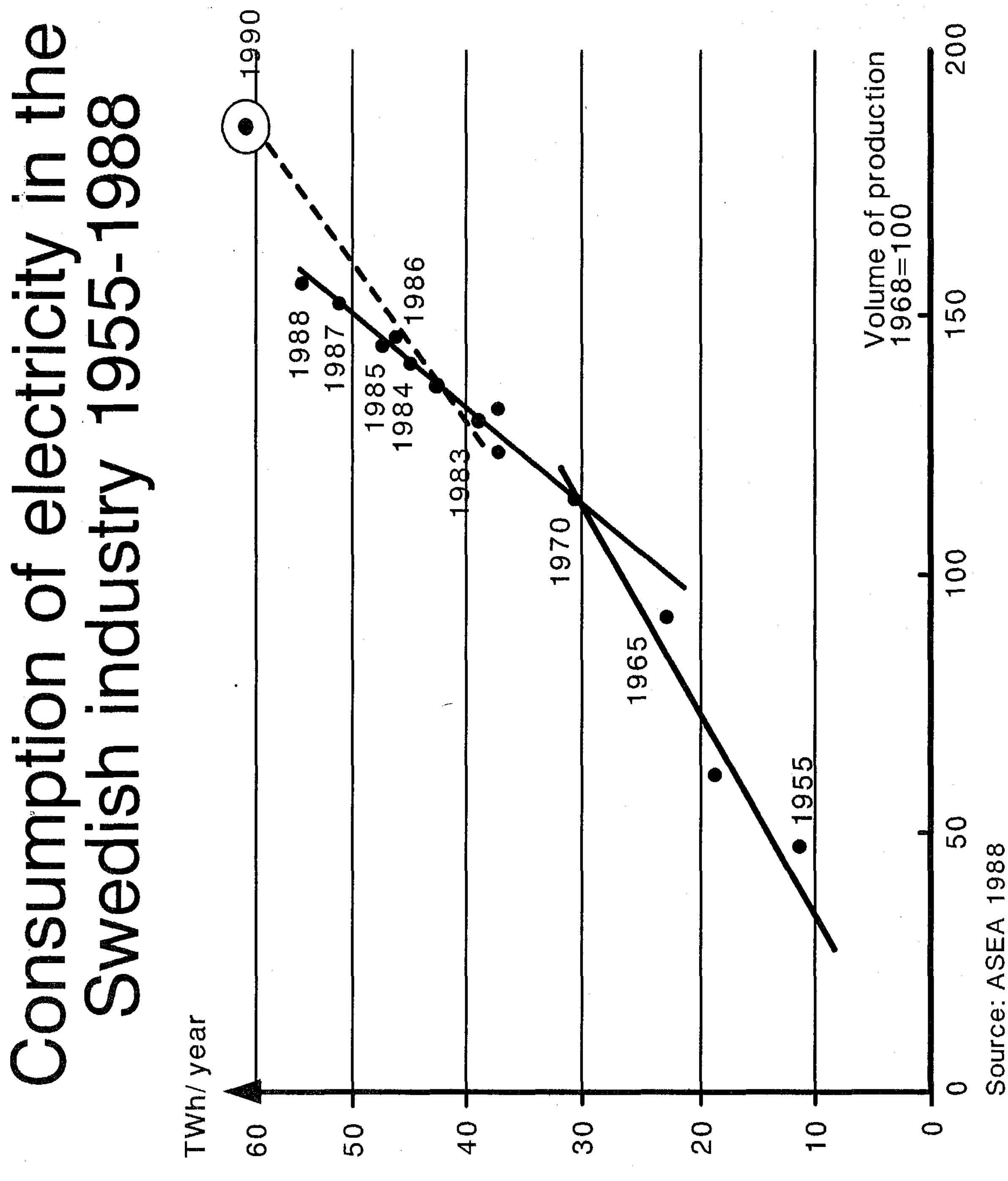

Consumption of electricity in the Swedish industry 1955-1988
TWh/ year
60
50
40
30
20
10
0
0
50
100
150
200
Volume of production
1968=100
1990
1988
1987
1986
1985
1984
1983
1970
1965
1955
Source: ASEA 1988

Fig 9

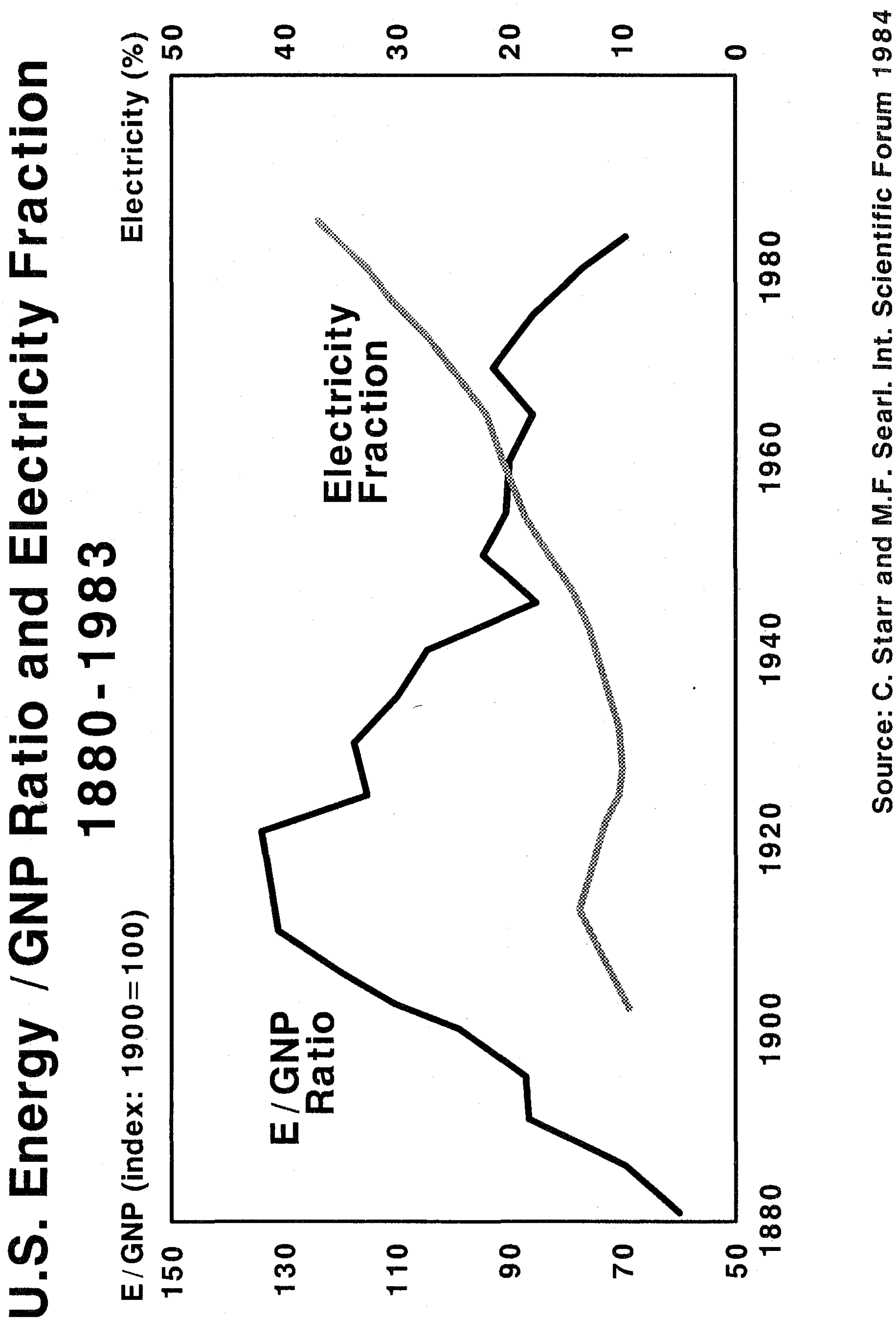

U.S. Energy / GNP Ratio and Electricity Fraction
1880 - 1983
E / GNP (index: 1900=100)
Electricity (%)
150
130
110
90
70
50
50
40
30
20
10
0
1880
1900
1920
1940
1960
1980
E / GNP Ratio
Electricity Fraction
Source: C. Starr and M.F. Searl. Int. Scientific Forum 1984

Fig 10

The electricity/ fuel ratio

$$\frac{\text{Electricity}}{\text{Fuel}} = \frac{E_N \,/\, E_1}{B_N \,/\, B_1}$$

E_N consumption of electric energy in year N

E_1 consumption of electric energy in year 1

B_N consumption of commercial fuel in year N

B_1 consumption of commercial fuel in year 1

Source: KRAFTSAM PM 1983:37

Fig 11

Summary of Comments on Nuclear Phase-Out Policy of Sweden
by
Bill Harris
U.S. Council for Energy Awareness
at
22nd JAIF Annual Conference
14 April 1989

Electricity is the key energy form driving modernization in the Western world because it can be used very efficiently, and can accomplish so many new jobs which no other energy form can. That is why its use is rising so dramatically: over 50% between 1973 and 1987 in the OECD countries.

Sweden, as one of the most electrified of all nations, has been in the forefront in this process. Most importantly, industry in Sweden is one of the most highly electrified in the world. That is a terrific advantage for Sweden because it means they are using the cutting edge technological processes.

The reason for this competitive advantage is that the sources of electricity in Sweden are plentiful and cheap: overwhelmingly nuclear energy and hydro-electric power.

Therefore we are puzzled about the intentions of undercutting the foundations of that electrified economy. From our point of view, it does not seem feasible to replace half of Sweden's electricity supply with renewables, or conservation.

The country's electricity use grew hand-in-hand with GNP from 1973 to 1982, and grew more readily than GNP in the past 5 years. Sweden is now more electrified than other modern countries. The reason is simple: electricity in Sweden is plentiful and cheap because of hydro resources and an effective nuclear power program.

In light of that trend, and experience in other industrialized countries, it seems very unlikely that Sweden will be able to avoid increasing its consumption of electricity in absolute terms, as called for in their National Energy Plan, nor does it seem possible for renewable energy sources to replace the 50% of electricity now generated by nuclear energy.

Much more likely, if Sweden continues the policy of phasing out nuclear power, is a return to the use of fossil fuels for electricity generation. If this occurs the remarkable gains over the past several years in reducing dependence on imported oil, and in reducing the burning of fossil fuels will be lost.

The conclusion we draw from a look at the patterns of Sweden's energy use is that the phase out of nuclear power is not likely to occur. It flies in the face of rational energy and economic planning. When the time comes to pay those costs, it is just seems obvious to us that the policy would be rescinded.

Comments on Nuclear Phase Out Policy of Sweden

by

Bill Harris

Senior Vice President
U.S. Council for Energy Awareness

JAIF Annual Conference
14 April 1989

Although we are considering the issue of electricity supply for Sweden, we should remember that electricity is the key energy form driving modernization and economic growth throughout the Western world. The fundamental advantages of electricity are its efficiency, flexibility and cleanliness, and thus it is more attractive than the direct use of fuels for a continually increasing number of applications. That is why the use of electricity is rising so dramatically: over 50% between 1973 and 1987 in the OECD countries.

Sweden, as one of the most electrified of all nations, has been in the forefront of this process of electrification. An astonishing 56% of all primary energy was used for electricity in 1987, compared to an average of 30% in the OECD countries.[1] (Note, I am measuring primary energy here, not secondary electricity against primary as is the statistical convention in Sweden. Either convention would still show Sweden as one of the most electrified of all countries.) That is a terrific advantage for Sweden because it means they are using the most modern technological processes, equipment, and services in the world, since new processes and equipment are overwhelmingly electrically based. Most importantly perhaps, **industry** in Sweden is one of the most highly electrified in the world, which is an important international advantage.

The primary reason Sweden has this competitive advantage is that the sources of electricity in Sweden are plentiful and inexpensive: virtually all her electricity is non-polluting nuclear power and hydro power. We in the United States have great admiration for Sweden's secure domestic energy source, since only 30% of our electricity is non-polluting hydro and nuclear. It is truly an enviable position for Sweden.

With that as an introduction, my remarks today will emphasize two points about the debate over nuclear power in Sweden:

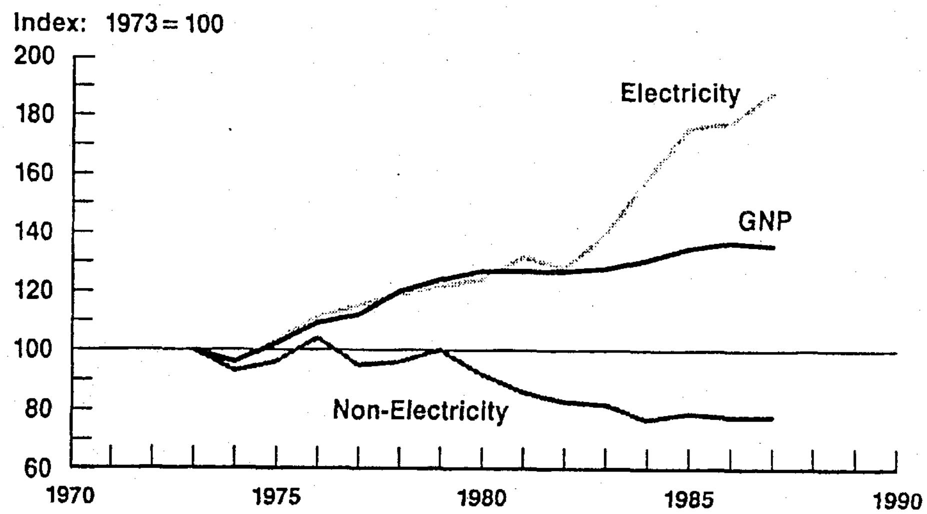
1. The importance of electricity, not just nuclear power, in Sweden, and

2. Our skepticism about a policy of phasing out almost half of the electricity supply. From our point of view it does not seem feasible to replace half of the country's electricity supply with renewables and conservation. In this, I believe I share Prof. Gerholm's point of view.

1. The Importance of Electricity

First, look at the way electricity use has risen in Sweden over the past 15 years. In this slide I avoid the unit of measurement problem by simply measuring all trends on an index scale. The lines show the percentage change in electricity, economic output, and all non-electric energy.

Electricity Growth, GNP, and Non-Electric Energy in Sweden



Source: OECD, IEA. *Energy Balances of OECD Countries, IMF. IFS.*

The country's electricity use follows a pattern which is familiar in all Western industrial societies over the past 15 years: electricity use has risen approximately in step with economic output while all other forms of energy use have declined over the same period. It is clear that electricity is the energy form for new uses, while fossil fuel use is falling off. In Sweden in recent years electricity use has risen faster than the economy, and in that it is pursuing an even more aggressive path toward electrification than are the other OECD countries.

Prof. Gerholm has already outlined the benefits which electricity has brought to Sweden, essentially bringing modernization to a country with no indigenous energy sources, except the potential for hydro-electricity and the uranium which can be utilized in nuclear power stations. But let me emphasize that electricity:

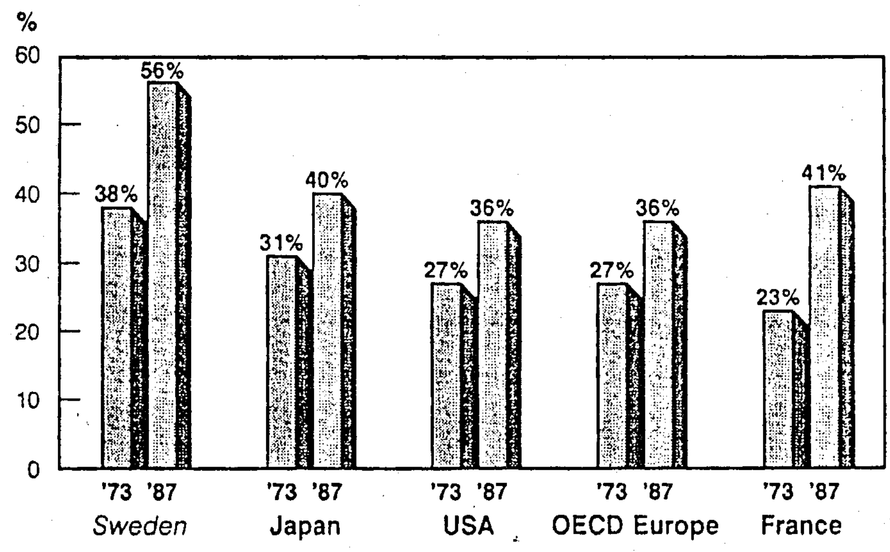
- is indispensable as an energy form in the home. Its use is almost synonymous with modern living, given its importance for lighting, labor-savings devices, and entertainment

- is the preferred new energy form for industry because the efficiency of industrial procedures from electricity surpasses that from the use of fossil fuels. In our country that is increasingly clear in the steel industry, paper industry, and in many industries which use process heat

- is non-polluting in Sweden. In this era of rising concern about the environment, it is important that electric processes emit no pollutants, and eliminate costs associated with environmental controls in industrial processes.

Sweden uses its natural water resource and man-made nuclear power resource to electrify more completely than almost any other country. A comparison with other countries shows that Sweden is in the forefront in the share of energy used to produce electricity:

Share of Primary Energy for Electricity



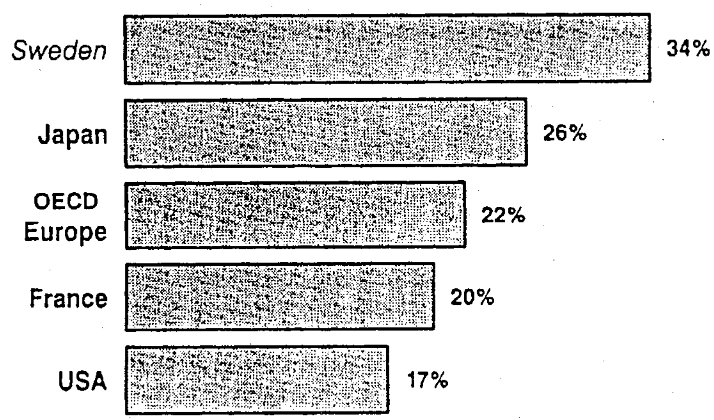
Source: OECD, IEA. *Energy Balances of OECD Countries.*

(Note, once again, I am comparing primary energy equivalents.)

As I noted at the outset, Sweden's **industry** is one of the most electrified in the world. The next slide compares electrification of industry in Sweden and three other countries, as well as to its neighbors in Europe.

Electricity as a Share of Industrial Energy

1987



Source: OECD, IEA. *Energy Balances of OECD Countries.*

Note in this comparison I have used the secondary heat value for electricity, as is the Swedish convention, because it measures the energy as it appears to the consuming industry. Fully 34% of the heat value of energy to industry in Sweden is in the form of electricity. This figure is over 50% greater than the average for all of Sweden's neighbors in OECD Europe.

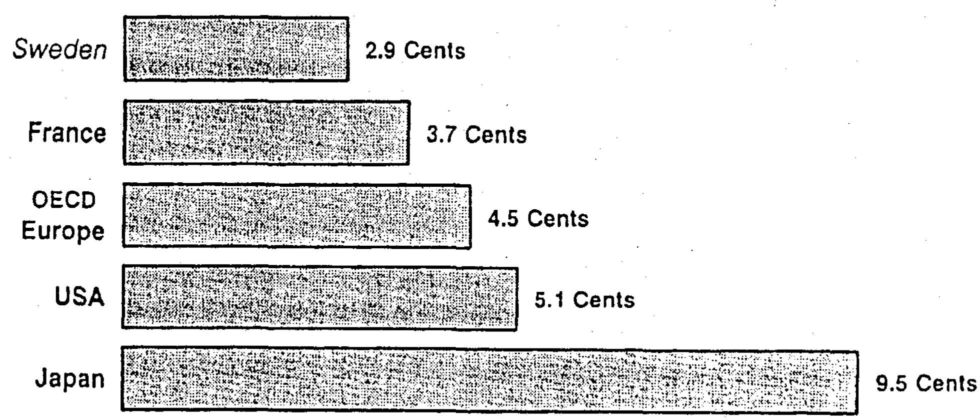
The degree of electrification, and thus the importance of electricity in Sweden's economy and society is certainly very large.

No doubt one important reason for Sweden's enviable position in terms of electrification can be found in the low cost of its electricity. In 1985 a kilowatt hour of electricity to industry in Sweden was about

35% cheaper than in the rest of Europe and, I am disappointed to have to point out, 43% less expensive than in the United States.

Cost of Electricity to Industry

1985

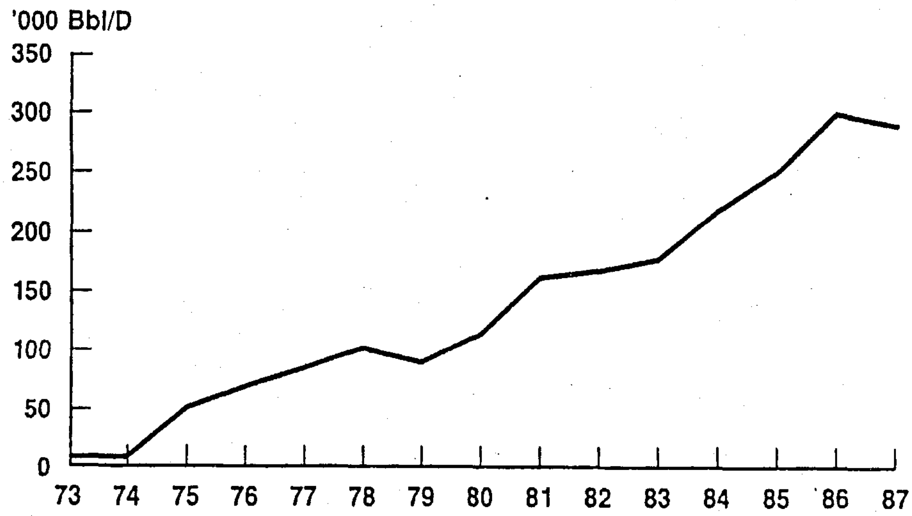


Source: U S DOE. *International Energy Annual, 1987.*

Clearly, Sweden depends on inexpensive energy in the form of electricity. It is a substantial national advantage, and the reasons for it are the rational and timely exploitation of hydro electric power and nuclear power.

Let me take a moment now to turn to the importance specifically of nuclear power in Sweden. The rising use of nuclear electricity, which now is about half of all electricity consumed in the country, has reduced the need to import oil to generate that electricity. Our studies show that nuclear power now displaces over 1/4 million barrels of oil per day, as the slide shows. This has been important in Sweden's declining oil use: from almost 600,000 barrels per day in 1973 to less than 400,000 in 1987.[2]

Sweden
Oil Displaced by Nuclear Power



Source: Science Concepts, Inc.

In total nuclear power in Sweden has displaced about 750 million barrels of oil over this time period. This conclusion is based on our research into the importance of nuclear power worldwide.[3]

2. The Feasibility of Phasing Out Half the Electricity Supply

From that perspective – of the importance of electricity and nuclear power in Sweden – let's look at the challenge facing Sweden if she were to remove nuclear energy from the energy picture.

Nuclear electricity in 1987 produced 67.5 billion kilowatt hours. (67.5 terawatt hours),[4] – half the total electricity supply.

Let us take the first objective of the national energy plan: conservation of electricity with the goal of keeping electricity demand constant.

To accomplish that goal, and continue to maintain economic growth, would require increasing electricity efficiency by 3.5% per year. That is, each year the country would need to use 3.5% less electricity per kroner of economic output as the year before. In simplest terms, this would require the use of electricity per unit of economic output to be reduced by 40% within a decade! This level of conservation is not only unlikely, given today's technology, but would handicap Sweden's electrified industry.

This alone will be very difficult in an economy which has **increased** its electricity use per unit of output in recent years. But the only way to accomplish this, as pointed out by Mr. Rode, is to raise the cost of electricity. Prices could certainly be raised by means of a special tax on each kilowatt hour of electricity consumed. Even after a price increase, however, the use of electricity might be so important that individuals and businesses would prefer to pay more than reduce consumption. Studies in the United States have shown that areas in which the price of electricity rose in the late 1970s and early 1980s were also the areas with the highest increase in electricity use. The reason is that the value of the use of electricity rose faster than its cost.

In any case, the effect of a punitive tax on electricity would be to hamper Sweden's own industry, which gains an important international advantage via an inexpensive supply of electricity. In our country we could call that "shooting yourself in the foot." One very likely, but unhappy, result of such a policy would be that electricity use would be little diminished from present trends, but there would be higher costs to Swedish industry and consumers.

But for the sake of argument, let us go ahead and assume that Sweden will never again increase its consumption of electricity in absolute terms — an assumption which seems to me to be somewhat far fetched, or at the least not economically wise. This will still leave the country with the daunting task of replacing nuclear electricity — half of total supply — with something else.

Can renewables replace Sweden's nuclear power? I believe the answer is no, at least in any practical economic terms.

Windmills are one option discussed. Of course windmills can not replace nuclear power completely because they only function when the wind is blowing. But if Sweden **were** to replace the nuclear power with wind power it would require over 50,000 very large (one megawatt) windmills which would require some 16,000 kilometers of ridge line. Thus Sweden would need to build a line of windmills which would stretch the length of the country approximately 10 times. One wonders what the environmental community would say about a commitment of land or scenic spaces to this kind of energy option?

Mr. Rode has also mentioned the use of **fuel cells.** Environmentally this is a very attractive option, and they are very effective in applications such as the space shuttle. But for large scale power the economics are years away and not at all certain, given the state of today's development.

Most serious analysts of this issue agree that, while research into renewables should by all means continue, there simply are not feasible alternatives to today's generation options on anywhere near the scale required to replace them.

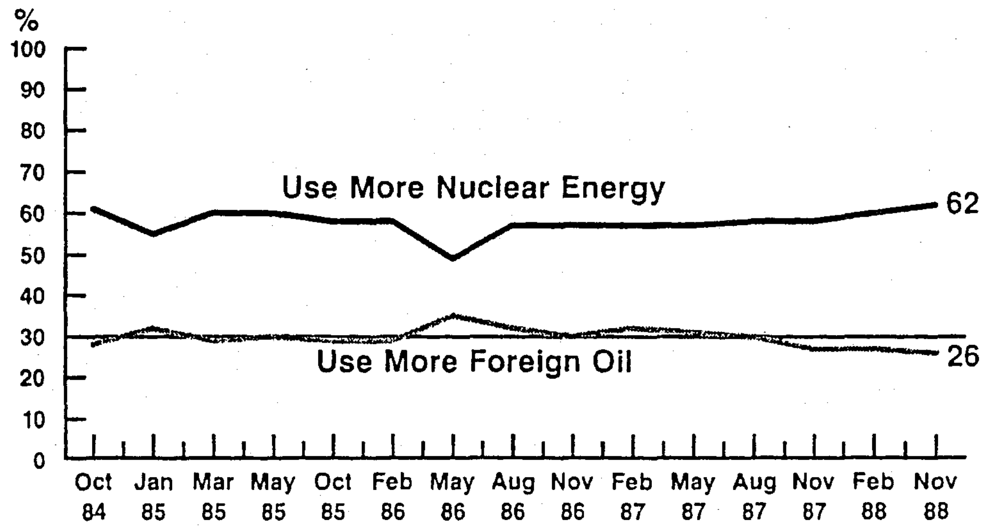
Much more likely, if Sweden actually begins carrying out the policy of phasing out nuclear power, there will be a return to the use of fossil fuels for electricity generation. If this proves to be the case, the remarkable gains over the past several years in reducing dependence on imported oil, and in reducing the burning of fossil fuels, will be lost. Any increase in fossil fuel burning will mean more airborne emissions; yet Sweden has been in the forefront of the environmental movement in Europe. More fossil fuel combustion would, of course, mean more carbon dioxide emissions, which contradicts recent Swedish legislation restricting increased CO_2 emissions. And, as Mr. Rode has said, these are global, not merely national, issues. With the recent worldwide concern about the Greenhouse effect, airborne emissions and especially carbon dioxide emissions are all the more important.

In addition, most industrial nations have for several years concentrated on reducing demand for imported oil, in part for their energy security and in part to reduce the price. That policy has succeeded and Sweden's decline in oil use is a prime example of that success. But returning to fossil fuels to generate electricity would be a renunciation of that policy and would eventually contribute to rising oil prices.

So, phasing out nuclear power does not seem at all feasible. Nor does it seem wise from any perspective. And, given Prof. Gerholm's point that public support for nuclear energy in Sweden returned to the pre-Chernobyl levels within nine months after the accident, it is puzzling to outsiders why the Swedish government persists in its current phase-out schedule.

In the United States the effect of Chernobyl on public opinion was even more short-lived, and support was restored within months. The slide (next page) shows the trend in public opinion on this question.

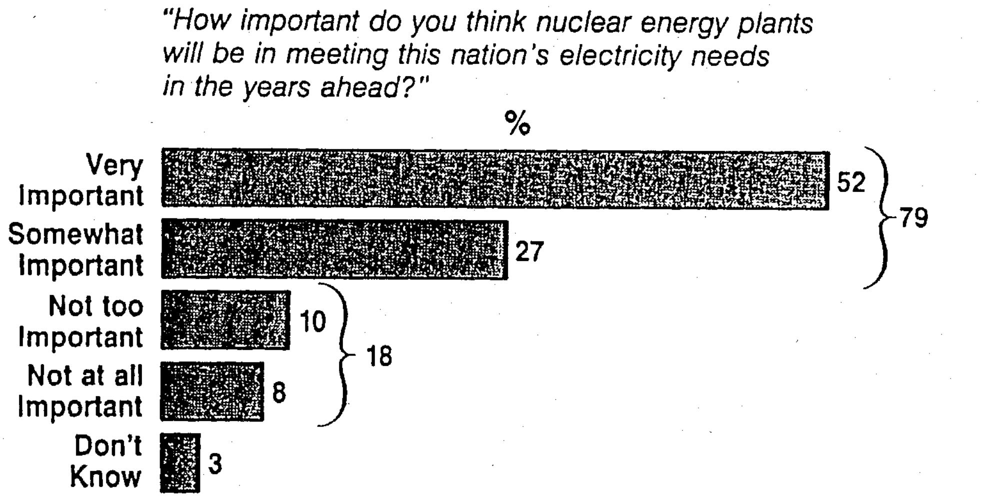
Nuclear Energy vs. Foreign Oil



Source: Cambridge Reports National Polls

In addition, 79% of Americans say nuclear energy plants will be important in the years ahead (see the bar chart, next page).

Importance of Nuclear Energy



Source: Cambridge Reports National Poll, Nov. 1988

Public opinion on this same question is almost identical in Great Britain, and I would not be surprised if the same were true in Sweden.

In closing then, the conclusion we draw from a review of the patterns of Sweden's energy use is that a phase out of nuclear power flies in the face of rational energy and economic planning, and on the environmental aspects alone is very unwise. When the time comes to pay those costs, it seems very likely that the policy would be rescinded.

Notes

1. OECD, *IEA Energy Balances of OECD Countries*, 1987/1987.
2. *BP Statistical Review of World Energy*, June 1988.
3. Science Concepts, Inc.
4. Measured gross, that is not net of the power consumed by the plant itself. Gross measurement is the international convention used by the IEA.

セッション５
原子燃料新時代へ向けて

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Ｋ．リーゼンフーバー

<議長コメント>

閉会挨拶
関西電力㈱会長
㈳日本原子力産業会議副会長
小林庄一郎

The Nuclear Fuel Cycle and Global Technological Change

by John Yochelson

I am deeply honored to have been invited to make a presentation at the Annual Conference of the Japan Atomic Industrial Forum. The leadership of this Forum with respect to research and international cooperation regarding the nuclear fuel cycle is well known not only in the United States but throughout the world.

It was certainly innovative of the Japan Atomic Industrial Forum to invite someone like me who is not an energy specialist to address you. My interests are focused on politics and the global economy and their interrelationship with technology. It did not take long to recognize the limits of my technical expertise on energy issues when I picked up the thirtieth anniversary commemorative issue of the Journal of Nuclear Science and Technology published this past January.

For a person spending most of his time looking at macroeconomic policy, trade issues, and the evolution of the international balance of power, I can assure you that it is not an easy task to grasp some of the impressive research presented in the journal.

Indeed, many of those assembled here are more qualified than

I to present a forward looking assessment of the energy situation in the United States. I have taken the liberty of bringing with me copies of such an assessment which has been done by my colleague Henry Schuler. Mr. Schuler makes classic distinctions between the challenges that lie ahead to meet stationary fuel needs (for industry, electric power generation, and residential and commercial use) and transportation fuel needs (for automobiles, trucks, aircraft, etc.). Mr. Schuler measures projected U.S. fuel requirements in the light of energy availability both within the United States and on a global basis. The CSIS assessment defines the stationary fuel challenge for the United States as one of developing ample, low-cost domestic resources with tight environmental and technological constraints. The transportation fuel challenge for the United States is equally, if not more, urgent. It results from inadequate, low-cost domestic supplies but ample, low-cost foreign oil, whose importation is surrounded by difficult strategic and international pressures.

This perspective, which looks at the full range of energy sources in terms of a global demand-supply relationship is a dominant framework for analysis, and rightly so. It is reflected in the energy visions that are regularly published in Japan and other countries. It highlights the interrelationship among various energy sources and the wide ranging factors which determine their development.

Technology affects both sides of the demand-supply equation in fundamental ways. On the demand side, significant gains in conservation during the past decade -- together with structural changes in the advanced industrial economies -- have decoupled the relationship between energy consumption and economic growth. Today's knowledge-driven societies depend less on heavy industry as an engine of growth, while conservation has made energy use more efficient. On the supply side, technology holds the key to further energy development with respect to both fossil fuels and the nuclear fuel cycle.

Demand-supply analysis points to several compelling realities for the decade to come: first, that nuclear power is likely to remain an alternative rather than a primary source of energy; second, that competition among oil importers is likely to intensify as supply tightens; third, that liquid natural gas is likely to become an energy source of choice for environmental as well as economic reasons.

Nevertheless, I would like to share with you a somewhat different approach to these issues -- recognizing that there is no substitute for the logic and importance of global demand-supply estimates. Instead of looking at the nuclear fuel cycle within this classical framework of analysis, I propose to raise some speculative questions with you regarding the relationship between nuclear power and some of the broad implications of global technological change.

There is wide agreement that we live in an era of revolutionary technological change, which is being driven by a handful of new technologies: informatics, transportation, new materials, new industrial processes, and biotechnology. The breakthroughs that are taking place in these technologies are transforming the structures of the world economy. They are internationalizing the marketplace, forcing adjustment in the workplace, fueling forces of economic nationalism, redistributing economic power on a global scale.

Four features of this new technological era stand out:

- the compression of time
- the tightening of global economic integration
- the sharpening of competition
- the growing pressure on multilateral institutions

Fresh insights can be gained by considering in what measure the nuclear fuel cycle reflects or contributes these far-reaching changes.

<u>The Compression of Time</u>

All of us in this room feel that the tempo of change of economic life is constantly increasing. To some degree, the compression of time results from improvements in transportation that have brought production centers and markets much closer in terms of time and relevant costs. More fundamentally, accelerating advances in computers, telecommunications, and information processing are providing enormous economies of scale in supplying services and transfering technology.

The compression of time is much in evidence in the operation of financial markets, where almost instantaneous flows of information and capital can create the kinds of movements that were last experienced in October 1987.

This phenomenon is equally in evidence in many manufacturing sectors in the shortening of product life cycles.

At the same time, horizons have shortened for both business and political decision making.

Yet the compression of time does not seem to apply to the development of the nuclear fuel cycle. This is particularly the case in the United States, where the Three Mile Island accident ten years ago introduced a period of striking immobility. Today, there is no electric utility in the United States planning for nuclear generation capacity.

The reasons for this slowdown are clear. The construction costs of recently completed plants are too high to make them economically competitive with alternate generation. The regulatory environment remains unpredictable. Public and political confidence in nuclear power has been shaken and has failed to recover. Therefore, U.S. industry is seeking to gain leeway in the future by concentrating its efforts on assuring the safety and reestablishing the economics of present systems and laying groundwork for the development over the long term of a future advanced light water reactor.

While the experience in the United States may reflect one end of a spectrum, it is neither unique nor isolated. Even in countries like Japan and France that have proceeded systematically with nuclear power development during the past decade, there is evidence that public concerns and technological hurdles have combined to slow the pace of change. The Chernobyl disaster, in particular, seems to have marked a general break point.

In short, our intuitive sense that everything is moving more quickly has not been supported by the dynamic of nuclear fuel cycle development -- at least since the 1970s.

But we can ask ourselves, speculatively, whether, in a more indirect but important way, whether the compression of time is not being felt through the impact of oil, gas, and coal utilization on the environment. While it is by no means proven, it is possible that forces are accelerating to create a so-called greenhouse effect warming the earth's atmosphere.

This contingency could alter the calculus with regard to nuclear power development by making nuclear a relatively more attractive energy source of choice. If so, current projections of nuclear power development might be revised during the decade of the 1990s.

Global Economic Integration

Many of the same technological forces that have shortened time horizons have also tied the world economy more closely together. Advances in transportation and communication are breaking down national markets. Computer-telecommunications networks and the diffusion of technology provide the underpinning for multinational companies to have global strategies. A world laboratory has emerged based on networks of cross-licensing, joint R&D ventures, and R&D subsidiaries in foreign markets.

A striking rise in cross-border direct investment has made it possible for manufacturing to be undertaken on a global basis. Outsourcing of components becoming increasingly routine for U.S. and Japanese companies. Intra-company trade is estimated to account for 40 percent of U.S. trade.

The development of the nuclear fuel cycle among the advanced industrial countries seems, in my judgment, to reflect and reinforce the new realities of global integration. These are reflected with respect to nuclear supply relationships, the setting of safety standards, longstanding cross-licensing, and the prospect of an increasing number of joint R&D efforts. The Chernobyl accident identified significant gaps in information sharing, which have been filled on a cooperative basis.

Despite the differential pace of nuclear power development in the United States, Japan, and parts of Europe during the past ten years, there is a widely shared understanding that the long-term future of the industry is more likely to be one of convergence than divergence. It is this shared sense of a common interest and common future that brings us here today under the auspices of the Japan Atomic Industrial Forum.

The Sharpening of Competition

Paradoxically, the tightening of global integration has been accompanied by the rise of economic nationalism and the sharpening of competion among firms. There is an increasing sense that the countries and industries that command the new technologies will derive crucial economic advantages. Comparative advantage is not as much viewed as a function of natural resource endowment than as a product of human resources and capital.

The acceleration of structural change has put national governments under relentless pressure. Many have seen their capacity to guide or manage change challenged, for example, as regulatory regimes are made obsolete. All governments are held accountable and feel responsible for the consequencies of changes taking place -- especially when these affect investments, employment levels, and the quality of jobs.

The very threat to national economic sovereignty posed by global integration has fueled increasingly nationalistic responses. The perceived need to increase national competitiveness in the face of global economic challenges is evident throughout the West and among the newly industrializing countries.

In the United States, concern over the diminishing U.S. lead in technology and its spillover effects on competitiveness now dominates the economic policy debate. While there is a recognition that wide-ranging domestic factors have hurt the U.S. performance in world markets, much of the focus has been on the policies and practices of foreign governments. One can see an element of this in the FSX affair and in U.S. demands to have a seat at the table in the creation of Europe's single market. More restrictive policies on technology transfer and more toughness on the trade side are now seen by many as central to the improvement of the U.S. competitive position.

In Europe, there is growing apprehension among the members of the European Community about the perceived Japanese-American technological challenge to Europe's future well-being. To a considerable degree, these fears have been a driving force behind the coalescence of support for Europe 1992.

In Japan, there has long been a feeling of vulnerability to external forces and technology has been seen as a vital offset to outside forces beyond national control. Government policymakers devote much attention to the encouragement of technological advance, partly through direct assistance but mainly through facilitation or even forcing of R&D cooperation and sharing of know-how among independent enterprises.

The newly industrializing countries have become increasingly preoccupied with enhancing their technological potential. Many have offered market-distorting incentives in order to secure technology transfer. Others have persisted in protecting high technology sectors such as informatics from overseas competition.

It is my contention that the nuclear power industry has been substantially insulated from the forces of economic nationalism. To be sure, there was intense commercial competition during the 1970s for international export markets. But the market-limiting political and economic constraints that have been experienced in the 1980s have damped down competitive rivalries. In the case of the United States, incentives have clearly grown to cooperate more closely with those nations which have been relatively less constrained and have proceeded with more vigorous R&D programs. Indeed, the narrowing of a U.S. lead in nuclear power development that once seemed insurmountable has not been regarded in the United States as a symbol of declining competitiveness in advanced technology.

Taking a longer view, however, it would be unrealistic to factor out energy from the competitive equation. For example, what if constraints on U.S. nuclear power lead to shortfalls in electric power capacity over the coming decade? What if the international market for nuclear power is revived? Furthermore, it is hard to imagine continuing insulation of the nuclear component if competion in fossil fuels heats up.

Pressure on Multilateral Institutions

As a general proposition, the rise of economic nationalism has eroded the credibility and discipline of the multilateral economic institutions -- particularly the GATT. The most fundamental norms of the GATT (nondiscriminatory most-favored-nation treatment) have given way to a rising tide of managed trade. The use of quotas, subsidies, and voluntary export restraints have made the actual trading system a series of improvisations. At the same time, the IMF and the World Bank have come under significant pressure to cope with widening gaps between some of the less developed and advanced economies.

There is no doubt that the dynamics of multilateral cooperation with respect to the nuclear fuel cycle reflect a different set of considerations from those in trade and finance. The issues of safety and nuclear proliferation cannot be compared with those of market access, exchange rate stability, and global economic development.

But can we be certain that cooperation in one domain can be walled off from others? It is difficult to imagine as viable a regime for international nuclear cooperation in a world of competing trade blocs. By the same token, the success of organizations like the IAEA in addressing issues of safety and nonproliferation can contribute to an international setting in which the commercial prospects for nuclear power development could improve.

In sum, the issues surrounding the nuclear fuel cycle do not provide a litmus test of the balance between cooperation and competition in the world economy. The scales are tilted toward bilateral cooperation between the United States and Japan and, more broadly, toward multilateral cooperation on a global basis. Yet both the spirit and the framework for cooperation in other high technology sectors remain fragile. Nuclear cooperation holds promise of setting a positive example, but it could also be a casualty of a more pervasive breakdown of international collaboration.

Concluding Observations

I would like to close by alerting you to some of the broad non-technological considerations that are likely to shape the approach of the new U.S. administration and Congress to the energy agenda.

First, environmental considerations are becoming an increasingly important factor in the U.S. energy calculus. These considerations are not necessarily reinforcing and sometimes cut at cross purposes. On the one hand, there is rising concern over the use of fossil fuels--most recently heightened by the Alaska spill--which would seem to make alternatives increasingly attractive. On the other hand, the preoccupation with the environmental spillover of nuclear power has not faded and growing attention has been placed on the hazards associated with military facilities.

Second, economic constraints on energy development will continue to tighten. A costly program of nuclear waste cleanup at military sites will eat into the funding of the Department of Energy. Moreover, the U.S. federal deficit will not permit ambitious funding for nuclear R&D or other energy alternatives. At the same time, the balance sheets and business calculations of electric power utilities do not suggest that the private sector will make up a shortfall of federal funding.

Third, the nuclear issue could be caught up in a far-reaching domestic debate over U.S. international economic interests and strategy. On the one hand powerful voices are calling for a more narrow, territorial definition of U.S. interests. They want to slow the pace of internationalization of the U.S. economy by protecting the home market and limiting foreign investment. They advocate treating technology as a national and strategic commercial asset rather than a shared asset which is bound to flow across borders.

On the other hand, other voices call for a global definition of U.S. interests. They want to accelerate the capacity of the United States to adapt to change. They prefer to see the United States remain at the center of the international technological and scientific community. They advocate open markets, joint ventures, and a U.S. commitment to make the multilateral system work.

A globally engaged America is more likely to approach the nuclear fuel cycle in a constructive manner that serves its interests and those of its trading partners. In the final analysis, I am confident that the Bush administration will advocate such global engagement.

第22回原産年次大会
平成元年 4月14日

科学技術としての原子燃料

東京大学工学部
鈴木篤之

「何故、原子力なのか？」 この素朴な疑問が、キュリー夫人の放射能の発見以来90年、ハーンとシュトラスマンの核分裂反応の発見以来50年経った今でも、なお、人々の頭の中にあるようである。この疑問が解消されない限り、原子力がいわば「普通の科学技術」として広く社会に定着することは難しいように思う。

それに対する答えの１つは、「石油、石炭や天然ガスなどの化石燃料はいずれ枯渇するものであり、それに替わるエネルギーとして原子力が必要である。」という代替エネルギー論にある。しかし、これらの化石燃料資源が物理的に枯渇する時期は、それ程近い将来ではないので、この点だけから人々の理解を広く得ることは難しい。この意味では、物理的に枯渇するか否かではなく、石油という経済的に貴重な資源の価格を国際的に安定化させておくべきであるとの観点が重要であり、原子力が現実に担っている役割もこの点が最も大きい。実際、全世界の原子力発電による石油代替量は、現在１日約800万バーレルでＯＰＥＣ生産量の40%程度にも及んでいる。

第２の答えは、「化石燃料資源は総じて偏在しており、それらの資源のみに頼っていることは、ナショナル・セキュリティの観点から好ましくない。供給源を多様化、分散化する上で原子力が必要である。」というセキュリティー論である。この意味での多様化や分散化についてはある程度のシェアがあれば一定の目的を達し、また、逆に原子力自体への過度の依存もナショナル・セキュリティ上好ましくないことへの配慮から原子力化に一種の制約が加えられることになる。この点からの説得力には、その必要性が必ずしも原子力に限ったことではないことから、やはり、それだけでは十分とは言い難い。

最近になって、殊更に人口に膾炙されるようになった「炭酸ガス問題から原子力の必要性を訴える」という地球環境論に第３の答えを求める人もいる。しかし、地球温暖化の要因となり得る環境放出物は炭酸ガスばかりでなく、他にクロロフッ化炭素、メタン、酸化窒素、オゾンなどがあり、炭酸ガス以外のこれらの放出ガスによる気温上昇の方が炭酸ガス自体による上昇よりむしろ大きい可能性があるといわれている。さらに、炭酸ガスの発生源としては、原子力が代替している発電所よりも自動車の排ガスなどの方が多い。原子力が炭酸ガス問題の解決に一定の役割は演じ得ても、それには自ずと限界があることも十分認識しておく必要がありそうである。

より本源的な、より本質的な答えは、「原子力はミクロのエネルギーであり、マクロの世界からミクロの世界へと進歩して来た科学技術の流れから考えてエネルギーの原子力化はいわば必然的なものである。」という点にあるのではないであろうか。

炭素が酸素と結合する反応によって得られる化石燃料エネルギーは、１原子当たり４電子ボルトであるが、ウランが分裂する反応によって得られる原子燃料エネルギーは１原子当たり２億電子ボルトである。これは、炭素と酸素の反応はそれぞれの原子核の外をまわっている電子が結合する反応であるのに対し、ウランの分裂反応は原子核自身の反応であり超ミクロの世界のエネルギーだからである。一般に、エネルギーはその物質や空間の大きさに反比例しており、電子がまわっている空間と原子核の大きさとでは桁違いに原子核が小さい。ここに、化石燃料と原子燃料との間のエネルギー生産性に桁違いの差がある科学的根拠がある。

化石燃料エネルギーの４電子ボルトは、ちょうど紫外線のエネルギーであり、いわば目で見えるぎりぎりのエネルギーである。これに対して、２億電子ボルトという原子燃料エネルギーは、目には全く見えない超ミクロのエネルギーであり、Ｘ線やγ線の領域である。目には見えなくともウランは地球上に広く存在しており、それが核分裂すれば莫大なエネルギーを産むことは、科学的事実であり何人もこれを否定することはできない。

化石燃料から原子燃料への転換が目に見える世界から目に見えない世界への転回であることは示唆的である。紫外線もＸ線も同じ電磁波として放射線的性質を持っているにもかかわらず、Ｘ線というと特別に怖いイメージを与えていることもこれと無関係ではないように思う。したがって原子力の安全問題が殊更に強調されるのもこの不連続性のためと考えることもできる。化石燃料と原子燃料との間にある８桁というエネルギー生産性のちがいは、人々が感覚的に理解し得る変化の範囲を明らかに超えている。

目に見える可視光線だけに頼っている限り、0.数ミクロン以下のこまかいところはぼやけてしまい観測できないことはハイゼンベルクの不確定性原理が教えるところであり、我々の世界はそれ以上に広がり得ないことになる。しかし、Ｘ線や電子顕微鏡を用いればサブミクロン以下のミクロの世界も観察できるようになる。ここに科学技術の本質的醍醐味がある。10万電子ボルトの電圧で電子を加速すると１オングストローム以下の波長の電子波が得られ、可視光による普通の顕微鏡に比べ分解能は桁違いに向上する。高分解能のＸ線を発生するＳＯＲ放射光に世界中の科学者が注目していることは人間の知的欲求として当然である。

電気や情報の分野が、真空管時代から半導体、ＩＣ、ＬＳＩ、超ＬＳＩの時代に移るにつれ、飛躍的な進歩を遂げたように、科学技術は、マクロからミクロへと進歩し、偉大な成果をもたらしてきている。マクロからミクロへの進歩は単なる効率の向上にとどまらず桁違いの不連続的な技術革新につながるからである。今日の電子時計、パソコン、スーパーコンピュータなどは、一昔前の人々には想像もできない程のもので、単なる性能の向上を超えた正に革新的技術の代表例である。

材料科学の分野においても、先端的技術は分子レベルや原子レベルで設計・加工するミクロ技術に最大の関心がある。分子レベルや原子レベルとは、可視光の波長以下のサブミクロン領域のミクロの世界で、レーザー、放射線あるいはＸ線の領域である。レーザーＣＶＤ加工やＸ線リソグラフィなどの材料科学技術が注目されている所以も正にミクロ化志向にある。

たとえば、半導体のトンネル効果や超伝導体のジョセフソン効果が量子力学によってはじめて理解されるように、ミクロの世界はいわば量子の世界である。原

子燃料のエネルギーの世界も量子の世界である。Ｘ線ＣＴやポジトロンＣＴなどの現代医学には欠かせない診断技術も目に見えないミクロの世界、量子の世界である。原子燃料を、このように、ミクロのエネルギー、量子レベルのエネルギーとしてとらえ、原子燃料への転換は科学技術史的に見てごく自然の流れであると考えることがこれからは重要であるように思う。そして、その原子燃料を利用することが、ＣＴ診断技術のように人類の役に立つことをいわば目に見える形で示していくことが求められているように思う。

ちょうど300年前に、ニュートンが「プリンキピア」を発表しニュートン力学を提唱したとき、デカルト主義者達はそれを必ずしも受け容れようとしなかったといわれる。ニュートン力学の絶対空間の概念を受け容れることは「空の存在」を認めることであり、それは神の創造である世界にはあり得ないと考えたからである。17世紀後半は工学の分野においては正に革命的であった。トリチェリの定理、ボイルの法則、フックの法則、ホイヘンスの原理など今日なお重要な原理とされている古典的理論のほとんどがこの時期に証明されている。これ程多くの碩学が輩出していたにもかかわらず、ニュートン力学の理解には、長い年月を要した。ベルヌーイがいわゆるベルヌーイの定理を発表したのは、18世紀の半ば近くであるが、彼はなおニュートン力学に否定的な見解を述べている。

今日では、ニュートン力学を超えて量子力学が存在することが知れており、また、これからの技術が量子力学に依拠することも科学技術史的に明らかになりつつある。それは、しかし、科学者という一握りの人々にとってであり、量子の世界が広く社会に受け容れられるまでにはなお年月が必要である。万有引力が何に由来するものか今なお謎とされているにもかかわらず、ニュートンの世界は多くの人の信ずるところであり常識化されている。量子の世界もいずれはその段階に達するであろう。

原子燃料が科学技術の一つとして常識化されるまでの道程は、したがって粘り強い根気を必要としている。石油価格の安定化という原子燃料導入の１つの目的が満たされつつある現状にあっては、原子力に対する社会の見方もその潜在的恐怖感の故に一段と厳しくならざるを得ない。この意味での民主主義コストの負担は覚悟すべきであるように思う。当然のことながら、原子燃料の常識化のためには、信頼される技術を目指し、着実にかつ確実に実績を積み重ねて行くことがまず重要であることは言うまでもない。

また一方、「安全第一」を強調しすぎるあまり、人々に却って恐怖感を与えてしまっている面もないわけではないことを想起すべきであるように思う。過度に保守的であることは、実は、逆により危険なものへの選択を人々に強いる場合もあることを忘れるべきではない。原子燃料への転換は科学技術の自然な流れであり避けて通れないとするならば、安易な保守主義を排し科学的に論拠のある事実により忠実であることが益々望まれている。ニュートンは「私は仮設をつくらない」と述べている。

情報科学、材料科学などの分野では、ミクロ化、量子化によって正に革命的な技術革新が進行し、新しいパラダイムが創生されつつある。原子燃料技術は、これらの先端技術とは対照的な前近代的パラダイムを追求した物とのイメージを与え勝ちである。大規模・大容量化による経済性の追求という重厚長大イメージが強すぎるためであるが、原子力こそミクロ化、量子化のエースであることを想起し、原子力型新パラダイムの創生に向けて新たなる発展を期したいものである。

NHK Survey of Public Opinion

(October, 1988)

A. Nuclear Power Development

1.	Progressive Support	7 %
2.	Prudent Support	53 %
3.	Stop	19 %
4.	Embargo	11 %
5.	Others	10 %

B. Nuclear Safety

1.	Safe Enough	5 %
2.	Comparably Safe	22 %
3.	Comparably Dangerous	46 %
4.	Very Dangerous	20 %
5.	Others	8 %

B'. Nuclear Safety, amongst A-2

1.	Safe	36 %
2.	Dangerous	59 %
3.	Others	5 %

Explanation for

" Why do we need nuclear power ? "

1. Substitutability for Thin Resources such as Oil, Coal, and Natural Gas,

2. National Security

   -Diversification of Energy Sources,

3. Abatement of Global Environmental Impacts, such as CO_2 and Acid Rain.

An Energy Balance for Nuclear Moratorium Scenario

(IIASA, 1981)

Primary Energy Consumption in 2030 [%]

	Base Case	Nuclear Moratorium
Oil	22	24
Coal	29	39
Natural Gas	15	20
Nuclear	23	- -
Hydro-Geothermal	7	7
Solar and Other Renewable	4	10
Total	100	100

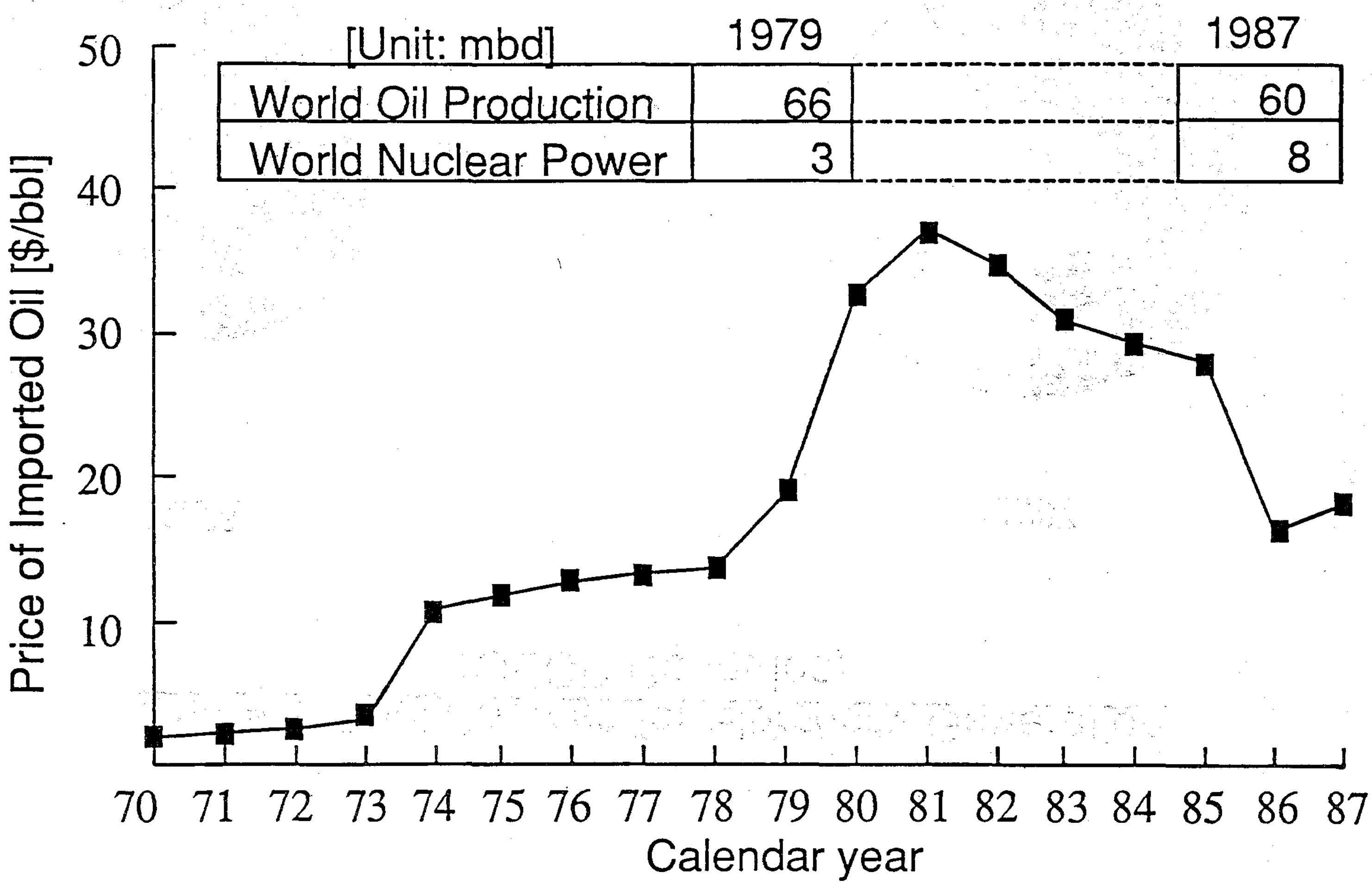
Fossil Fuel Resources Remaining at 2030 [%]

Oil,	< $ 12/bbl	21	14
Coal,	< $ 25/ton	65	44
Natural Gas,	< $ 12/bbl	51	32

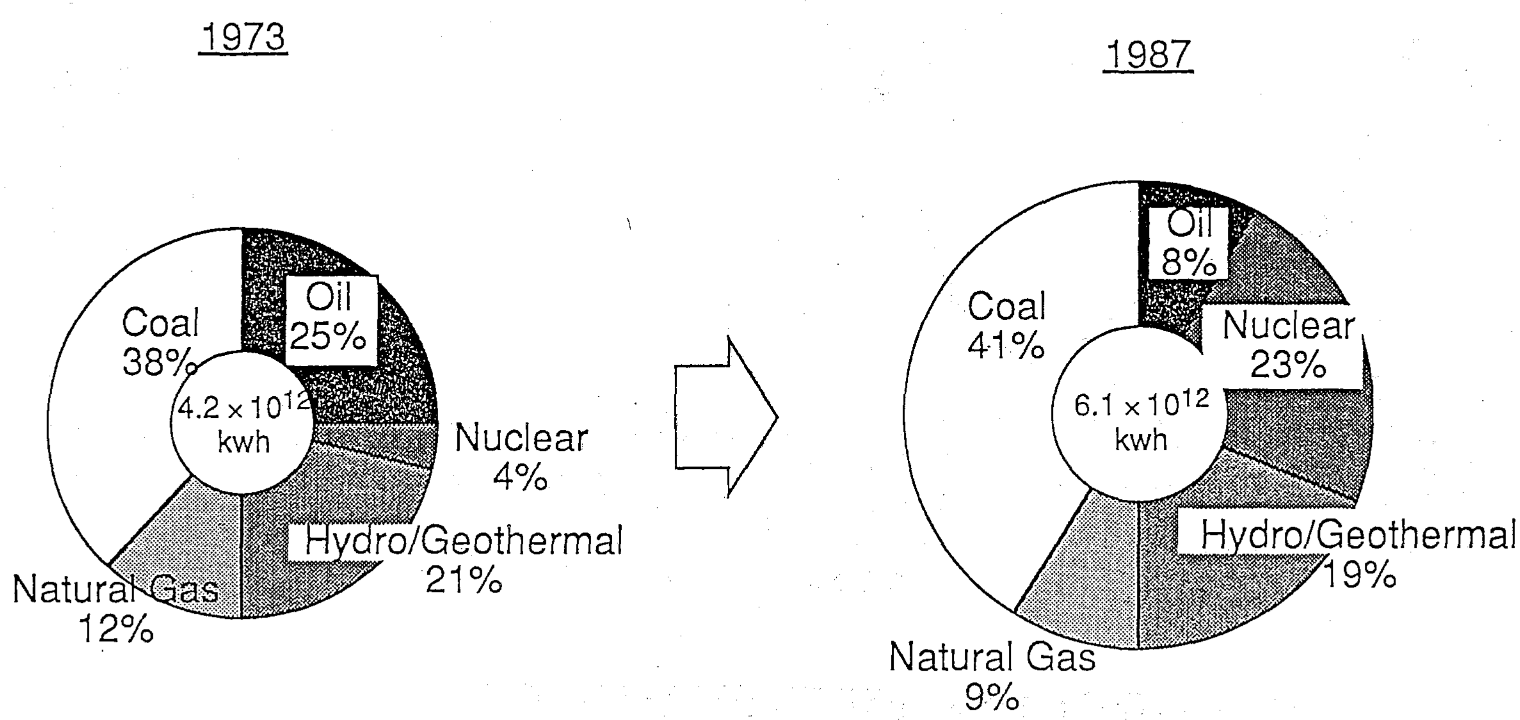
Oil Conservation and Price Stabilization by Use of Nuclear Power

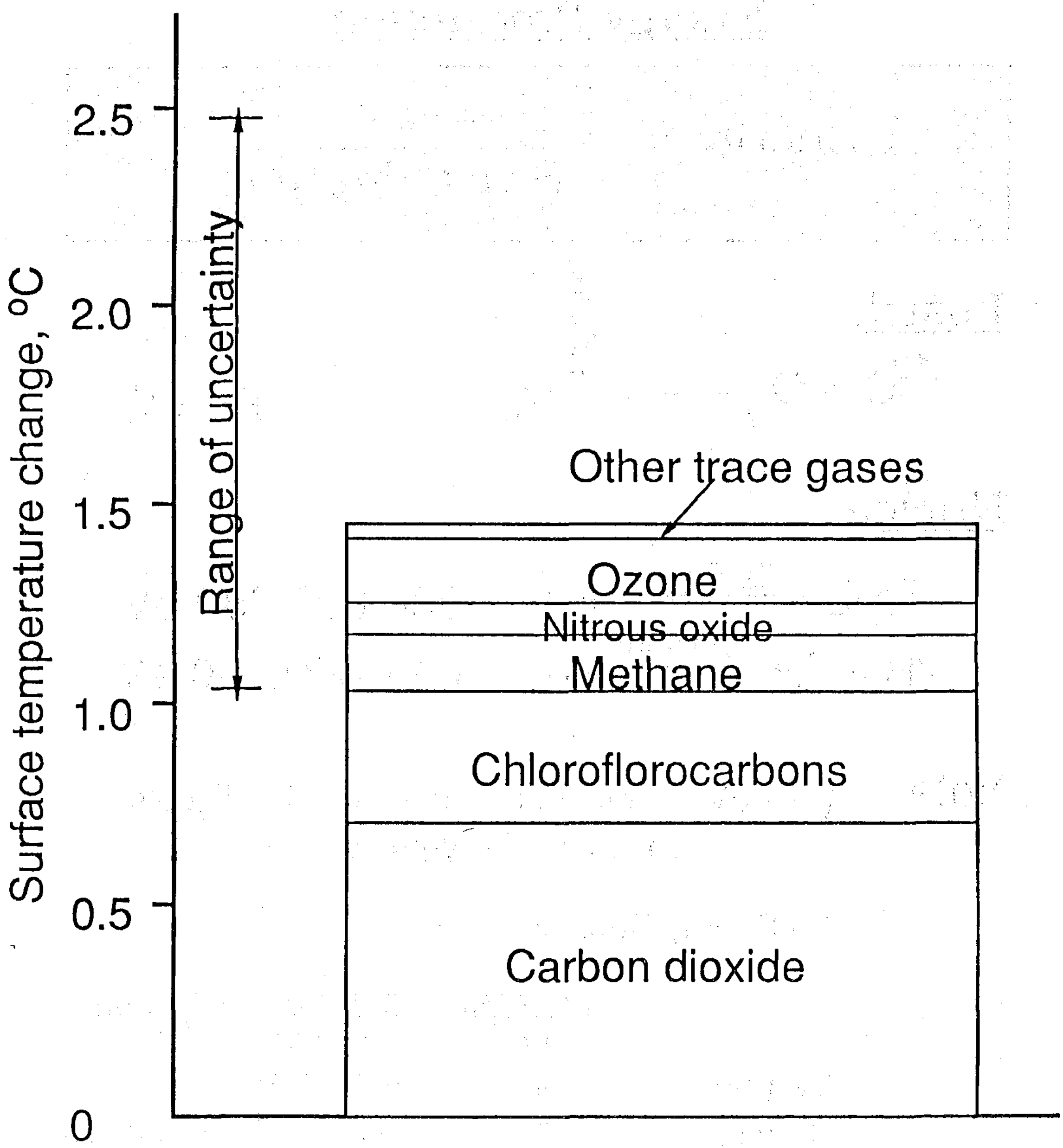
[Unit: mbd]

	1979	1987
World Oil Production	66	60
World Nuclear Power	3	8



Share of Fuel Sources for Electricity Generation (OECD Countries)





Cumulative equilibrium warming due to increased greenhouse gases from 1980 to 2030 (IEA, 1988)

Energy Production

$$\text{Energy} \propto \frac{1}{\text{Size of Matter}}$$

Fossil;

$$^{12}C + O_2 \longrightarrow CO_2 \qquad + 4\ \text{eV}$$

Nuclear;

$$^{235}U \xrightarrow{\text{Fission}} \text{FP's} \quad + 200{,}000{,}000\ \text{eV}$$

$$^{2}H + {}^{3}H \xrightarrow{\text{Fusion}} \text{He} \quad + 17{,}000{,}000\ \text{eV}$$

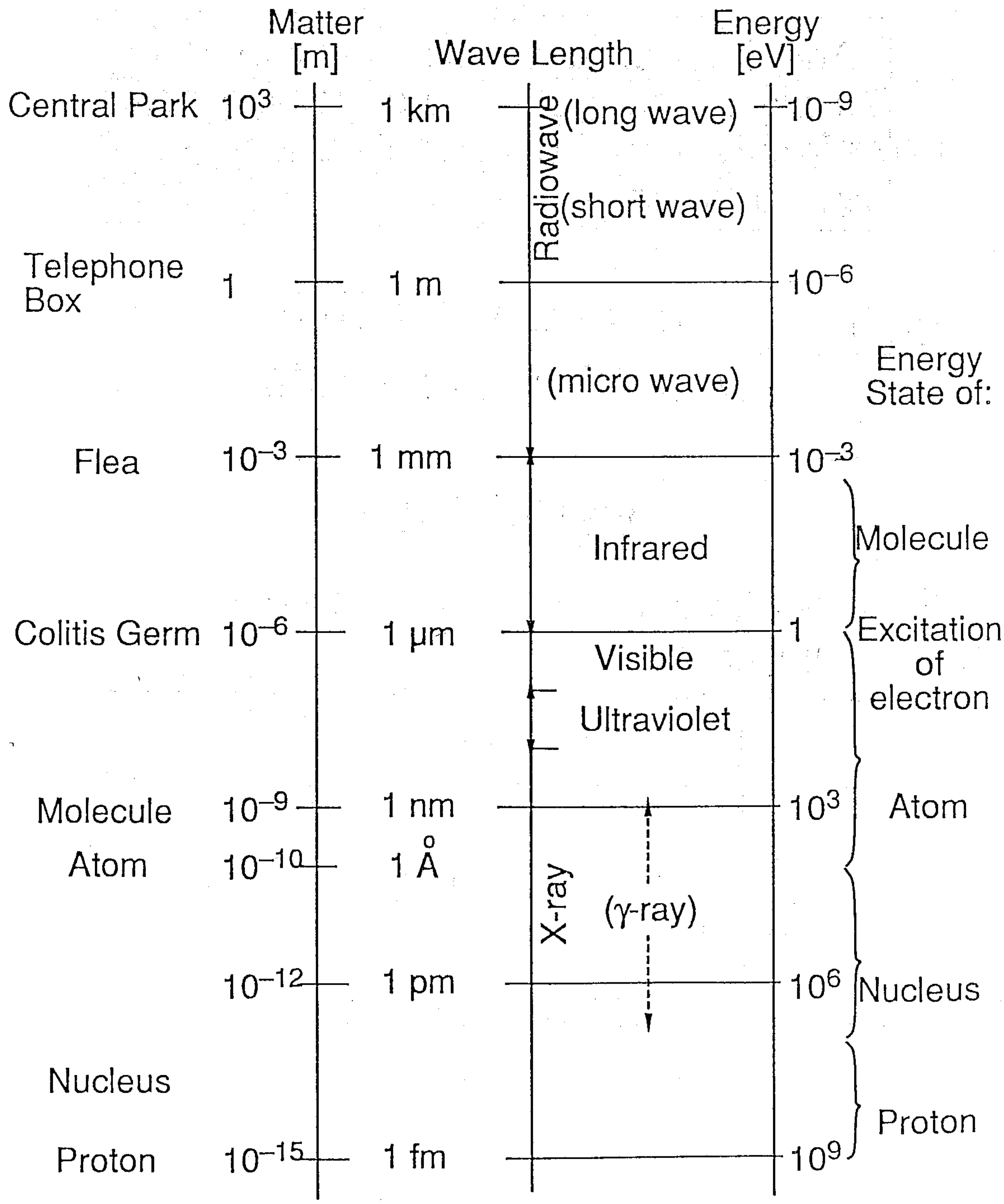
Notes

(1) 1 eV = 1 electron Volt = 1.6×10^{-19} joule
= 1.6×10^{-19} Watt•sec

(2) Energy Density

	per atom [eV]	per mol [W•sec]	per gram [W•hr]
Carbon	~ 4	~ 4×10^5	~ 10
Uranium	~ 2×10^8	~ 2×10^{13}	~ 2×10^7
Hydrogen	~1×10^7	~ 1×10^{12}	~ 5×10^7
Photon(1μm)	~ 1	~ 1×10^5	———

Relation Between Size of Matter, Wave Length and Energy

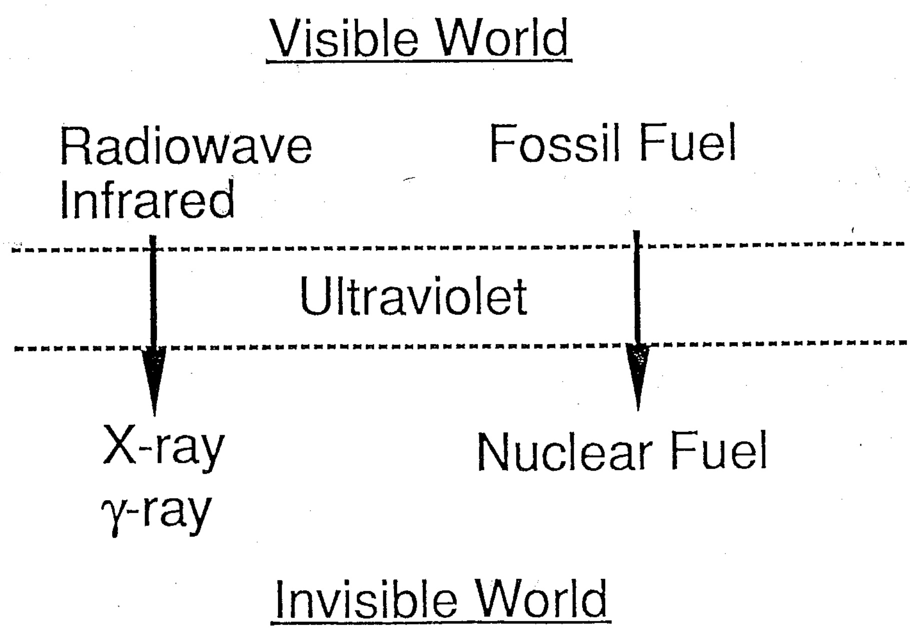


The Definition of Radiation

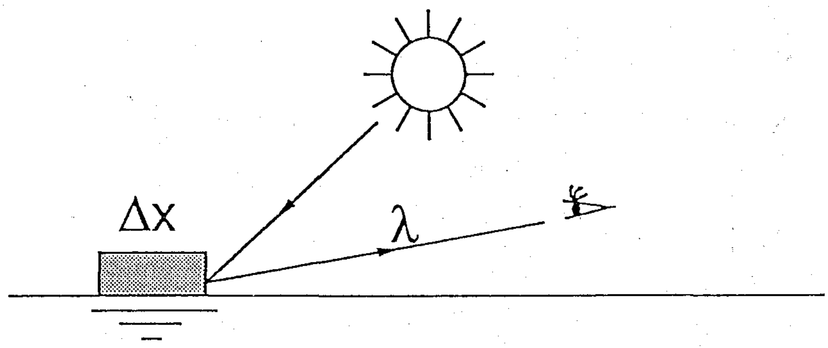
(Ionizing) Radiation:

> Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter.

Technological Shift from Visible to Invisible



Heisenberg's Uncertainty Principle



$\Delta x \gtrsim \lambda$

i.e., Laser Disc

Pit width 0.4 μ
Pit Spacing 1.67 μ (10^{-6}m)

Expanding Observable World

Electron Microscope
~ 10^5 Volt ⟶ $\lesssim$ 1Å (10^{-10} m)

Historical View of Scientific Revolutions in Electronics, Energetics and Mechatronics

Industrial Revolution	1st (18c ~ 19c)	2nd (19c ~ 20c)	2.5th (20c)	3rd (20c ~ 21c)
Scientific Basis	Classical Mechanics (Newton)		Theory of Relativity (Einstein)	
	Thermodynamics (Kelvin)	Statistical Mechanics (Boltzmann)	Non-Equilibrium Statistical Mechanics (Onsager)	[Unified Theory]
		Electromagnetics (Maxwell)	Quantum Mechanics (Heisenberg/Schrödinger)	Weak Interaction Strong Interaction
	Atom (Dalton) Periodic Law (Mendeleev)	Electron (Thomson)	Neutron (Chadwick)	Elementary Particle
Electronics	Battery-Magnet	Vacuum Tube wire (telegraph, telephone) wireless (radio, television, telecommunication)	Semiconductor· IC Computer Radar· Optical Communication Laser NMR-CT	Quantization Element 5th Gen. Computer Coherent Optical Communication Earth Crust CT-scan
Energetics	Steam Engine	Electric Power Distribution System Internal Combustion Engine	Superconductivity Nuclear Fission Jet Engine	HT Superconductivity Nuclear Fusion
Mechatronics	Locomotive Mining-Textile Machine	Automobile, Aerocraft Machine tool	Rocket Robot NC	Space City·Ocean City Autonomous Machine
(precision)	(mm: 10^{-3})	(μm: 10^{-6})	(sub-micron: 10^{-7})	(mili-micron: 10^{-9})

<u>Historical View of Material Used</u>

Level - 0 (the paleolithic age)
<u>No Processing</u>

Level - 1 (the neolithic, bronze and iron ages)
<u>Fire Processing</u>
(Earthenware, Ceramics, Bronze, and Iron)

Level - 2 (the modern age)
<u>Electrochemical and Thermochemical Processing</u>
(However, molecular or atomic configuration in materials is not completely stable.)

Level - 3 (the coming age)
<u>Microlevel Processing</u>
(Material design, synthesis and fabrication in molecular or atomic level, for creating new materials with innovative properties and functions)

EX. Lithography, Molecular Beam Epitaxy, Laser CVD, Laser Isotope Separation, etc.

Classical Theories of Engineering Science

- Torricelli's Theorem (1643)
- Boyle's Law (1660)
- Hooke's Law (1678)
- Newton "Principia" (1687)
- Huygens' Principle (1690)

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- Bernoulli's Theorem (1738)

(30) The use of linear extrapolations, from the frequency of effects observed at high doses, may suffice to assess an upper limit of risk, with which the benefit of a practice, or the hazard of an alternative practice - not involving radiation exposure - may be compared. However, the more cautious such an assumption of linearity is, the more important it becomes to recognize that it may lead to an overestimate of the radiation risks, which in turn could result in the choice of alternatives that are more hazardous than practices involving radiation exposures. Thus, in the choice of alternative practices, radiation risk estimates should be used only with great caution and with explicit recognition of the possibility that the actual risk at low doses may be lower than that implied by a deliberately cautious assumption of proportionality.

Nuclear Paradigm

Nuclear Fuel : Micronization or
Quantization of Energy

- Clean, Safe and Reliable,
- Incomparably High Cost Performance,
- Responsive to Social Trend,
- Creative and Innovative Applications, and
- Undoubtedly Visible Benefits.

ENVIRONMENTAL ISSUES OF THE NUCLEAR INDUSTRY

Dr. Dennis B. Cearlock
Battelle Memorial Institute
Pacific Northwest Laboratories

INTRODUCTION

Many feel that nuclear energy is environmentally less desirable than other forms of power generation. However, the environmental soundness of some currently important forms of energy production is coming under question.

Perhaps no other environmental issue has captured worldwide public attention like that of global environmental change. People are demanding solutions to the "greenhouse" effect, acid rain, and ozone depletion. Answers to these questions will not be easy to find.

Since the Industrial Revolution, factories have been discharging carbon dioxide and other gases into the earth's atmosphere. Scientists do not agree totally about the relationship between these gases and climate, but four of the last eight years have been the warmest since we began taking global surface measurements in the 1880s.

Last summer's drought - the worst in North America in 50 years - increased public concern about global warming.

Acid rain is also changing the global environment. The problem is shared by all nations that use fossil fuels to generate energy. It disregards national boundaries, disturbs the ecology of lakes and rivers, and disrupts forest ecosystems.

Ozone depletion is another recent environmental problem that has aroused public concern. Last month, representatives of 124 governments met in London to discuss worldwide elimination of ozone-threatening chemicals by the year 2000.

I have mentioned just a few of the environmental issues that may be omens of long-term changes in the global environment. They could affect the environmental health and economic well-being of every nation. Two of these issues - the greenhouse effect and acid rain - could have profound impacts on utilities worldwide.

Because fossil fuels are viewed as one of the culprits responsible for the greenhouse effect and acid rain, some people are reconsidering the role of nuclear power in the United States . . . even some environmental activist groups. These phenomena may convince the public that the perceived safety of fossil-fueled energy production is an illusion and that the perceived risks of nuclear energy production are more acceptable than the alternatives.

To expand the use of nuclear power, however, we must make significant headway in the areas of health, safety, and the environment.

Since waste management is perhaps the most controversial environmental issue for the nuclear power industry in the United States, I am going to talk about nuclear waste management and briefly compare it with our management of hazardous waste. I will also talk about the need to improve our understanding of the chemical and physical processes involved in waste management, so we can ensure the safety of the global environment for coming generations.

RADIOACTIVE WASTE MANAGEMENT IN THE UNITED STATES

The task of developing effective waste management strategies and technologies has been complicated by public fear of exposure to radiation. Most likely, this is because the concept of the "peaceful" atom was the second stage of the nuclear era rather than the first. As a result, nuclear waste management issues often raise political as well as scientific questions about public health and safety, and the protection of the environment.

In the United States, the Atomic Energy Act of 1954 specified conditions for activities using atomic energy and radioactive materials for civilian and national defense purposes. But in the late 1960s, popular movements increased public awareness of the need to preserve and protect the environment.

Our legislators and government officials responded by enacting laws and establishing regulatory agencies. These actions placed the nuclear industry under more rigid controls - perhaps more rigid than any other industy. All activities - from the site selection of the nuclear power plants to the disposal of its wastes - are covered by the regulatory process, which often includes the public involvement.

For example, the National Environmental Policy Act requires all federal agencies to prepare impact statements if they are planning actions that could affect the quality of the environment significantly. The Act also requires that these proposed actions be reviewed. The highest and most complex level of review is for the Environmental Impact Statement.

The average environmental impact statement process takes two years to complete. Controversial issues can take much longer. The preparation and review of an Environmental Impact Statement concerning the handling of six classes of waste of Hanford, Washington, took six years to complete.

Public participation is a critical part of the review process. From the time a Notice of Intent is issued to announce that an Environmental Impact Statement is being prepared until the final document is published, public input is invited. The process is time-consuming, but it is essential for public acceptance.

The regulatory agencies which have important roles in regulating radioactive waste management are:

Nuclear Regulatory Commission
Department of Transportation
Environmental Protection Agency

The Nuclear Regulatory Commission is the primary regulatory body for the nuclear industry. Civilian nuclear reactors must be licensed by the NRC. This is a two-step process. First, the utility must obtain a construction permit, and public hearings must be held before the permit can be issued. Then, the utility must obtain an operating license before loading fuel. Additional public hearings can be requested before the operating license is issued. The NRC is preparing a rule change that will cut the average licensing time in half, to approximately six years.

The NRC also licenses federally operated facilities that receive, transport, store, and dispose of defence and commercial wastes.

Before civilian wastes can be transported, packagings must be certified by the NRC and the Department of Transportation.

Because chemicals considered hazardous are often present in radioactive wastes, both utilities and federal agencies operating nuclear facilities must comply with hazardous waste standards established by the Environmental Protection Agency to protect the environment and public health. As I have stated, these regulatory requirements have placed the nuclear industry under very tight controls.

To meet the regulatory requirements, the Department of Energy has been charged with the responsibility to develop and deploy technology to treat, store, and dispose of radioactive wastes. The Department is responsible for the disposal of all high-level wastes. This includes commercial and defense wastes as well as all other wastes generated by the federal government.

I would now like to discuss briefly the status of important waste management activities: spent fuel storage, monitored retrievable storage, and high and low-level waste management.

Spent fuel storage is becoming a real problem in the US. When the nuclear reactor development began in the United States, planners did not expect the volume of waste that exists today. They assumed that spent fuel from civilian and military reactors would be reprocessed. Some fissionable materials would be recovered for use as reactor fuel. The rest of the high-level waste would eventually be sent to repositories.

For this reason, most commercial nuclear power plants were designed to store no more than a three-year accumulation of spent fuel. When the only U.S. commercial reprocessing plant closed in 1972 and the Carter Administration banned civilian reprocessing in April 1977, the spent fuel storage problem became more difficult. Because of these changes in policy, the Nuclear Waste Policy Act of 1982 assigned the U.S. Department of Energy the responsibility for assisting utilities with the storage of spent fuel until a federal repository is established.

Currently, U.S. spent fuel is stored underwater in steel-lined concrete pools. Most pools are filled to near capacity. To address these problems, the DOE has been working with the utilities to demonstrate new technologies for increasing at-reactor storage. In many cases, high-density racks have been installed to increase storage capacity. Another concept for increasing temporary storage capacity is to disassemble the spent fuel and consolidate the rods in can-isters that will also be stored under water.

In addition to wet storage, dry storage of spent fuel is being evaluated. In 1986, the Nuclear Regulatory Commission licensed the first dry spent fuel storage facility. Since then, the NRC has licensed certain types of metal and concrete casks for some dry storage applications.

It is possible that spent fuel will be consolidated and packaged in a monitored retrievable strage facility. A Congressional commision is now studying the need for such a facility. At present, the deadline for selecting a site for the monitored retrievable storage facility is 1994. This schedule depends on the conclusions of the Congressional commission and on progress in selecting and constructing a geologic repository.

The Department of Energy is assessing Yucca Mountain in Nevada as a site for the geologic repository for high-level wastes . Construction of the repository is scheduled to begin in 1998, and the facility is scheduled to begin accepting wastes by 2003.

Low-level waste from utilities, academic and medical research laboratories, hospitals, and industry is being disposed in near-surface facilities at three commercial sites in South Carolina, Nevada, and Washington. In 1993, each state will become responsible for managing its own waste.

To date, forty-one states have joined together to form nine compacts and will address the problem collectively. Four states have elected to manage their own waste, and five states are undecided about how they will handle low-level waste.

The key issue in managing our waste is how to dispose of them in an environmentally sound and publically acceptable manner. The public wants assurances that generations hundreds and thousands of years from now will not have to deal with radioactive waste generated today. These are reasonable demands, but they pose difficult technical problems.

Through research, development and demonstration, the nuclear industry has made significant progress in developing technologies to manage radioactive wastes. Some examples developed by the Pacific Northwest Laboratory follow.

- Our ceramic melters have demonstrated that high-level liquid waste can be solidified into a solid, glass-like product which can be stored in deep geologic repositories.

- We are testing engineered barrier systems under simulated disposal conditions to determine their long-term performance and to improve our understanding of reaction mechanisms.

- Our performance assessment models are being used for site assessment and engineered barrier design.

- We developed and demonstrated the technology for solidifying and disposing low-level liquid wastes using a cement based matrix.

- Barrier technologies have also been developed. Earthen multilayer, and voidless asphalt covers are used to confine radon emissions from uranium mill tailings and to prevent water from seeping into radioactive wastes.

- Sorbent barriers have been developed to line waste sites. These barriers act as filters, capturing specific contaminants but allowing harmless substances such as water to pass through.

- Biobarriers that combine herbicides with polymers can protect low-level radioactive waste disposal sites from root intrusion. The herbicides are released slowly into the soil and keep out plant roots for more than 100 years without interfering with surface vegetation.

- For accidental releases or failed disposal systems, in-situ vitrification can immobilize these wastes in-situ in a block of glasslike material that resembles natural obsidian. The process is effective in most soils, including those saturated with water.

U.S. HAZARDOUS WASTE MANAGEMENT

In contrast with nuclear waste management, hazardous waste disposal problems in the United States have only recently begun receiving the same high level of public scrutiny. Whereas the nuclear industry has been subject to strict regulatory control since the beginning, the chemical industry - and particularly chemical wastes - have been controlled to a much lesser degree.

Our hazardous waste environmental problems are the legacy of a technological revolution that begun just after the turn of the century. By 1965 the American Chemical Society had registered more than four million chemicals. Many of these were synthetics created since 1945. Today about 55,000 chemical substances are widely used in the United States. About 98 percent of these are considered harmless to man and the environment.

Before 1970 federal laws guarded against only the most obvious dangers such as chemicals in food additives and cosmetics. Little or no attention was focused on industrial chemicals or their waste products, which has resulted in a national problem of epidemic proportions. Between 32,000 and 50,000 waste sites may contain hazardous materials.

Over the past ten years, the widespread distribution of hazardous and toxic waste in the ecosystem has become a serious concern. Often these wastes are the primary source of human exposure to toxic materials.

The public's fears about hazardous waste are intensified by discoveries that citizens have been exposed to toxic substances dumped in abandoned or undiscovered waste sites. Stories about environmental problems such as New York's Love Canal - where more than 200 families left their homes when hazardous chemical wastes seeped into basements from an abandoned disposal site - receive widespread media coverage and increased public concern.

As the scope of the hazardous waste problem became clear and public interest grew, environmental regulations multiplied. Today, more than 24 federal laws and a dozen agencies are concerned with regulating the manufacture, distribution, and disposal of hazardous and toxic substances. These laws affect not only the chemical industry but also everyone who uses toxic or hazardous substances . . . from farmers and gardeners who use fertilizers and pesticides to businesses that use solvents and corrosive agents.

Three federal laws establish the basic framework of existing regulation: the Toxic Substances Control Act of 1976, the Resource Conservation and Recovery Act of 1976, and the Comprehensive Environmental Response, Compensation, and Liability Act, or Superfund, of 1980. Together, these laws form a comprehensive program for the regulation of all chemical substances from the time they are developed until they are disposed of.

The Toxic Substances Control Act regulates the creation, manufacture, and distribution of chemical substances.

The Resource Conservation and Recovery Act controls waste management practices and promotes resource conservation and recovery.

The Comprehensive Environmental Response, Compensation, and Liability Act known as Superfund controls remediation of abandoned hazardous waste sites.

With these regulations, the United States is attempting to gain control of the hazardous waste problem. As with radioactive wastes, the primary difficulties in dealing with hazardous waste is finding a place to dispose of it. The public generally rejects the idea of a hazardous waste site in or near a community. Many people tend to disregard or fail to understand the actual risks involved, and they are suspicious of reassurances of their safety.

For example, when the state of Pennsylvania began issuing permits for waste sites under the Resource Conservation and Recovery Act, more than 75 percent of the proposed permits were challenged during the first year. More than a third of these protests were led by municipal officials or other government officers. Almost half of these protests resulted in the rejection, withdrawal, or delay of the permits.

To satisfy regulations and gain public acceptance, we must develop the technology for safely disposing chemical wastes and remediating abandoned sites. The knowledge and technology developed for managing radioactive wastes is being used to help solve these problems. Some examples follow:

- Ground-penetrating radar, electromagnetic induction, and soil gas vapor analysis can locate and identify buried drums, abandoned disposal cells, and contaminant plumes.

- Geochemistry and contaminant transport analysis computer codes can predict exposures to chemicals and the resulting impacts.

- In-situ vitrification can be used where other cleanup methods would be difficult and expensive. Instead of excavating, repackaging, transporting, and reburying these wastes, they can be immobilized in a glasslike mass where they lie. Organic components are destroyed by the high temperature. This process is especially useful where hazardous waste has spilled or leaked out of a disposal site and where the risk and cost of removal far exceed the risk and cost of in-place treatment.

Although these technologies are applicable to hazardous waste management, there are some basic differences between the approaches to managing radioactive and hazardous wastes in the United States. Our approach to radioactive waste management has been long-term, and we have worked hard to improve our ability to predict problems that might arise far in the future. As a result, we have developed advanced monitoring and detection systems and performance assessment capabilities.

In contrast, our approach to hazardous waste management has been short-term, and the assessment and monitoring technology is less well-developed. The flaw in this approach, of course, is that unlike radioactive waste which eventually decays, some hazardous chemicals never go away once they are introduced into the environment.

EXPANDING THE CURRENT KNOWLEDGE BASE

As we have discussed previously, and extensive body of knowledge about the behavior of radioactive contaminants has been developed and we have used this knowledge to develop technology for improving waste managemnt. But our work is not finished.

Historically, public demands for environmental responsibility have been much greater for the nuclear industry than any other. People want 100 percent guarantees. But some of the radioactive materials we are dealing with have half-lives measured in tens and hundreds of thousands of years. We cannot produce test results that prove beyond a shadow of a doubt that our technology is foolproof. To a great extent, public acceptance must be based on trust . . . trust in our integrity, skill, and wisdom.

Events such as the Three Mile Island accident on March 28, 1979, erode that trust. After Three Mile Island, public concern about the safety of the nuclear industry increased dramatically. The impacts were tremendous. For instance, many nuclear plants under construction had to redesign to meet new regulatory requirements. Some operating plants had more workers making Three-Mile-Island-related changes than were needed to build the plants originally. As a result of Three Mile Island, the U.S. nuclear industry and federal regulators began a detailed review of plant design, management, and operations.

The Chernobyl accident on April 26, 1985, intensified public concern, the demands on the nuclear industry became even more stringent and public confidence deteriorated further. As a result, one of our most urgent needs is to rebuild public trust. One aspect is reassuring the public about the long-term performance of the waste disposal systems.

However, we cannot conduct 10,000 year experiments in our laboratories. We cannot afford to examine empirically or experimentally all the potential combinations that exist among waste forms, engineered barrier, host media and other environmental conditions. To meet these demands for reassurance, we must improve our understanding of how wastes behave at a fundamental level.

For example, we know that many radionuclides containing solid phases are extremely insoluble. Except under very low pH conditions, the maximum expected dissolved concentrations of actinides, such as thorium, plutonium, uranium, and neptunium, in an anoxic environment, are below analytical detection limits. Therefore, if reducing conditions that produce tetravalent actinides can be maintained for over 10,000 years, these actinides will still exhibit low solubility.

If we understood the factors controlling the levels of oxygen and the pH on a fundamental basis, we may be able to show that a wide range of environmental conditions does not substantially change the pH or anoxic conditions. We would then have the knowledge to show that extreme changes in environmental conditions would not affect the solubility and thus, the mobility of important contaminants. On the other hand, if environmental changes do affect the pH and/or anoxic conditions, we would have the knowledge base from which to develop engineered barriers to prevent such changes. In either event, we would not have to rely on the host rock as a part of the isolation system. This would significanly reduce the high costs and technically difficult task of characterizing the host rock to the level of detail required for its inclusion as a part of the barrier system. This is just one exmple of how fundamental and applied research could help improve public acceptance and at the same time reduce the costs of waste disposal.

Understanding waste behavior on a fundamental basis is not only important for regaining the public trust, but is equally important for reducing the cost of disposal because waste management is expensive. For example, wastes accumulated at Department of Energy sites over the last 40 years are mixtures of chemical and radioactive materials. It has been estimated that cleaup may cost up to $100 billion and take a minimum of 25 to 30 years. The U.S. cannot afford this. We have to reduce the time it takes to characterize these sites and asess our alternatives. We have to reduce the cleanup costs. And we have to provide treatments and technology that are legally defensible and that meet regulatory requirements.
We need to test and validate our scientific concepts, computer models, and advanced measurement and sampling technologies. We need to demonstrate and prove in-situ remediation techniques. This is why the United States is investing in long-term basic and applied environmental research and technology development.

These investments include the Molecular Science Research Center, the Environmental Research Center of Excellence and the Northwest Hazardous Waste R.D and D Center at the Pacific Northwest Laboratory. The Molecular Science Research Center is focused on understanding at a fundamental level how wastes, microbes and host rock interact to mobilize and/or transform important contaminants. The Environmental Research Center of Excellence is responsible for (1) establishing the scientific basis for waste remediation at all of the DOE sites and (2) producing bench scale remediation technologies. As part of this effort, three national user facilities are currently being developed: the Subsurface Experimental Research Facility, the Numerical Test and Evaluation Laboratory and a National Field Validation Site. The Northwest Hazardous Waste R,D & D Center is charged with developing remediation and characterization technologies.

SUMMARY

Nuclear waste management is the number one environmental issue facing the nuclear industry. We have developed extensive knowledge about the behavior of radioactive material in the environment and used this knowledge to develop technology for managing nuclear wastes. This knowledge and technology base is being used to help solve environmental problems associated with hazardous wastes. However, we still have a long way to go if we are to regain the public confidence in the merits of nuclear energy. Long-term investments in fundamental and applied research, and technology development are essential to regaining the public confidence and reducing the costs of waste management.

We have a sound technical basis from which to solve the environmental issues facing the nuclear industry. I am confident that by working together, industrial nations around the world will be able to develop the scientific knowledge and technology to safely and cost-effectively solve radioactive waste management and other environmental issues facing the nuclear industry.

原子力技術の人間論的展望
―― その思想史的位置づけの試論 ――

K・リーゼンフーバー

この会議では、原子力発電と燃料サイクルの様々な技術的また社会的問題が、議論されてきましたが、この発表ではこれらの問題に直接解決を与えようとすることでもなければ原子力の産業的利用の可否を究極的に判定することでもありません。この様な判断を下すのは、社会全体の共通な責任ですが、それを行うことができるためには技術・経済のデータが不可欠であると共に、原子力問題の全体的な展望すなわち人間にとってその意味を解明することが何よりも必要でありましょう。何故なら、原子力発電産業の目的の設定と実現の過程は、とりもなおさず人間の営みであり、人間がその電力を利用することによって原子力発電産業を自らの生きる環境の中に組み込み、放射性廃棄物を後の世の人間に残しているからです。そのために原子力産業の様々な事実と問題を人間を中心にしたパースペクティブの中に位置づけ、それらのデータを人間を尺度にして慎重に検討しなければなりません。

その際、原子力技術は、一方では、他のあらゆる技術と基本的に同じレベルにありますが、幾つかの理由で現代、特に注目され問題視されています。それは例えば、原子力のイメージが、その最初の利用、つまり軍事目的のための破壊的な利用から規定されており、またその産業的利用にも特別な危険性が含まれていると見なされ、更にこの技術は、その発見がすでに５０年前にさかのぼるにもかかわらず、現代でも、一般に最先端の技術と評価され、従って、近代的な技術開発そのものを象徴的に代表しているなどのためでありましょう。この意味で、原子力というテーマにおいて人間の技術的能力そのものの可能性やその価値と限界が問題となり、またその技術が自然界を変容させているため、人間の自然への関わりや自然そのものの意味が、新たに検討されるべきものとなっています。すなわち原子力問題が、人間と世界との関係という最も普遍的で、最も根源的な、哲学的で、しかも倫理的な問題を引き起こし、そのためにそれは世界観的な色彩を帯びているので、この問題は、一般社会の関心を引くばかりではなく、人間の情熱さえも動かす力を持っています。

人間と世界との関係は、１７世紀前半のデカルト以来、近世においては自立的主体である人間と、人間に対して単なる客体にすぎない自然界という図式で考えられてきました。すなわち、世界は、人間の科学的実験や探求という技術的支配に服従する物体世界として理解されてきたのです。人間の主体性と、物質世界との徹底的な区別や分裂は、近代自然科学の基盤を成していると共に、人間には自然物を自分の任意のままに利用できるという確信を与えてきました。しかし、人間の生きている世界ははたして、根本的なレベルで、この様な物質的な材料にすぎないのでしょうか。世界とは何かというこの問題は、自然科学の探求する領域をもはや全く越え出て、人間の存在理解そのものの問題であって、また近代自然科学の基礎づけという問題にもふれています。自然科学の分野では、今世紀の不確定性理論や量子物理学が、すでに研究者、つまり人間とその対象が不可分的につながり、互いに影響しあうことを示しました。哲学の方では、現代、デカルト的な主体客体分裂と、それに基づいている科学的認識にそった技術の理念は、人間にとって世界との根本的な関わり方ではなくて、かなり特殊的で派生的なものにすぎないことが明らかとなり、つまり人間がもともと世界内の存在者であり、世界もまた人間の生活世界であり、人間の優先的な関心という観点のもとで、認識され、取り扱われるということが理解されてきました。つまり人間は、決して単なる物体から成っているような世界の中に生きているのではなく、いつも何らかの意味で理解され、解釈された世界の中で、つまり人間全体のニーズ、希望、不安、意図などによって、パースペクティブ的に構造化された世界の中で存在し、動き、その様な世界の中で初めて自分を対象化する理性をもって科学と技術を営んでいます。私達の問題と関連していえば、没価値的な科学的認識も、人間全体と関わりのないような単なる技術的な活動も一切存在しないということです。自然のあらゆる認識と利用は、すでにそれに先立ったより全体的な世界理解と人間の自己理解によって根拠づけられ方向づけられているのです。世界との関わりを導くこの主導的理解は、確かに常に反省され、再検討されていますが、この認識は個別的な所与のように対象化されえないで、むしろ、たいてい反省されていない地平と背景として作用しています。そのため、その構造と内容を調べるにあたって、この根源的な世界理解や存在理解が形成されてきた思想史にさかのぼらなければなりません。従って、原子力問題の内に人間と世界との関係そのものがテーマとなるまで、この関係が現代人の根本的な理解を形作った思想史の中でどの様に考えられてきたかをまず吟味する必要がありましょう。その際、ここでは西洋思想だけに絞りますが、それは、現代の科学技術文明が西洋の歴史の内にその起源を持ち、その思想の産物なのだ

からであります。。

人間と世界との関係を思想史的に主題化すれば、まず世界、つまり自然観から出発すればよいでしょう。というのは、人間は自分のことを反省するより先に目前にある自然について考えているし、また、自分自身への実践的な関わりも外からつまり他物、自然を通して行われ、他において、その立脚点を持っているからです。それゆえ自然についての考え方が逆流的に人間の自己理解をも形成し、人間の意志的行為にもその目的を与えています.こうして、自然観は人間にとって鏡となり、また現実全体についての理解を一つにまとめるものでもあります。

自然観のこの様な普遍的で存在論的な役割が、最初に西洋の思想、なかでも哲学の原点である古代ギリシャ思想、具体的には、紀元前６、５世紀のソクラテス以前の自然哲学において展開されました。古代ギリシャにとって「自然」という言葉は、ただ人間以外にある物体をさすというよりも、世界内に変化し成長するものの全体をさしています。その意味で、日本語の「自然」「ジネン」、つまり、「自発的になるもの」に深い類似性を持っているようです。この包括的な意味での自然は、人間をも含んでおり、人間が自然の外に立ちそれを支配するのではなく、自然を基盤にし、また自然の範囲内でそれを模倣しながら技術的な発明と行動を行っています。こうして「自然」は、本来世界内的存在の全体をさしているので、それには規範的な意味が備わっており、自然の法則が、ある秩序、コスモスを成しているのです。そしてそのために人間が自然を変化させるのではなく、それをそのままで受け入れ、ストア学派でいうように「自然に従って」生きるべきなのです。こうしたギリシャ的な自然理解において事実的形而下学的物理的な意味での自然と、人間にとって規範的で倫理的な意味での自然が自然の最も根本的で存在論的な意味、つまり本性としての意味の内に結合されています。まさにその理由で、ギリシャ・ローマの世界において、そこでは技術的な発明が決して少なくはなかったのに、自由な技術開発やその産業的な使用は生ずることができませんでした。しかし、ギリシャ人が自然を存在論的なもの・規範的なものとして、多くの場合には、神的なものとしてさえ捕らえているにもかかわらず、彼らにとって自然は明確な理性的な構造を持つものとされ、人間によって理性的に探求可能なものと考えられています。この点ではおそらく、ギリシャ的な自然観は東洋的日本的な自然観と異なっており、それゆえ自然科学の発展に道が開かれてきたと思われます。従ってギリシャの哲学者達は自然という秩序の原理、つまり、自然の起源と法則、またその発展がいきつく目的を調べようとしました。この探求ではまだ実験が行われていな

いという点で、それは自然科学的というよりも哲学的な関心と方法によるものであったことがわかります。しかし自然を理性的に説明するにあたって、自然の諸要素や諸成分エレメントを探っていったので、この哲学的探求は自然学的な関心に導かれていたことは明らかでしょう。

さて、自然のこの理性的理解の試みを私達にとって肝心である原子力問題から見れば、大ざっぱに二通りの自然に関する思考方向が区別できるようです。その一つは、自然の機会学的唯物論的な説明であり、もう一つは、その目的論的本性論的な見方であるといえましょう。前者の見解は特に紀元前５世紀のデモクリトスに代表され、後者はプラトンとアリストテレスの説です。デモクリトスの自然理論によれば、自然、つまり存在自体は無限の数の「原子」（アトモイ）から成り、この真の存在者そのものとしてのアトモイは性質を持たず、ただ量的に、すなわち、形・大きさ・重さ・空間における位置づけによってのみ規定され、常に動くことによって互いに衝突したり、分離したり、結合したりしています。この唯物論的な自然観により、自然における変化は不可変的、つまり、不可分（アトモス）的な成分の、可変的で偶然的なつながりとして捕らえられ科学的な説明を与えられています。しかし、デモクリトスが全体を目的論的に秩序づけるような精神的な原理を認めずに、その原子論でもって人間の認識と心、また倫理までも説明しようとしたところに、プラトンとアリストテレスの批判が生まれ、彼らの目的論的な自然観が続くほぼ2000年、つまり中世末期まで支配的になりました。すなわち、アリストテレスは自然物のパラダイムを単なる物体にではなく植物や動物に求め、植物や動物の成長はそのものの本性から発してその完成を目指す自然本性的な努力や、エン・アルケイア、つまり、エネルギーによるとしました。従ってもともとエネルギーは意義や良さを持った秩序を築き上げる、目的論的に働く本性論的な力として理解されていました。要するに、プラトンとアリストテレスは精神的な要素を自然に対立するような形で捕らえずに、それを観念と言い、形相と言うような、自然物そのものを内的に構成しその意義をなす原理として捕らえ、究極的には自然の存在論的な秩序は神的な原理、つまり神に由来すると考えました。

古代ギリシャ・ローマの自然観は確かに近代の自然科学を準備しましたし、また、特にデモクリトスなどの原子論は１７世紀前半でガッサンディやボイルなどの自然科学者によって新たに取り上げられるようになり、現代の原子理論の歴史的な根源の一つとなりました。しかし、古代の自然観から直接に自然科学と技術的開発が生じなかったのは、すでにあげた理由、すなわち、自然を規範とみなすことのほかに、次の関連する諸理由によるこ

とでした。つまり、自然全体が静止的なすでに完全なもの、あるいは神々に満ちたものとさえ考えられていたので、技術的な努力にはそれを押し進める根源的な動きが欠けておりむしろその様な努力は自然の秩序を混乱させるようなものとして評価されていたのです。それに加えて、人間の使命は存在の永遠なる真理を観想するところにあるとか、また、古代後期には物質世界が悪とも思われ、物質と関わる肉体労働は奴隷の仕事として軽蔑されていたことなどがあります。このような自然観と、現代行われている技術的原子あるいは核分裂を照らし合わせて考えるならば、これらの間の対立があらわになってくるでしょうすなわち、原子力技術において自然に対する人間の支配が顕著な形を取り、人間がもはや自然を自分の基盤にするというよりも、あたかも自然の外の立場から自然の最も基本的な秩序、つまりその原子の構造へと介入しています。このような技術は、人間が規範としての自然から解放されたことや、人間の自由な主体性が発見されたことを前提としています

古代の世界観は西洋思想の第二の根本的要素であるキリスト教によって根源的に変容されました。ユダヤ教、また後のイスラム教と共にキリスト教は、世界が無から存在せしめられ創造されていることを強調しています。世界創造という教義には人間と世界との関係について測り知れない含みがあって、それは西洋思想史において次第に展開されるようになりました。簡単に述べますと、まず、世界は全面的に神の積極的な意志によるものであり、その表現でもあるため、あらゆるものが本質的に善いものであり、物質もまた神の美しさを反映しているのです。それゆえ世界はそれ自体で無意味な単なる材料ではなく、それに固有な尊厳と価値を持っているので、人間はその様な世界を意のままに乱用することはできないはずです。また、世界が神の計画、つまり神の創造的認識からできあがったので、世界は本質的に認識可能であり、世界内存在のこの認識可能性は科学のたゆまない努力を根拠づけそれに目的を与えています。また超越的純粋な存在、つまり神への関連づけによって世界内存在は象徴的な意味を含み、人間の理解を超越へと向かわせる力を持っています。つまり、世界創造という教義は物質世界の内に真理と意義がひそんでいることを保証することによって、科学的探求と芸術的創造力に道を示し、物質世界に対する人間の関心をわきおこさせるのです。人間の使命は、もはやギリシャ思想にあったように身体や物質世界を魂の牢獄と見なしそこを脱出しようとするのではなく、自然世界を通してまたそれと共に神に向かっていこうとするところにあります。同時に、世界が無から造られたというまさにその同じ理由に基づいて、世界はそれ自体では決して神的なもの、つまり、触れてはいけないようなものではなくなりました。人間の企画と働きによって形成されて

も良いような対象となり、人間の責任にゆだねられることとなりました。それゆえ、技術的な開発は自然に暴力を加えるというよりも、神の創造によるこの生成する世界をその完成へと導く創造的な行為と見なされることができるようになりました。今や人間の働きは、世界に含まれる可能性と萌芽的な意義を積極的に受取り、展開させることによって、神の創造的な働きに協力するようになります。人間のこの創造的力自体も、神が創造によって世界内的なものに与えられた力の最高の段階とみなされています。

創造という観点のもとで、世界観と共に人間の自己理解もまた深い変更を受けています。すなわち、人間の理性と意志に備わる創造的な力がうきぼりになることによって、人間はただ世界の中に世界の一部として位置づけられるだけではなく、世界を自分のものとし、それをその形と意味において形成し支配して良いようになります。物質世界に関する探求と作用はもはや物質から規定され、それにとらわれるというよりも、人間の自由な主体性の自己実現と自己表現とみなされています。そのために、例えば、修道生活のキリスト教的伝統においては、農業や手工業が生活に必要な苦労につきずに神への奉仕と人間に適した務めとして高く評価されているのです。人間が神の似姿として自由であり創造的に働く主体性を持っていると同時に、自分自身の身体を持ったものとして創造されているので、世界に属しており、アッシジのフランチェスコにみられるように他の被造物との兄弟的な連帯感を持っているのです。このように人間が世界を自分の場とし自分の生命を維持するために回りの自然物に頼らざるを得ないことから、世界は本質的に人間の住んでいる家やその庭という意味を受け持ち、人間の生命の前提と支えにもなるようになります。世界は本質的に人間に奉仕するためにも存在しているので、人間がそれを自分の必要に従って、また人類の真の発展を目指して使って良いということです。しかし世界という美しい庭がもともと神のもので、人間にそれを手入れし育むように任されただけの話なので、人間は神の前そして同じ世界に今生きこれから生きるであろう人間同士に対して責任を持っているのです。すなわち、人間はこの世界を多くの人間が共に生きるに相応しい場としなければなりません。環境の破壊や資源の乱用は従って自然の本性に反するものであり、人間同士と神の創造に対する人間の責任に背くものでもあります。

まさにこの様な人間と自然との間の対立が、聖書では人間の罪から生じると言われています。罪によって人間と自然との間の本来的な調和関係が潰れ、つまり、人間が楽園から追放されるようになり、世界の資源を勝手に利用する傾向に走りがちであると共に、世界もまた人間のためにはもはや実を結びたくなくなります。結局、人間と自然とは緊張に満

ちた対立関係に陥ってきます。世界が人間の欲望と支配欲で辱められながら、また、人間にとって誘惑と危険性に満ちた場へと変わってしまった限り、人間だけではなく自然世界も罪から影響されて、はかなさからの救いを待ち望んでいるとされています。

自然世界のはかなさと危険性また救いや完成に対する望みは、同時にキリスト教の終末的思想において表現されています。この終末的未来への展望は、原子力問題を巡る論争の中にも少なからぬ役割を果たしているようです。それは、この未来に向かうパースペクティブが人間の心の内に眠っている最も深い望みと不安に声と形を与えているからでしょう。すなわち、終末思想とその黙示文学的表現形態は、一方では高まってきた対立と苦悩、戦争と自然世界の破壊や消滅を暗示することを通して世界と人間の力の限界、その究極的な行き詰まりをイメージを持って強調し、最終的な災いをさえ指摘している限り楽観的な進歩思想や世界の自然的な均衡状態に対するおおらかな信頼に区切りを打っています。他方、同じ終末思想は、神が自然の含んだ全世界に究極的な完成を約束しているということで、人間の自然世界との共通な部分を越えてあらゆる限界を越えさせる希望を与えています。

今まで取り扱った西洋思想の二つの主な柱、すなわち古典古代思想とキリスト教思想に含まれる様々なモチーフは近代的科学技術を根拠づけることに貢献したし、また同時に現代科学技術の使用に対する批判にとっても一つの出発点でしょう。しかし、近代の技術開発が生まれるために、中世の形而上学的な自然観から近世の経験的な自然科学への移行がまず行われなければなりませんでした。すでに１４世紀から始まる１７世紀に至るまでアリストテレスの形而上学と自然学は運動の説明という問題を中心に批判され、物の性質と本性を要にしたアリストテレスの理論から最初は目的因性、つまり物に内在する意義と目的へのダイナミックが否定され、物体が世界の全体的な秩序への目的論的な関わりを持つのではなくて、盲目的な衝動で動くと考えられるようになった。次に、物体の本性が人間にとって不可解なものなのでその本質は単なる延長にあるとされて、そう考えることによって自然物を量的数学的に計ることができるということが発見されました。それ自体で価値も本性も持たないとされた個物は対象化され、つまり人間とその生活世界から切り離されて人間の問題設定に従って実験によって分析され、また、技術において人間の目的に従って新たに構成されるようになりました。このように自然に対する人間の支配が科学的知識と技術的産業によるものとして解釈されてきたので、自然が人間の機械学的な働きかけに服従するものとなりました。この科学的方向が大きな成功を治めたのはいうまでもありませんが、同時に人間は、自分が自然によって条件づけられ自然と本質的につながってい

ることを軽視し、人間をただその知的意識と自由な意志を理解して、また人間と自然、主体と客体を包括し互いに方向づけ合うような基盤と規範を無視して、つまり根源的な存在理解に対する忘却に陥ったといえましょう。

核分裂の産業的な利用が現在注目と批判を引くのは、おそらく核分裂反応の技術はその構造から見れば近代的な自然観と近代的な自己理解を典型的に実現しているように思われているでしょう。核分裂技術にはそのように程度の極めて高い象徴的な意味が認められる。つまり、そこで自然への分析的なアプローチが知識にとどまらないで技術的に徹底化され、また人間の自然に対する距離 —— 放射線に対する防衛の問題、また人間の生活範囲からの自然の追放 —— 放射性廃棄物処理の問題 —— などが直感できるほどの具体性を持つに至り、同時に人間と自然のこの区別の困難と限界も、つまりこの様な技術的取扱いを受けた自然物に対する人間の不安 —— 安全の保証 —— という問題も具体的に感じられます。

これらの問題が現在切迫した形をとっていることのもとにも、思想的なモチーフが伺われます。すでに核分裂反応や地球の資源の限界が発見される前に、つまり今世紀の２０年代あたりから哲学や文学において自然科学的な思想形態の限界が指摘され、それより本来的な世界理解と人間の自己理解が求められてきました。すなわち、人間が自らの身体性、世界内性、環境に対する依存性などを省みて、自分の主体性の限界を主題としました。また主体客体の弁証法的逆転で、自然にあてはめた考え方と行動パターンがまた人間自身に逆戻りして、つまり主体と客体を全面的に切り離し人間が自分を絶対的な主体としてとれる試みは挫折したことが様々な体験、学習を通して学ばられなければなりませんでした。原爆もその一例だと言えます。すなわち人間の自然に対する根本的な態度は、自分自身や他人に対する捕らえ方と本質的につながっていることは明らかとなった。人間の新しい理解と世界との正しい関わり方の思想的な基盤とパラダイムは現在ではまだ確立していないので、極端な反動、またイデオロギーが生じやすい状態でありましょう。この様な状態に向かって、おそらくまず科学研究と技術に対する現代の私達の責任を確認する必要があるでしょう。そのため思想的な展望を踏まえた上で、これから原子力の産業的利用に関わる幾つかの倫理的な基準を立ててみたいと思います。その様な原理的な考察は原子力発電産業の可否を簡単に解決できるものではないし、ここで展開するやむをえずに抽象的な思想定式、具体的な技術的経済的政治的なデータを入れても結論が必ずしも反論を許さないほどの明確さを持って出てこないということを初めからことわっていたいです。この様なた

いへん複雑な問題に関して、宗教、キリスト教からも簡単な即答を期待できないので、逆に原子力の使用を絶対的に無分別に支持することも、同じようにそれを絶対的に拒否することも、つまり、原子力問題を一つの信仰箇条であるかのようにみなすというような素朴な態度を克服する必要がまず先決でしょう。この様なイデオロギー的な捕らえ方を避けて私達が本質的に新しくて見通し難い状況に向かっていることを認めた上で、どの様な方策が正しくて人類のためになるかを社会全体の共通な識別を尽くして検討しなければなりません。

まず問題を正確に定義しなければなりません。問題となるのは原子力を発電のために使用しても良いかということではなく、どういう材料と技術でもって現代社会に必要なエネルギーを最も良い仕方で給油できるかというより広い問題なのです。こう見ますと原子力は他のエネルギー源と同じレベルで問われ、同じ基準で判断されるべきであることは明らかとなります。

この問題提起の内に前提となっているのは、現代社会にとって経済的で長期的で充足的なエネルギー給油が基本的な正当なニーズの一つである、将来にもその必要量を大幅に削減できないだろうということです。確かに十分なエネルギー給油は現代に経済の維持と発展、それで高い採用率、社会的経済的安定、大衆社会における人間に相応しい生活の保証も第一条件でしょう。

この人間に相応しい生活を可能にするところにエネルギー研究とエネルギー産業の唯一の目的と基準があるのは、私達の問題に関して最も基本的な倫理的な原理でしょう。つまりそれ自体で意義を持つものとして中心に置かれるべきなのは、自然世界の保存でもなければ、科学・技術・経済の発展でもないのであって、人間の全人格的発展のみなのです。ですから、自然科学技術、経済が人間の全体的な発展に貢献するその限りで科学・技術・経済の使用と拡大は倫理的に正しいのです。結局、科学・技術・経済は人間のための手段にすぎないので、それらのものの持つダイナミックそれ自体はその発展の支配すべきではありません。それらは人間の営みであって、また人間に影響を及ぼすので人間の福祉を規範として考えるべきものなのです。技術・経済などは人間をその人間性において人間として助けるはずのものなのに、それらはただ特別なグループだけではなく、社会全体、ひいては人類全体のために、つまり社会や人類の共通善のために存在しています。また、人間が非常に多様的な存在なので、生活の人間らしさがただその経済的物質的な裕福だけから判断されるべきではなく、量られるべきではなく、何よりも社会的な、また精神的な価値、

例えば、平和と自由が規範として認められるべきでしょう。人間の様々な価値の内に生命と健康が他の多くの価値の実現、つまり人間の自己実現にとってその可能根拠になっているので、生命と健康の保存と促進、例えば、飢餓や病気の克服は社会的なレベルで第一に優先されるべきものであって、それに被害を加えるものが何よりも避けるべきです。そのために特定な技術や経済のもたらす利益とリスクを比較検討する時に、人間そのものにとっての利益とリスクが決定的な要素であって、その単なる技術的また経済的な利益とリスクには人間は選択に対する究極的な批判性を認めてはならないでしょう。

しかし、人間が自然世界の中に生き、また自分自身も生物的な生命を持って自然世界と共に生きているから、人間の尊厳の保証は同時に自然環境と自然世界全体の保護を要求しています。その際自然の意味は人間にとっての単なる手段に尽きません。むしろ人間が自然によるので、自然自体には無条件無制限的ではないにしても何らかの守るべき尊厳が備わっていて、人間によって勝手に取り扱われて、あるいは破壊されてはいけません。他方、自然界の再新生化や神話的な絶対視またはタブー化も自然界の真の在り方に対して根本的にずれています。すなわち、人間自身も自然な存在者なので、自然そのものが人間の内にその最高の尊厳を獲得し、従って、人間によって人間の尊厳をより良く実現するために使って良いものです。そのため、人間は自分の人間らしい生活と発展のためにそれが有益や必要と思われる限り、自然界に影響を及ぼしその資源を利用しその生存領域にさえも介入して良いはずです。しかし自然界は限られており、また人類全体の生きる場なので、その所有と利用は人間個人、あるいは特定なグループの特権ではなく、根本的に社会、また人類全体の共通な権利なのです。

資源の大部分は人間によって再生不可能であり、また動物世界の豊富な多様性とその生態学的均衡状態が人間によって新たに造られるものではない以上、可能な限りでの保存は一つの重大な課題です。その環境保護は生存領域から始まる、綺麗な空気、水道、土、自然の景色の保存まで及びます。こう考えてみれば、人間の尊厳に対する尊重と自然世界の保存という二つの不可分的な課題は長期的なスケールで考えられるべきものであって、つまりこれから生きるだろう世代に対する責任を私達に負わせるのです。すなわち、私達はただ現在の必要性に目が奪われることを避けて、未来の世代の人間らしい生活に必要な自然環境、資源などを配慮すべきです。ただし、現代の大きな困難の克服と未来のための資源などの保存が相入れない場合には、現在の大きな必要性を優先しても良いように思われます。自然環境の保護などは社会の程度の高い裕福を前提とし、それ自体もまたエネルギ

一給油によるし、また科学の更なる発展によって新しい環境にあまり負担を負わせないような開発が必要なので、技術の開発と自然環境の保護が平行してつながっている問題でもあります。

未来に対する責任という観点から見れば、原子力発電産業は二つの対立的な側面を表しているように思われます。すなわち、一方、原子力の産業によって化石によるエネルギーの資源 —— 石炭・石油・ガス —— の使用を節約し、それを第三世界や未来の世代に残すところに大きな業績があります。また、化石エネルギー資源による空気と土の汚染、いわゆる「温室効果」を減少することができるのも、原子力発電の長所と評価すべきです。他方、放射性廃棄物の処理は、そのたいへん長期な危険性のために原子力産業の最も大きな問題だと思われます。様々な技術的な利益だけではなくそのリスクをも十分に検討し、一般社会の人々に正確に説明し、その克服に必要な研究を極力で押し進めることは、科学者をはじめその技術に関わるエコノミスト産業家の重大な責任です。同時に原子力産業に携わる責任者は、常に必要な研究を促進し、技術的な発明を人間社会の福祉のために生かし、すなわち、単なる経済性という視野を社会全体の人間らしい生活可能性というより根本的な目的まで拡大することに基づいて、その目的のために常により良い技術を産業のプロセスに組み入れなければなりません。それより技術的に可能である、経済的により優位な方策であっても、それは人間の生命や健康に関して、また生態学的に責任が取れる以上に危険なものであれば、その様な新しい技術の産業的な使用を放棄せざるを得ません。もちろんどんな技術にも有限的な世界における生活そのものに常に危険が含まれているから、これもその危険の程度の問題と他の危険との比較検討の問題に他なりません。しかし、技術的にできるということと、実際にそれを実行に移すということは直接につながらなくて、その問いには人間全体の幸福に対する責任、その責任に基づいた識別と決断が置かれていることは重大なことでしょう。今まで述べてきた考えは科学研究を不当に制限することにならないのは言うまでもないでしょう。確かに、学問、科学は、その自らの領域内にその研究の目的や結果が人間の尊厳と生命に大きな害を与えない限り、自由で自発的な探求によって新しい分野を開発し、新しい可能性を解明して良いはずです。その意味で科学的認識や技術的能力そのものは倫理的な意味で善でも悪でもなく中立的であり、その倫理的な価値づけは人間がこの知識と能力をどの様な目的のために、また、どの様な仕方と効果を持って使用するかということによるのです。しかし、この多少抽象的な見方にとどまってはならないでしょう。というのは、研究そのものは研究者によるものであり、研究の目的

を自由に選ぶ問題と手続きを設定し、可能な結果をある程度期待、予想し、またその研究のために社会の資金を利用する、その研究者という人間が実際に存在し、その研究者や産業家に人間として自分の研究や産業的営みを人間的な目的連関全体の内に位置づける責任があります。その責任を避けて技術や科学研究が自動的に自らを調整するだろうという考えは、空虚な思考にすぎないと言わざるを得ません。

他方、一般の社会の方からは現代の生活、従って人間に相応しい人類の生存の可能性が、科学技術の発展によって支えられており、科学と技術の開発なくしては、知識を向上し、世界中の病気と飢餓を克服し、職業と収入を保証し、自然環境を保存し、第三世界を援助し、創造的生活の形態を拡大する、そのすべてのことが不可能であることを全面的に認める必要があります。つまり、一般社会は科学と技術、またそれに基づいた経済を連続的に承認して、その発展を支持し、そのために必要なある程度の信頼を与えるべきでしょう。

同時に、ある技術の経済的産業的使用が単なる中立的な手段にとどまらないでそれ自体が人間の生活と環境に影響を及ぼしていけばいくほど、それらの技術の選択、採用に関して社会全体の賛同が必要とされるし、社会そのものが民衆的な問題解決の手続きを通してその選択、決定のプロセスに能動的に与かる権利を持っています。「社会全体」「民衆的と言えば、この様な社会的な共通な識別と選択は、十分な情報購入と意見交換を必要とします。また、最終的な決断に関して様々なグループが自らの見解が過半数のそれとは違った場合、民衆的な方法で社会が至った結論を受理すべきです。社会全体には、どの様な環境の中で、どの様なまたどれ程のリスクを受けて、どの様な価値順位のもとで、生活に営みたいのかを決める権利があるからです。社会の中で、また、相対立する立場を主張する諸グループの間で真実でオープンな対話をできるために、それに必要な雰囲気と両側の意志を造らなければなりません。つまり自分側の意見を支持する様々な理由を正直に説明すると共に向こう側の見解を真剣に理解しようとする態度、また、単なる権力や暴力をもって自分の意見を通したり、向こう側の真実を疑ったりするような態度が初めから放棄すべきでしょう。そのために、産業化世界では一般社会の信頼を得るためにも、あらゆる新エネルギーの研究を金銭的にも支持する態度を示し、例えば、この様な研究の促進を目的とする独立した財団を設立、また援助する、あるいは発電産業にあたって、ただ一つの技術によるのではなく多様で柔軟なアプローチを取り将来の新しい技術的な可能性を積極的に受け取ることができるような組織を造ること、また、保留なしに十分な情報を公表するなどは、社会の中の対話を進めるために有益でしょう。

すでに申し上げたように、どの様な技術とエネルギー源を優先させるべきかということは、宗教、哲学、倫理学の一般的な原理だけでは十分に答えられるような問題ではありません。技術とその産業的な使用には常に二重の結果が伴うので、より正しい技術を選択するという問題を利益とリスクを量り合って比較検討するによって結論へと導かなければなりません。比較検討という倫理的な原理は、ある問題追求に伴う、それ自体では望ましくないネガティブな副次的な効果がただ次ぎの条件のもとで許されるべきである。すなわち、この副次的効果を起こす行動を放棄するならば、望ましくないこの副次的な効果より大きいネガティブな効果が起こるという条件なのです。すなわち、ネガティブな効果がより少ない行動の方が優先されるべきです。比較されるものの価値は違った次元、例えば、技術、経済、社会、政治、また人間の生活に即しているところにこの価値の比較の困難さがあって、また責任をとった思慮深い考察の倫理的課題もあります。比較検討に基づいた判断は、必ず一種の価値順位を表現しているからです。この量り合いの内に人間に相応しい生活と直接に関わる価値、また、それを脅かす危険が特に重大視されるべきことは言うまでもありません。また、この様な判断は一般的な倫理的な原則から厳格な論理を持って帰結されないから、価値の優先の内に人間や社会の自由な理解が正当にも形を取ります。例えば、経済的な利益による生活の裕福の程度と自然環境の保護との比例、許されると社会によって判断される危険性の種類と度合いなどは、ある程度で社会の自由な選択にもよることはさしつかえません。

その比較検討、比較評価にある程度の自由を認めてもその基準はポジィティブな面、つまり目的から見れば、社会又、人類の共通善をなるべく高揚することであって、それを実現する為に偏見に促らわれていない賢明な判断が最も必要でしょう。　又、他方ネガティブな面つまりさけるべき危険から見れば比較検討では、人間の存在とその全人格的発展をさまたげておびやかす技術が許されるべきではありません。エネルギー供給は、人類全体の共通の問題で、各国の国境内には解決不可能なものなので、解決を求めるに当たって、各自がただ自分の国の利益だけを目ざしてはならなくて、視野を、世界全体の共通善までも拡げて、その枠内に第二のものとして自分の国の発展を考えるべきでしょう。具体的に言えば、人類の共通財産である空気、水、気候などは人間の生命を可能にするその条件であるから、それらのものの充分な保存は第一に目ざすべきものでしょう。次に、限られていて再生不可能な資源、また特に、多様な目的に使用できるような資源ー例えば、化石によるエネルギー源ーの使用をなるべく節約し、それを第三世界また将来の人類全体に譲ることが望ましいのです。

地球と人類の未来に対する最も重要な責任は同時に比較検討のネガティブな基準つまり危険はさけるべきであるということに関わっています。現代知られている技術の内に、原子力技術は、リスクが最も大きい技術のひとつであることは一般的に認められています。確かに、この技術を安全に取り扱うことは可能ですし、又、日本の原子力技術産業は現在までのその実績をみますと、この安全な取り扱いの優れた一例だと言えます。しかし、ドイツのビブリスなどの最近の事件が示すように、予想しなかった、あるいはできなかったリスクが、複雑な技術に本質的に備わっていますーどんな技術でも、ただ原子力技術ということだけではありません。つまり、リスクがないような人生は存在しません。原子力産業の安全の内に、その技術を利用できる人間自体によるリスクをも減らすことができても、それを排除することはできません。また原子力関係の大きな事故の場合、それは人間の生命、健康、遺伝という最も重大な遺産に影響を及ぼします。このような影響は、事故が起こった国の国境には留まらなくて、周りの国までもひびいていますから、原子力使用の安全は、国際的な問題であって、安全の基準とその実現の保証に関して国際的な協力と協約、またその実行の監視が必要と思われます。このような安全な使用の保証は、ある程度すでに始まったようです。その完全な実現は、おそらく遠い未来にしか見えないでしょう。この意味で、原子力技術に備わっている危険性は小さくないと言わざるをえません。

もうひとつ、放射性廃棄物の処理の問題ですが、燃料サイクで廃棄物を、ある程度消滅できますが、残っている廃棄物は、計り知れない程遠い将来までも生命にとって、危険です。

そのことは、人類の今までの文化が一万年余りにすぎないのに対して、放射性廃棄物の危険性は数万年に存続することを考えれば、明らかでしょう。

その為にマイクロ次元から危険な放射性がない、あるいはもっと少ないエネルギー源と技術を発展させることが差し迫っている課題でしょう。結局、どんな技術にもその限界があって、それより良い、より安全な技術によって克服される可能性がありますから、どの技術も暫定的なものであって、より良い技術のための予備段階でもありましょう。最近話題になっている低温核融合が核分裂に代わり得る技術であるかどうか、まだ判断不可能でしょう。しかし、一般的に言えば、原子力技術を代用することができるエネルギー技術を捜さなくてはならないでしょう。

そのような研究を積極的に押し進めることは、原子力産業自体の課題でもありましょう。例えば、そのような研究を促進する独立した研究財団の設立と経済的援助などは考えられるかも知れません。またこのような手段をとることによって、原子力産業は、一般社会の信頼を得て、この問題を巡る社会的対話に於いて真実な話し合いとして認められるでしょう。つまり、真実な中立を示し信憑性を得ないと、真剣な対話が不可能となります。そうした場合、問題の解決は対話とは別な非民主的な手段に、例えば暴力などに求められないとは限りません。

しかし、現在のところでは、素人の私に見える限り、原子力にとって充分に代わることができるようなエネルギー源が、私たちにまだないので、原子力産業はおそらく、これからの数十年にわたって不可欠である。そうだとすれば、またその限りで原子力技術の責任ある発展と使用が、人類の共通善に貢献するものだと判断できるのではないでしょうか。