POWER REACTOR DEVELOPMENT STRATEGIES IN THE UNITED STATES

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Strategies of the U.S. organizations that are developing and marketing light-water reactors and gas-cooled reactors are outlined. Probable enrichment policies to back up U.S. reactor sales are mentioned. Reviewed are environmental considerations and the need for technical information exchange and expedited nuclear standards development. Predictions concerning progress in U.S. fast-breeder reactor development are made.

Introduction

The basic strategy of the developers of nuclear power reactors in the United States is to dominate the United States market and be the major suppliers of nuclear reactors to the world.

Strategy implies the existence of an adversary — in this paper I consider the main adversary to be the markets of the United States and the world and secondly, the improvement of our knowledge about how nuclear reactors should be designed for maximum economic benefits to mankind.

Frequently one unconsciously employs a strategy and shifts the original direction of the strategy to best fit the changing target. No organization willingly tells its own strategy. Therefore, economic and development strategy are frequently best reviewed and interpreted by one who is familiar with the developments while at the same time not directly or commercially involved.

That is why, as Secretary of the American Nuclear Society, I have been asked to give my personal views on the approach and development strategy being used by the United States in the marketing of power reactors. These views and opinions are my own and are based upon my personal observations, contacts, and information from the published literature. Almost all of the information in this paper has been

published in some form in Nuclear News or in papers given recently at the Geneva conference on "Peaceful Uses of Atomic Energy", held September 6–16, 1971, and in the Fast Reactor Conference held at Aix-en-Provence, France, September 2–4, 1971.

In this paper I shall cover briefly the development strategies of U.S. organizations as they apply to:

1. Light water reactors,
2. Gas-cooled reactors,
3. Fast reactors,
4. Enrichment,
5. Environmental considerations,
6. Information exchange,
7. Nuclear standards.

In conclusion, I will, as I see them, list some of the long-range plans and concepts associated with power reactors.

1. Light water reactors

1.1. General survey

The predominant commercial reactors that exist today in the U.S. are light-water reactors (LWRs) consisting primarily of pressurized-water reactors (PWRs) and boiling-water reactors (BWRs). The

LWRs committed throughout the world and under construction account for approximately 120 000 MWe of which about 100 000 MWe has been committed in the United States. Unit sizes currently run about 1100 MWe. Present reactor technology does permit the construction of units up to 2000 MWe.

While LWRs are expected to take the major share of nuclear base-load capacity in the United States, there is naturally some concern by the LWR manufacturers about the recent strong entry of the high-temperature gas-cooled reactor systems in the commercial markets.

In large unit sizes, LWRs have achieved economic parity and in many locations have an economic advantage over fossil-fired stations. Standardization of many components and multiple orders will continue to make LWRs very competitive. Increased reliability of nuclear units throughout the world have helped to give nuclear power a favorable position in the United States market. Licensing and regulatory procedures, while somewhat lengthy at the present time, are expected to lengthen and then shorten as more nuclear and environmental standards become available and are required by licensing and regulatory agencies.

1.2. Core performance design

Light-water reactors have attained increased power ratings as suppliers increase the physical size of the equipment.

The very favorable operating experiences of LWRs has encouraged designers to increase power density modestly. LWR fuel elements of the future also can be expected to yield 15 to 20% more energy than current designs. Burnup levels for both PWRs and BWRs have demonstrated reliability at value of approximately 27 000 to 30 000 MWd/MTU. Steam pressures for both BWRs and PWRs are approximately 70 atm. While there is some slight variation, further increases in steam pressures in both systems are considered possible though not necessarily economic at this time.

1.3. Plant simplification

Plant simplification over the next 10 to 20 years is expected to reduce capital costs of light-water reactors. Standardization of large major components and auxiliary units and the use of pre-assembled and

tested modules will decrease field labor and capital investment costs. Computer-aided plant monitoring will prevent meltdown of fuel elements as occurred several years ago in the Fermi reactor located near Detroit, Michigan, U.S. It is now realized that computer-based automatic sensing units could have detected the high temperatures in the Fermi fuel elements and could have prevented meltdown of these elements in the Fermi reactor.

1.4. Licensing procedures

US AEC licensing procedures have tended to become slower and more agonizing in recent years. Recent court decisions concerning environmental matters will cause further delays for a few years. Nevertheless, increased standardization and increased experience in the operation of reactors is expected to cut the licensing time for light-water reactors considerably. Newer, more advanced concepts will require more detailed review in the early stages of development. On an 1100 MWe electrical plant, any delay—including those caused by licensing procedures can cost a utility approximately \$50 000 000 per year.

1.5. Economics of light-water reactors

Light-water reactors, especially in large units (1100 MWe), now dominate nuclear power sales because in many areas larger units can produce electrical energy more competitively than alternate fossil fuel or hydro sources. The recent concern throughout the world for environment protection undoubtedly will increase the capital cost requirements of all electrical energy plants. However, the effect of these increased costs for environmental protection probably will place the nuclear plants in a more favorable competitive position compared to fossil-fired plants. LWR reactor designers have constantly and continuously lowered the release of radioactive gases and liquids to limits that are below one percent of the acceptable limits approved by the US AEC and based upon recommendations of international radiation protection groups. The thermal efficiencies of nuclear plants over the next ten years surely will be improved and possibly will excel the most efficient fossil fuel plants of today. The public is becoming increasingly aware that so-called "thermal pollution" is associated with all types of thermal energy plants.

Maintenance cost and operation expenses now constitute less than 10% of the total generating cost of light-water reactors. Some lowering of costs can be expected and in fact is anticipated and provided for in the economic evaluations of LWRs over the next 10 to 20 years. Continued safe operation of the plant also is expected to lower the cost of nuclear insurance.

Fuel fabrication costs are expected to decrease and, in my opinion, and those of many utility managements, no shortage of uranium or other nuclear fuels is anticipated over the next 30 years. While uranium prices might go up, this is not a major competitive factor in power generation costs. Utilities are well aware that fossil fuel prices have climbed sharply in recent years. Many utilities are required to switch to low sulphur fuels which are higher priced and not available in sufficient quantities for the long term.

1.6. Future market for LWRs

LWRs currently dominate the market for nuclear electric energy production. Some authorities believe that LWRs will continue to dominate the market. This probably will be true for the next 10 to 15 years. After that, advanced technologies and improvement in high-temperature gas-cooled reactors and liquid-metal fast-breeder reactors will gradually decrease the importance of LWRs in the U.S. market. The effect of these technologies may not be apparent for all reactor manufacturers and utilities to be aware of these newer type of reactors and to follow their development closely.

At any one time a major U.S. reactor manufacturer may have as many as 50 possible clients for a reactor, but a sale may take 4 to 6 years of intensive work and education of the client.

In the next 30 years the U.S. is expected to install about 1 500 000 MWe of new electric generating facilities. If half of this is nuclear, the U.S. will need to build about 800 plants of about 1000 MWe capacity. Over a 30-year period this means 25 to 30 plants per year — a rate higher than the 1971 rate of sales of about 18 plants. Of these 800 plants to be built over the next 30 years, I estimate about 600 will be LWRs. (The US AEC estimates 1000 nuclear reactors of 1000 MWe will be needed in the year 2000). This LWR market in the United States

apparently will be shared by Babcock and Wilcox, Combustion Engineering, General Electric and Westinghouse. The role of Atomics International appears to be associated with sodium technology and the fast breeder reactor. Any participation in this U.S. market by a manufacturer outside of North America probably will need to be in conjunction with one of the firms I mentioned. I understand the same is generally true when any U.S. firm tries to sell outside of the U.S. market.

1.7. LWRs and the breeder program

Fast breeder reactors probably will be introduced in the U.S. on a commercial scale in the late 1980s. While some writers have been warning of possible plutonium shortage to fuel these fast reactors, I personally feel there will be adequate plutonium available at the time of the introduction of commercial fast breeder reactors. Weapons-grade plutonium certainly would be used for commercial purposes if necessary. For economic reasons, I believe, most of the plutonium produced over the next 15 years will be recycled in water reactors rather than put into inventory. Because the U.S. fast breeder development program has been delayed, plutonium will not be needed in any real quantity for 15 years unless the program is greatly accelerated.

2. Gas-cooled reactors

Until several weeks ago, gas-cooled reactors were not considered a major factor in the U.S. nuclear electric power market. However, all utilities and reactor designers are weighing the implications of the recent announcement by Philadelphia Electric Co., of Philadelphia, Pennsylvania, that it will buy two 1150 MWe nuclear plants of the high-temperature gas-cooled reactor (HTGR) type from Gulf General Atomic Corporation (GGA). Philadelphia Electric has had excellent experience with the 40-MWe Peach Bottom HTGR (near Philadelphia) since 1967. The performance of this HTGR plant has undoubtedly been the major factor in Philadelphia Electric's decision to build two large commercial units.

A 330-MWe HTGR is expected to go into commercial operation in 1972 in the Denver, Colorado, area of the U.S. If the Denver plant works as well as the

Peach Bottom plant, HTGRs will make a sizeable impact on future reactor sales.

Based upon more advanced technology, higher thermal efficiencies and, presumably, better ability to cope with "thermal pollution" and radiation releases, these HTGRs will attract more and more attention.

Backers of the HTGR claim it has less effect on the environment than any other electric power generating system.

A very important economic factor associated with the HTGR in the U.S. is the fact that GGA is wholly owned by Gulf Oil Company — an energy company known to have considerable financial resources. GGA has demonstrated its willingness to make the HTGR successful and has put considerable resources of its own into the development and construction of the HTGRs near Philadelphia and Denver.

3. Fast reactors

The U.S. fast breeder reactor program is lagging, short of the funds necessary to make it as effective as it should be. According to some U.S. critics, the program is spending too much time on paper studies and testing instead of building a prototype demonstration plant. The utility industry after years of waiting for government funds to build the demonstration plant now seems ready to put up as much as \$300 million to help do the job. The mood in the U.S. Congress and the Executive Branch indicates that an additional \$100 to \$150 million or more of government funds may be forthcoming. The \$400 to \$600 million to do the job is being mustered. However, it is likely to take another year or two to get the FBR demonstration project moving.

President Nixon's appointments of James R. Schlesinger and William O. Dobbins to the U.S. Atomic Energy Commission are expected to help US AEC relations with the U.S. Office of Management and Budget (OMB). Dr. Schlesinger was assistant director of OMB and Mr. Dobbins generally is considered to have the respect of environmentalists.

It is estimated that loss of potential benefits is costing the U.S. \$1.3 billion for each year that the breeder is delayed. Program costs until recently were escalating at \$1 million to \$2 million per month. The question of building two demonstration plants

simultaneously in the U.S. seems academic at this time. The U.S. private sector of the economy generally concedes that building two demonstration plants will in the long run prove to be less costly to the industry. We know from experience that competitive design concepts for light-water reactors have indeed lowered costs and contributed to better designs. While the situation is not clear, I would expect two demonstration plants to be built — but not simultaneously.

To date the U.S. fast reactor program has emphasized "technical excellence along with exacting technical standards", in the words of Milton Shaw, Director of the U.S. AEC Division of Reactor Development.

Acquiring basic technology has been emphasized in preference to early construction. Whether or not this strategy will indeed develop a commercial fast breeder by 1986 remains to be seen. Certainly today the French, Russian, German and United Kingdom construction programs for fast reactors are ahead of the U.S. program.

Nevertheless, there is a very valuable and considerable body of knowledge available to the U.S. through its experiences with experimental breeder reactor No. II (EBR-II), the Southwest Experimental Fast Oxide Reactor (SEFOR), Fermi Atomic Power Plant (FERMI), the Liquid Metals Engineering Center (LMCE) and the Molten Salt Breeder Reactor. I think the United States will catch up with the other nations once we start putting the financial resources into the fast breeder program.

4. Enrichment

There is considerable discussion in the world press about the availability of enriched uranium to fuel the reactors now sold by U.S. manufacturers. As you know, the United States is very interested in increasing its exports of all kinds and this extends to nuclear reactors and the fuels to keep these reactors going. I can assure you that the strategy of the U.S. is to foster the development and sales of enriched reactors and to supply enriched fuels to our customers on time and when needed.

Certainly additional enrichment capacity will be required. While centrifuge methods theoretically look

promising, I believe the U.S. favors and has continued confidence in the economics of the diffusion process for the next 15 years. Relatively lower power costs in the U.S., Canada, The Congo and perhaps Australia give considerable latitude as to where a new diffusion plant might be located.

I would think the U.S. or Canada is in the favored position because of economics, access to capital markets, and political considerations. I believe the cascade improvement program (CIP) of the U.S. will be completed on time to meet increasing needs and that new diffusion plants will be built on time. The U.S. has already appropriated \$16 million for the CIP and for next year an additional \$35 million is recommended by the joint committee on atomic energy of the U.S. Congress.

5. Environmental considerations

Some of my very good European friends tell me that as part of our strategy we in the U.S. are "exporting" environmental critics to Europe to assure that local opposition to nuclear plants is at least equal to or greater than the opposition we encounter in the U.S. I think we all know that critics tend to travel worldwide and, as far as I know, it is not part of the planned strategy of the U.S. to encourage these critics to travel overseas — but of course, the more time they spend overseas the less time they spend at home. Besides we in the U.S. are bound to learn new techniques from you on how to best answer these critics if you have a little experience with them.

Nevertheless, I find many of the critics to be sincere, well-informed and helpful to nuclear energy. An attack on nuclear always attracts attention but soon the public begins to look at alternate sources of electrical power and discovers that "thermal pollution" is not unique to nuclear plants. In fact the public soon realizes that thermally treated water is quite good in hot coffee, tea or warm milk — and is considered a necessity for bathing.

It also comes as a great surprise to many to learn that, in addition to sulphur dioxide and particulate matter from fossil-fired units, there is on an average as much radioactivity coming from a fossil-fired plant as there is from a nuclear plant.

The general strategy of the U.S. is to build nuclear

plants with near-zero release of radioactivity and within 10 to 15 years to have nuclear plants at least as thermally efficient as the best fossil-fired plants. We are building nuclear electrical plants that have the minimum effect on the environment, and produce electricity at the lowest cost. This electrical energy in turn is desperately needed to help improve the industrial processes which have in some instances contributed to pollution.

The real polluter is man himself and without electric power to run his sanitation systems and produce improved products, man is lost in a morass of pollution. This is the story the nuclear critics are helping us tell the public. As the facts become known nuclear power becomes very welcome to the public. In the U.S. we are gradually putting the view of the critics in perspective and making it clear to the public that the nuclear business from its very infancy has been honestly concerned with how it affects the environment.

The most important court decision to date in the U.S. involving nuclear power in the environment occurred recently in the Calvert Cliffs case. Calvert Cliffs is the name of a nuclear plant on Chesapeake Bay in the state of Maryland near the Washington, D.C. area. A group opposing the plant on environmental grounds brought suit against the US AEC and claimed that "the rules recently adopted by the Atomic Energy Commission to govern consideration of environmental matters failed to satisfy the rigor demanded by the National Environment Protection Act (NEPA)". The court agreed with the critics and remanded the case for further rule making.

The court ruling will stand as a landmark not only for the nuclear field, but for other environmentally sensitive industries where government action is involved. The court argued "That in keeping with NEPA's requirement that agencies consider the environmental impact of their actions to the fullest extent possible", environmental issues must be considered at every important stage in the decision-making process, including the independent review of staff proposals by hearing boards.

The court also stated that the AEC must independently evaluate and balance certain environmental factors, such as thermal effects — notwithstanding the fact that other federal or state agencies have already certified that their own environmental standards are

satisfied. In reviewing the Water Quality Improvement Act of 1970 the court stated that the act does not preclude the Commission from demanding from its licensees water pollution controls more strict than those demanded by the applicable water quality standards of the certifying agency.

The court also stated that the AEC is to conduct a NEPA review, and take appropriate action after such review, for cases in which construction permits have been issued prior to January 1, 1970, but for which an operating license has not as yet been issued, and that such steps should take place prior to the normal time for operating license review.

The US AEC, in response to the court's ruling, stated that the US AEC will issue as soon as possible appropriate regulations to implement the court's decision. The US AEC plans not to appeal the Calvert Cliff's decision. The US AEC cautions that possible modifications may be required in environmental reports, especially with regard to thermal effects. Additional delays in licensing of nuclear plants affected are estimated generally at between six months and a year.

The AEC expects that the court's decisions will directly affect 61 licence applications involving 88 nuclear power reactors. Ten of these applications — seven for operating licenses and three for construction permits — presently are in the hearing process or nearing issuance of a license.

The Commission in its press statement about the ruling added, with a touch of irony perhaps, that "the nuclear power reactors directly affected by the court's decision represent a total electrical generating capacity of about 80 million kilowatts" — adding the perspective that "the current electrical generating capacity of the United States from all types of power plants is approximately 340 million kilowatts".

Last July, the U.S. Environmental Protection Agency (EPA) stated that the anticipated heat discharges from the Calvert Cliffs plant are not expected to violate approved federal-state water quality standards. In reviewing the environmental impact of the project, however, the EPA added that permissible Maryland thermal discharges are much higher than the limits established in most approved federal-state standards. The EPA said this was its most significant finding in examining the proposed

plant operations. The Maryland standards received federal approval in August 1967.

As you can see, for the moment things appear to be in a mess. It is clear that differences between state standards and federal standards for water and air quality control must be resolved and soon. In an earlier case involving differences between federal standards and more stringent standards proposed by the state of Minnesota, the court ruled in favor of federal standards. And now it is clear the US AEC has much greater jurisdiction over all aspects of nuclear plants and their licensing than it had previously assumed.

5.1. *ANS/AIF*

Two non-government organizations exist in the United States to help with public information problems concerning nuclear energy. These are the American Nuclear Society (ANS) and the Atomic Industrial Forum (AIF). The AIF regularly publishes "Info", a four to eight-page monthly report on what the critics are saying — how they are being answered — and what the current environmental issues are in the various geographical areas of the U.S.

The ANS has provided the information officer in each of its 35 local sections with a copy of a recently compiled "ANS Facts File on Nuclear Power in the Environment". This loose-leaf reference document gives him technical facts on various "public concerns" about nuclear energy and the environment and a short summary of the position taken by various critics. With this document and his own personal knowledge, the information officer is equipped to answer inquiries or rebut critics. Often the public information officer coordinates his activities and responses with public information services of a local industry or utility.

By early in 1972 the ANS expects to offer this "Facts File" for sale on a subscription basis. The revised Facts File also will be distributed to each of the ANS faculty advisors to 50 ANS Student Branches located in all the major U.S. universities.

6. Information exchange

Members of the ANS throughout the world have always promoted a quick, free, efficient exchange of

technical and scientific information through scientific conferences and technical publications. We know these exchanges avoid duplication of effort, and personal contacts foster the exchange of ideas which frequently speed advances in research and development. ANS sponsorship and participation in this Berlin conference is one example of our desire to exchange information.

Unfortunately in every country there are always "bureaucrats" who tend to impede technical and industrial progress. I sense the exchange of information in the fast-reactor field, the fusion field and centrifuge technology is suffering from this malaise, and I believe the United States is one of the major offenders in this regard. It may be that we are developing an inferiority complex in these areas.

The fact that countries outside the U.S. are making substantial advances in these and other areas does in fact help us in the U.S. to focus attention on your research and promote funds for our research. I am sure you use the same techniques at home — and this is the way we all make progress—hopefully for the benefit of mankind. In spite of some weaknesses, I believe our strategy in the U.S. is to exchange information as quickly as possible and I urge you, too, to continue to do so. We shall do our best to improve.

7. Nuclear standards

All of us recognize the importance of standardization and the savings we realize through standardization. In the U.S. we are even becoming aware of the metric system — so much so that the U.S. Congress has before it a recommendation of the Department of Commerce to make a gradual change-over in the next 10 years to the metric system. This change is expected to cost \$10 to \$40 billion.

I ask you in the nuclear engineering business: where do you go to find a nuclear standard — and if you want an international nuclear standard, how do you find it? The job is easy — only because in most instances few accepted standards exist. However, if you ask what standards are being prepared and what do the proposed standards look like — then you are confronted with hundreds of draft standards and recommendations.

The U.S. strategy on standards has been to produce as many as possible and to get them accepted industry-wide by general consensus and thereafter to recommend that some of these be considered international standards.

To get standards written and the information distributed, U.S. industry and the US AEC are supporting an Information Center on Nuclear Standards (ICONS) which is owned and operated by the American Nuclear Society. Your organization may subscribe to the Center and become quickly informed about which nuclear standards exist and which standards are being proposed. The Center publishes a monthly newsletter called Nuclear Standards News and furnishes library research services on standards.

In the area of international nuclear standards, the American Nuclear Society acts as the Secretariat under the American National Standards Institute for the International Standards Organization Technical Committee number 85 (ISO/TC 85) which deals with nuclear standards. In this capacity the ANS has direct contact with 42 nations participating in ISO/TC 85.

You can see that our strategy on standards is to try and develop standards as quickly as possible and to make this information available world-wide. The U.S. has published a list of 78 urgently needed standards and is working on all of them. For more information, we will welcome your contact at the American Nuclear Society.

8. Conclusion

In conclusion, I want to list some of the long-range plans and concepts associated with power reactors, as I see them.

The U.S. strategy for long-range developments of power reactors at this time seems to involve:

1. Continued development and improvements of LWRs and gas-cooled reactors so as to have minimum disturbance to the environment;
2. Development of a commercial fast breeder, hopefully before 1990;
3. Continued investigation of other concepts, such as the molten-salt reactor and the thorium-fuel cycle;
4. Development of power reactors for space propulsion and moon-based laboratories;

5. Continued studies and possible rejuvenation of an aircraft nuclear propulsion system;
6. Reactor siting concepts which involve floating islands and underseas installations;
7. Increased emphasis on nuclear reactors for naval and maritime propulsion;
8. Application of developed reactor concepts to

large agro-nuclear desalting and industrial manufacturing complexes;

9. Development of waste-management systems at the reactor sites to lessen transportation of radioactive materials; and

10. Rapid development of national and international nuclear standards.