D. NUCLEAR ISSUE PAPERS

1. Standardization

ISSUE

The present procedure for the design, construction, and licensing of a nuclear powerplant is time-consuming, inefficient, and costly. An ERDA-supported standardization program could allieviate these difficulties.

SUMMARY

At present, virtually every nuclear powerplant is custom designed and built by a combination of suppliers. This procedure leads to very complex interfaces between the various suppliers, the utility, and the NRC. The incomplete status of the design at the time the construction permit is issued (conditioned upon the resolution of incomplete design features) and the changing regulatory requirements result in many design changes, imposition of retrofitted systems, delays, and cost increases. Standardization is a potential solution that is not feasible in the present environment of fragmented responsibility and rapidly changing regulatory requirements.

ERDA could support the development of a standardized design of a complete nuclear powerplant for which the NRC would issue a "license to manufacture. " Participation by all concerned parties would ensure a high-quality design. The licensing review of the utility's application would be limited to site-related issues and would require only a small fraction of the present licensing time and cost .

QUESTIONS

1. Is ERDA willing to consider participation in a program to promote standardized nuclear powerplant design and construction'?
2. Are there significant antitrust issues involved in terms of specifying brands of pumps, valves, control systems, instruments, etc, ?
3. What are the advantages of standardization over present procedures if the latter were implemented more expeditiously?

BACKGROUND

When a utility decides to build a nuclear powerplant, it usually selects a nuclear steam system supply (NSSS) vendor, an architect/engineer [A/E], and a constructor, The NSSS designs are fairly well standardized by each of the four LWR vendors. The balance of the plant, which costs considerably more than the NSSS, is designed by the A/E. The A/E generally starts with a previous design and revises it depending on NRC requirements, utility preferences, and site requirements. The constructor (often the A/E) then builds the plant according to the NSSS vendor and A/E drawings. This is basically the same procedure historically followed for fossil plants. It results in a custom-designed and built plant, which then must be individually reviewed by NRC,

This fragmented approach leads to a division of responsibility and contributes to uncoordinated overall systems design. In addition, there are so many combinations of NSSS vendors and A/E's that the A/E may find all his projects quite dissimilar. If the A/E does have a prior design to follow, he may copy previous mistakes or otherwise fail to cut costs as much as possible because of the pressure of the schedule.

Standardization is a potential solution to these problems, but it has not happened yet for a number of reasons. The multiplicity of A/E's and NSSS vendors could make each combination a separate design. Technological advances leave previous designs outdated, but this process seems to be slowing, The largest roadblock of all, however; has been the NRC and its changing regulatory requirements.

At the time the utility submits an application to NRC for review, the detailed final design of the nuclear plant is generally no more than 10 percent complete, and it is usually less than 50 percent complete at the time that the construction permit is issued, This lack of a completed design leaves the utility extremely vulnerable to NRC-imposed design changes, which all too often involve ripping out a portion of the plant already constructed and replacing it at a significant cost and delay in the schedule.

Some of these changes are the result of oversight or the analysis of previously unsuspected but creditable ramifications of accidents, These changes should be incorporated into the designs if they involve a significant risk to public health and safety. Many changes, however, are attributed simply to new regulatory guides and changes in requirements that are applied retroactively,

Two years ago, the AEC announced a policy of supporting standardization. There have been a number of recent attempts to improve the situation—the SNUPPS group of plants (five virtually identical plants ordered by four utilities), the Duke Power Company "six pack" and the floating nuclear plant being put forth by Offshore Power Systems (OPS), Indeed, the NRC regulations were actually modified to provide a "license to manufacture" to OPS who will manufacture the FNP in a factory and then deliver it via water to the utility's prepared site, None of these concepts, however, has enjoyed the full anticipated benefits of standardization, particularly in regard to the licensing process,

One possible role for ERDA would be to support the complete design of a land-based nuclear powerplant through the whole licensing process, including the issuance of a "license to manufacture," and then to offer it to all interested utilities for a prorated fee, based on the projected number of users. If the design is carried out with the input from a number of utilities who are interested in proceeding with the project, it should represent an acceptable design, Indeed, the possibility y of saving up to 3 years in licensing time (especially if a procedure for preapproving sites is also implemented) would be so attractive to a utility that prudence might dictate that it accept such an approved standardized powerplant.

The principal advantage of this arrangement is that the design, once approved for a period of time, would be subjected only to those changes which have a significant impact upon the health and safety of the public. As a result, the financial exposure of the utility would be minimized, since it has only to secure the approval of the site via the environmental and site suitability hearings.

2. Performance and Reliability

ISSUE

Problems relating to the performance and reliability of light-water reactors have received insufficient attention since the AEC ceased nonsafety light-water reactor R&D.

SUMMARY

Until the late 1960's, substantial governmental research work was carried out on light-water-cooled nuclear power reactors. At that time, the AEC decided that LWR's had reached commercial status area. Following that decision, a number of problems developed. First, the nuclear industry has been slow to see the need for and to initiate extensive R&D efforts of its own. Second, increases in reactor power levels greater than those warranted by existing technology resulted in component performance and reliability problems. Third, continuous AEC tightening of safety-related design criteria and operating restrictions over the past 6 to 8 years has resulted in economic penalties and reduction of plant operating flexibility. With respect to the first two problems, it is noted with approval that ERDA is planning to renew governmental support of R&D aimed at improving LWR performance and reliability. The third problem would seem to be NRC's responsibility. However, it is questionable whether NRC has adequate incentive for doing research to optimize the balance between costs and safety. Furthermore, it has little incentive to develop improved safety concepts or systems so long as it considers its primary responsibilities to the review of proposed systems for adequacy. The ERDA LWR safety program can serve both to control the costs of safety systems and reduce the unknown factors in safety-related areas, thereby possibly increasing safety margins and reducing public fear.

QUESTIONS

1. What is the proposed scope and level of effort by ERDA on LWR component performance and reliability?

z. What will be the relationship between the ERDA and NRC programs in LWR safety research?

3. Who will ultimately decide the balance between economies and safety in LWR's?

BACKGROUND

Over the past 20 years, substantial Government research and development has been carried out on light-water-cooled nuclear power reactors, Most of this work ceased in the late *1960's* as a result of an AEC decision that light-water reactors had reached commercial status and that, except for safety research needed to support the regulatory process, the nuclear industry should assume the responsibility for further research efforts. Subsequent to the AEC decision a number of difficulties have developed.

- The industry has been slow to initiate extensive research efforts. For example, significant research efforts by the Electric Power Research Institute (EPRI), supported by the electric utility industry, have only begun within the past 2 years.

- Over the past 6 to 8 years, there has been a large increase in the operating power levels of light-water-cooled nuclear power reactors. Although efforts are made to accomplish this power increase in a way which makes maximum use of previously developed technology, a number of performance and reliability problems have resulted that require substantial R&D in order to be satisfactorily resolved. Such problems include fuel densification, Zircaloy-clad hydriding, stearn-generator tube failures, and premature component failure, The new large fossil plants exhibit somewhat analogous behavior, but downtime on nuclear plants is more costly because of their higher capital costs, which must be carried regardless of the output. When the baseload units are inoperative, utilities must make up the missing power by using higher priced fossil fuels. This generally means oil, because oil-fired units are most economical for peak loads or emergencies.

- Safety-related design criteria and operating restriction imposed by the AEC (NRC] have tightened continuously over the past 6 to 8 years. This trend, exemplified most recently by the decision to adopt new criteria for evaluation of light-water reactor emergency core cooling systems, has led to a situation where a few reactors are operating at power levels below the power level for which they were designed and/or are severely limited in operating flexibility. In addition, new fuel designs are being pushed in a direction which significantly reduces economic performance. That these trends and effects are in the direction of increased safety and that reactor safety is important cannot be questioned. Nevertheless, there is a wide difference of opinion among qualified engineers and scientists as to whether this increased level of safety is either significant or needed and therefore worth the cost,

With respect to the first two of the above problems, it seems evident that if light-water reactors are to continue to be developed and utilized effectively, additional R&D will be required in individual component and system performance and reliability, Moreover, if this is to be done quickly, a significant increase in the level and scope of Government support will be needed. It appears that high payoff will result from increasing Government support of R&D relating to these areas of reactor technology. In addition, more advanced concepts to improve performance could be investigated. These might include the production of superheated steam, either in the core of boiling water reactors or in advanced steam generators of pressurized water reactors.

At first glance, it would appear that resolution of the third problem area is the responsibility of NRC and/or the nuclear industry, and, indeed, a number of research programs funded by both industry and NRC are presently underway. However, in considering the possible eventual result of such programs, it is important to note that, over the 10 years since the AEC began limiting its R&D efforts to safety R&D in support of its regulatory role, there have been virtually no instances where safety regulations have become less rather than more restrictive, The problem is that NRC does not have an incentive to do research needed to develop and justify regulations which provide adequate assurance of safety at a minimum cost. Also, it has no incentive to develop improved safety concepts or systems so long as it considers its role to be primarily the review of proposed systems for adequacy. ERDA, on the other hand, having a responsibility for effective development and use of nuclear power, does have such an incentive, It seems likely that industrial efforts will need to be supported by the Government if they are to be effective in the near future. Therefore, it is recommended that ERDA increase its efforts in areas relating to LWR safety,

3. Floating Nuclear Powerplants

ISSUE

Floating nuclear powerplants (FNP's) offer potential improvements in LWR licensing and construction, but implementation is in doubt.

SUMMARY

FNP's are commercially available, although none have yet been built. After several years of design and sales effort, only four units have been sold to one utility, and all four of these units were recently delayed from the 1979-86 period to the 1984-90 time period. As a result, the supplier is in financial difficulty. If this company fails, the FNP, which represents a major step forward in standardization, will be eliminated for the foreseeable future as an option in meeting the Nation's energy generation needs.

The FNP is to be built in a factory setting favorable to rapid, high-quality construction and controlled costs. The plant design is to be approved by NRC prior to the issuance of a "license to manufacture"; hence, a utility has only to license the site. Indeed, the concurrent construction of the plant and the licensing and preparation of the site significantly reduces the time to install FNP's.

The present reservations about FNP's among utilities concern the licensability of the plant and site, and the performance of the plant upon completion. ERDA should consider aiding utilities in the licensing process and guaranteeing operating performance if the reactor vessel melt-through problem can be satisfactorily resolved.

QUESTIONS

1. Are the licensing questions of FNP's so serious that a utility committed to nuclear power would not accept the risk of delays and additional costs to resolve the issues involved?

2, Are there any reasons that a FNP would not be expected to reach rated power or be restricted to less than rated power by NRC?

BACKGROUND

An innovative concept which has been brought to the point of commercialization is the FNP, in which standardized plants are assembled on a regular schedule in a factory. Each plant would be installed on a barge and towed to its site, which might be located offshore or in a more protected site in a bay or lake. The FNP concept offers significant financial, schedule, and quality control advantages, but it does involve some uncertainty in licensable nature and performance. ERDA could assist in resolving these questions,

Siting of FNP's is a unique problem in that a specially designed protective barrier around the plant will probably be required, even shore-based units, will require some protection. The loss of coolant accident protection systems requires special attention since, according to the Rasmussen Report (WASH 1400), the chance of an accident leading to a reactor vessel meltthrough could be as high as 1 in 100,000 reactor-years. Some of these in turn could lead eventually to a containment floor burnthrough. At a landbased unit, extensive release of radioactive material might still be avoided if the molten core cooled sufficiently to solidify without coming into contact with ground water. At an FNP, however, after burning through the containment floor, the molten core would drop into the ocean or lake where the plant is located. The special problems associated with fission products in the water present a unique type of licensing issue. Resolving such uniquely different licensing questions is a task ERDA could undertake with NRC.

Certain other technological questions still are being examined by NRC. Some of these issues—such as turbine/generator alignment on a floating barge—could result in a restriction of the plant power level or operational difficulties, The only existing plant using a containment ice condenser pressure suppression system similar to that planned for FNP's is presently operating at less than rated power due to licensing restrictions,

ERDA could assist the utilities by undertaking R&D to resolve any problems that impose power restrictions. Since the first few utilities to install FNP's will bear the brunt of any technological problems, it may be advisable for ERDA to guarantee the performance of the first plants.

4. Helium-Cooled Reactors—Converters and Breeders

ISSUE

Helium-cooled reactors have some potential advantages not offered by water- or sodium-cooled plants, yet have a relatively low priority in ERDA's program.

SUMMARY

The HTGR has never been accorded the degree of AEC support enjoyed by LWR's, but private and foreign development have brought it to the point where it could become a significant factor. The HTGR and its potential successor, the very high temperature reactor (VHTR), can be used to generate electricity at much higher efficiencies (up to 50 percent) than LWR's, but they may have even greater potential for producing industrial process heat. In addition, they would extend uranium resources and possibly present more easily managed safety and safeguards problems, although the spent fuel safeguards advantage is somewhat counterbalanced by the need to protect the clean fuel. The HTGR, however, is less developed than LWR's, thus presenting cost, performance, and licensing uncertainties.

The GCFR has been viewed as a backup to the LMFBR. It may, however, have sufficient advantages to warrant concurrent development. The breeding ratio is about 1.4, somewhat better than the LMFBR. The thermal efficiency is higher than the LMFBR, and the capital cost could turn out to be lower since the system is inherently simpler. There exists, however, serious uncertainties regarding the loss of coolant accident, since the power density is higher than the HTGR and the core heat capacity is lower, resulting in a faster temperature rise.

QUESTIONS

1. What is the potential of helium-cooled reactors for industrial process heat, both in the medium term as an alternative to coal and in the long term with breeder technology?
2. What is the relative importance of the inherent safety features of the GCFR compared to those of the LMFBR?

BACKGROUND

The HTGR is conceptually similar to the PWR. In current designs of the HTGR, helium at approximately 700°C (1300°F) circulates from the reactor core to steam generators, compared to water at about 330°C (600°F) in PWR's. The gas temperature can be much higher than the water in a PWR because helium remains an inert, single-phase fluid, while water presents corrosion and hydrodynamic problems at high temperatures. The efficiency of the HTGR powerplant is limited by the maximum temperatures and pressures allowed in the steam system, as are fossil units. It should be relatively easy to add a topping cycle gas turbine and achieve efficiencies of up to 50 percent. It would then be advantageous to raise the helium temperature even higher, and 1000° C (1800° F) appears to be feasible.

Industry now consumes about *40* percent of the

Nation's energy, much of this in the form of high-temperature process heat, The HTGR and VHTR appear well suited to provide such heat, and their use could replace the consumption of large quantities of fossil fuel. One potential use is in steam-methane reforming to produce hydrogen for use in coal gasification and liquefaction. Other possible applications are in petroleum refining and chemical industry processing, A process heat reactor would be the first major use of nuclear energy for nonpower use, and many new problems would have to be solved, For instance, an entirely new type of industrial organization would have to learn how to cope with nuclear reactors, and the load-following characteristics in some applications could be much more demanding than in central station power generation.

The HTGR uses mainly uranium-233 as fuel, although the initial core contains highly enriched U-235, The fertile material is thorium-232, which is converted into U-233, corresponding to the conversion of U-238 to plutonium-239 in LWR's and LMFBR's. With appropriate fuel management, as many as eight U-233 atoms can be produced for each ten consumed, Thus, the HTGR utilizes fuel much more efficiently than does the LWR, and this fuel cycle demands much less uranium than that of the LWR, Thorium resources are several times uranium resources, so the use of HTGR's could somewhat postpone the time when breeders are needed, On the other hand, fuel reprocessing facilities are vital to the HTGR, but not the LWR.

The HTGR fuel has significant safeguards advantages over the LWR fuel. The fissile material produced is U-233 rather than Pu-239, Both are suitable for weapons manufacture, but U-233 is much more easily detected than Pu-239 because of its higher gamma ray production, Thus, surveillance and recovery is greatly eased. In addition, *U-233* is far less toxic, so accidental or intentional dispersion is a lesser problem, Some proposed fuel designs, however, leave the fresh fuel in a form that could easily be converted to weapons. This fuel would have to be safeguarded, unlike that of the LWR.

Loss-of-coolant accidents are less severe in an HTGR than in the LWR. The coolant loss rate is slower for the same size pipe break, since the fluid has a lower density, and core heatup is delayed by the graphite in which the fuel is interspersed. Thus a core meltdown is even more improbable,

The HTGR has been commercially available for several years, Several orders were taken for it, but most were deferred or canceled in recent years either because of the general slowdown in the nuclear industry or because of special concerns about the HTGR on the part of the utilities, The Fort St. Vrain demonstration plant *(330* MWe) has suffered from a rash of operating problems which have greatly delayed its power rise. There are also many licensing uncertainties, since HTGR's have not been subjected to the same scrutiny by NRC as LWR's. Initial costs also are high, though there are indications that this problem can be eliminated.

The GCFR is being funded at a much lower level than the LMFBR or LWBR. Much of the technology of the HTGR and the LMFBR will be usable in the GCFR, but the program could be pursued more energetically.

The core of the GCFR is more like that of an LMFBR than an HTGR. The fuel is enclosed in fuel rods, and no moderator, such as graphite, is present, This eliminates the HTGR advantage of slow-heating following a loss of coolant. Helium is a less effective cooling medium than liquid sodium. Hence, the loss-of-coolant accident must be a central design parameter as in the LMFBR.

The GCFR is a natural adjunct to the HTGR, since one GCFR can keep several HTGR's fueled. The breeding ratio of *1.4* results in a doubling time of about 10 years, better than is forecast for the LMFBR with oxide fuels.

The capital costs of the GCFR might turn out to be lower than the LMFBR because the system is inherently simpler. There is still a great deal of uncertainty over this, however, since the technology is not as advanced.

5. Liquid Metal Fast Breeder Reactor

ISSUE

The liquid metal fast breeder reactor (LMFBR) has great potential as an "inexhaustible" long-term energy source, but it poses serious technological and societal problems.

SUMMARY

A successful LMFBR could provide the bulk of the electricity for the United States for millenia at a competitive price. The U-238 which would be used in the LMFBR is readily available and is otherwise useless, Much of the technology has already been demonstrated here and abroad during the past 25 years. Advocates believe that the LMFBR will be an attractive energy source, both economically and environmentally, and that a delay in the present schedule would cause the dissipation of expertise in the development program and probably would lead to a stronger ultimate demand for fossil fuel. In addition, some form of a breeder will be vital if fusion is to be a major source of energy in the twenty-first century, and the LMFBR is the most advanced and promising of the various alternatives.

Opponents of the present plan argue that a year or two delay would make possible a better design, that electric forecasts and uranium reserves do not require the LMFBR on an expedited schedule, that proper safeguards for plutonium will be impossible to design and implement, that plutonium toxicity is not well enough understood, that 1arge technological and economic uncertainties remain, that there will be preferable alternatives, and that proceeding with the Clinch River demonstration will commit the United States so strongly to the LMFBR that it would be commercialized even if it turned out to be a bad choice.

QUESTIONS

1. What steps will ERDA take to resolve the principal safety issues relating to the LMFBR? On what time scale are these issues expected to be resolved, if proposed facilities and programs are completed satisfactorily and on schedule? Does this schedule mesh with ERDA's proposed schedule for developing designs for commercial LMFBR's and for initiating construction of near-commercial plants?
2. How much and what kinds of assistance to industry does ERDA foresee will be required in order to achieve commercial deployment of LMFBR's?
3. To what extent and in what ways does ERDA propose to reduce the cost of LMFBR development in the United States by taking advantage of foreign experience and technology?
4. Why does the U.S. LMFBR program seem to be so much more costly than the very successful French program?

BACKGROUND

The major attraction of the breeder reactor is that it produces more fissionable fuel then it consumes, In the I.MFBR this is accomplished by placing a blanket of Uranium-238 around the core, When struck by a neutron, U-238 generally does not fission as does U-235 or plutonium-239. Instead, it absorbs the neutron and eventually emits two electrons from the nucleus to transmute itself into Pu-239. The core itself consists of fuel rods containing uranium enriched in U-235 or Pu-239 as in an LWR. The familiar chain reaction takes place in the core. On the average, more than two neutrons are produced per fission. One of these is required to produce another fission, and the rest are available for absorption, The LMFBR is designed so that for every atom fissioned, about 1.2 atom of Pu-239 is created. This plutonium can be removed by fuel reprocessing and used to refuel the core, while the excess can be used to fuel an LWR or another LMFBR.

Large quantities of U-238, essentially a waste product of uranium enrichment plants, are now available. When this is exhausted, only small quantities of ore will have to be mined. Since it is worthwhile to mine our vast reserves of low-grade ore for a breeder (but not for the LWR), the LMFBR is for millenia an "inexhaustible" energy source.

There is already substantial experience with LMFBR's. EBR-I produced the first electricity ever obtained from a nuclear powerplant in 1952. Both EBR-II and the Enrico Fermi demonstration plant started up in 1963. The Fast Flux Test Facility (FFTF) is currently under construction at Hanford, Washington, and is scheduled for operation by 1977, The basic purpose of this 400-MW reactor will be the testing of a variety of materials and fuels that can be used in a commercial breeder, The LMFBR has the highest energy priority abroad and plants are being operated successfully in France, England, and the Union of Soviet Socialist Republic,

The prime impetus for developing the commercial breeder is the limited availability of uranium. LWR's require large amounts of uranium, but can only fission about 1 percent of it compared to the LMFBR's 70 percent. Present estimates of high and medium quality domestic uranium reserves and LWR demand show consumption exceeding supply early next century. Some time before then, the fuel price for LWR's will have risen enough so that the higher capital cost of the LMFBR will be justified by its lower fuel cost. The economics of the transition, however, are hard to predict, The capital cost differential will not really be known until a commercial-sized plant is built, but so far none has ever been designed in this country. The fuel-cycle cost of the LMFBR is expected to be extremely low, depending on the actual amount of plutonium produced, but the ultimate breeding ratio (and the future price of plutonium) can still only be estimated. Uranium prices have recently risen sharply, possibly giving credence to fears of a short supply; however, a great deal more could still be discovered, thus delaying the necessity for commercialization of the LMFBR. This topic is discussed in Issue Paper 13. Many cost-benefit studies and discounted cash flows for costs and benefits of the LMFBR program have been made with net benefits varying from over $100 billion to zero, depending upon the choice of parameters with improbable parameters at the extremes.

The growth rate of LWR's is also a critical economic parameter. Critics of the LMFBR program argue that the energy growth rate in general and the electric and nuclear segments in particular must be brought down drastically because of increasingly serious social and environmental impacts, They also point to other industrial nations such as West Germany, where the ratio of per capita consumption of energy to income is much lower than here—thus indicating that the United States should be able to reduce consumption. This would stretch out uranium resources. Advocates of the LMFBR, however, point out that it is by no means clear that the United States can decouple economic growth from energy growth; that large segments of the population still lack energy consuming but desirable amenities; that socially attractive developments, such as electric automobiles and mass transit, will increase demand substantially; and that the imminent shortages of petroleum and natural gas must to some extent be compensated for by electricity.

Emphasis on other types of reactors could slow the consumption of uranium. The HTGR and CANDU can be operated so as to use uranium more efficiently than present LWR's. Their probable rate of penetration into the market, however, is too low to greatly influence the price of uranium. Plutonium recycle in LWR'S would also extend resources about 25 percent as would lowering the U-235 component of the depleted uranium tails at enrichment plants, though this would decrease enrichment output. Both these options would be available later if the need for more LWR fuel appears to be critical and both are discussed in other issue papers.

Some critics also question the quality of the design for the Clinch River (CRBR) demonstration plant. The breeding ratio and reactor safety are specific points mentioned by critics. This 350-MWe plant is designed to demonstrate the licensable nature, operability y, and maintainability of a LMFBR in a utility system. Site preparations for the CRBR has been delayed from 1975 to 1976, to reflect the additional time required to address key licensing and environmental concerns.

Concern over safety has been expressed because the LMFBR, unlike water reactors, is not dependent on moderation by the coolant; hence, a loss of coolant would not directly shut down the LMFBR but would in fact increase reactivity. For this reason, the so-called "core disruptive accident" has been analyzed for the LMFBR in which it is assumed a nuclear transient mechanically disrupts the fuel elements. Energy releases for such incidents have been calculated to be from 100 to a few hundred megawatt seconds for the FFTF, which is equivalent to the energy released by burning 1 gallon of oil or exploding 2 pounds of TNT. Both European and American program experts believe that the chain of events that must be hypothesized for a core disruptive accident to occur is so unlikely that such accidents are not credible. Nevertheless, the reactors are constructed with the capability to contain a wide range of very improbable events, The lack of an inherent shutdown mechanism, however, is troublesome to NRC, which is considering mandating a core catcher for the CRBR. This device would hold the molten fuel in a noncritical configuration if there were a core meltdown. Another strong objection to the LMFBR is the danger of diversion by terrorists of some of the plutonium it produces, Only a very small fraction of the plutonium produced yearly in a breeder economy would be sufficient to construct a crude nuclear bomb capable of releasing energy equivalent to approximately 100 tons of high explosives. It seems impossible to some critics that a safeguards system sufficiently effective to prevent this can be designed and implemented at a reasonable cost and without intruding on the privacy of other citizens. Advocates disagree, saying that the safeguards system which will add only 1 to 2 percent to the cost of power will be reasonably unobstrusive, and will hold the public risks to much lower levels than for other catastrophic accidents. Nuclear parks are a possible partial solution in that the most vulnerable transportation links are eliminated.

The intentional or accidental release of plutonium possibly from a preprocessing of fuel fabrication plant is also a controversial topic. While plutonium is an extremely carcinogenic substance, it is an unlikely terrorist weapon since no effects other than psychological are felt for 25 years, but very tight controls will have to be maintained over all equipment handling it. Safeguards and plutonium toxicity are discussed in other issue papers.

Under normal operation, the LMFBR economy should be environmentally more acceptable than LWR's or fossil plants, The plant itself will have a thermodynamic efficiency approaching 40 percent, equivalent to the best units today. Mining and milling will be virtually eliminated. The environmental objections center mainly around the safety and safeguards problems already discussed.

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6. Light-Water Breeder Reactor

ISSUE

The light-water breeder reactor (LWBR) concept has several advantages, but the need for it is questionable.

SUMMARY

The LWBR is the only breeder reactor now being seriously pursued by the United States that uses thorium rather than uranium as its primary fuel. The technology of the LWBR is based on that of the main line light-water reactor; the original idea of the LWBR is that it would afford an all but inexhaustible source of energy yet would require relatively little development, About $25 million per year has been spent on this concept for the past 9 years, and a demonstration LWBR is expected to operate in the pressurized water reactor vessel at Shippingport, Pa., by 1976. If a 1,000 MWe LWBR over 30 years requires as little as 1,500 tons of uranium, rather than the 3,000 to 5,000 required of other reactors, it could become a serious contributor to the nuclear energy programs, yet in the ERDA nuclear program there seems to be no mention of LWBR actually carrying some of the nuclear load at any time, and utilities have shown little interest in the concept.

QUESTIONS

1. Why is LWBR not mentioned in ERDA projections of future nuclear mixes?
2. What measures does ERDA intend to take to make LWBR technology more accessible to possible users of this reactor type?
3. At what uranium price and rate of deployment does the LWBR look attractive?
4. Does ERDA intend to make a detailed economic assessment of the LWBR fuel cycle?

BACKGROUND

The LWBR was conceived in 1965 as a simple, inexpensive way of breeding in the thorium cycle that did not require new and unproven technology, The fundamental idea was to replace the slightly enriched U-235-U-238 fuel elements in a PWR with “seed blanket” fuel modules: each module consists of thorium-U-233 fuel rods (seeds) surrounded by thorium rods (blankets). The normal fissioning process takes place in the seed rods, Neutrons produced in the seed are caught in each blanket and thorium there is converted into U-233. It is estimated that breeding ratios of around unity can be achieved with this arrangement.

When the LWBR was first proposed in 1965, it seemed to defy most of the precepts set forth for a good breeder: high breeding ratio; low inventory of fissile material; high thermal efficiency; simple fuel recycle. The one countervailing advantage was that the LWBR largely used standard pressurized water technology, and therefore it could be developed for a fraction of the cost of any other breeder, such as the LMFBR. The AEC, in weighing the matter, decided that the simplicity of the technology outweighed all other considerations, and it assigned the task of developing the LWBR to the Naval Reactor Branch under Admiral Rickover. The LWBR is now at a point where a demonstration of the principle is about to be made in the Shippingport, Pa. reactor facility.

Originally, it was hoped that utilities would find the concept interesting as a means of transferring easily from the standard PWR to a breeder without having to switch to a completely different technology. Thus far, utilities have shown little interest in LWBR, primarily because LWBR fuel-cycle costs were estimated to be much higher than PWR fuel cycle costs; and, second, because so little hard information has been made available about the LWBR.

The rapid rise of capital costs and the approaching shortage of uranium may have improved the commercial outlook for the LWBR. Because of the higher capital costs, fuel cycle costs (which are probably high in LWBR) are no longer so important; and the shortage of uranium may make even the fuel-cycle cost of LWBR's competitive, especially if prorated over 30 years, during which time the uranium shortage may become acute.

There still remain a number of technical uncertainties. For example, the LWBR has a more tightly packed lattice than PWR's which may cause some difficulty with the emergency core cooling system; there will probably be less power output for a given core size compared to a LWR; the breeding ratio is so close to unity that LWBR may turn out not to breed at all. The initial loading of uranium in a LWBR is much higher than in a PWR; hence, an expanding LWBR economy may place even heavier demands on total uranium resources during the first several decades. The purpose of the Shippingport test is to prove the feasibility of light-water breeding. Full technological development and economic development will require a substantial R&D program.

However, the situation since the LWBR was first proposed has changed sufficiently that it seems prudent to consider LWBR to be a more serious contender than has previously been the case, Information on LWBR will soon be available in the Environmental Impact Statement so that potential buyers of LWBR's can assess the system more realistically.

7. Molten Salt Breeder Reactor

ISSUE

Support for the molten salt breeder reactor (MSBR) development program is small compared to other reactors and maybe insufficient to permit evaluation within a reasonable time period.

SUMMARY

The MSBR program is presented by ERDA as a potential backup for solid fuel breeder reactors. It uses an inherently different nuclear technology, and hence provides technological insurance, Even if fast breeder reactors prove to be commercially successful and environmentally acceptable, the MSBR, based on thorium rather than uranium, would enlarge the options available for future energy systems and offer substantial advantages such as more easily managed safety and safeguards problems, There are unique problems associated with the development of the MSBR, however, which must be solved.

QUESTIONS

1. What are the major milestones seen by ERDA in the MSBR program?
2. What criteria will ERDA use in deciding whether or not to continue the program?
3. Is the funding level proposed by ERDA ($3.5 million adequate to reach a meaningful decision point in FY 77, as suggested by ERDA?
4. What level of funding would be required to maintain the MSBR program as a realistic alternative to the fast breeder reactor program, so that commercial deployment of MSBR's could be undertaken by the end of the century, if needed?
5. Would the MSBR be more secure than solid-fueled reactors against diversion of fissionable material for unlawful purposes?

BACKGROUND

The MSBR offers the possibility of a significant breeding gain in a thermal-neutron reactor using thorium rather than uranium as the basic fertile material. To reach self-sufficiency (ability to fuel its own growth), an economy based on the MSBR would probably require no more natural uranium than a fast breeder reactor economy if deployed at a comparable rate. Its advantages are a short fuel cycle, fast reprocessing, low fuel inventory, and high thermal efficiency. The disadvantages of the MSBR are high tritium product ion, chemical complexity, and more extensive requirements for remote maintenance of radio active components, since contamination is heavy throughout the entire reactor system. Fuel reprocessing is done by continually withdrawing a small amount of the molten fuel, removing the fission products and excess uranium-233 and reinfecting the clean fuel, Thus, the fuel in the reactor at all times has a low inventory of fission products, which are the major potential source of safety problems in solid fuel reactors. The safeguards problem may be reduced because the fissionable fuel produced by the MSBR is much less toxic and more easily detected than plutonium. The fuel recycle process would be part of the reactor plant; successful development of equipment for this is an essential part of the MSBR program.

Molten salt breeder reactor technology has been under development for more than 20 years. Two reactor experiments have been operated successfully: the Aircraft Reactor Experiment (ARE) in 1954, and the Molten Salt Reactor Experiment (MSRE) in 1965-69. Key areas in which further development is needed are listed below:

- Graphite moderator (reduced sensitivity to irradiation)
- Structural metal (reduced sensitivity to chemical attack by fission products such as tellurium)
- Retention and control of tritium
- Chemical processing (materials for equipment and processing)
- Component development, including equipment for removal of fission-product gases from the fuel salt.

Recent funding has been at $3.5 million per year, This is far less than any other reactor concept currently funded by ERDA. Problems are being addressed, but at such a low level that even determining the potential for solutions is far off.

8. Nuclear Environmental Effects

ISSUE

There is a continuing need for the evaluation of the environmental effects associated with nuclear energy sources.

SUMMARY

In the establishment of biomedical and environmental research priorities, ERDA has not identified clearly the continuing efforts needed in the assessment of environmental issues associated with nuclear-based technology. These efforts must be maintained on long-term studies of radionuclide accumulations and recycling in the aquatic and terrestrial environments, Other programs that should receive increased attention are concerned with reprocessing facility releases and impact/recovery studies of accidental releases from reprocessing facilities and reactors to local or regional areas.

QUESTIONS

1. In order of priority, what are the remaining questions connected with the environmental impact of nuclear energy?
2. To what extent is ERDA investigating the range and historical relationships of radionuclide concentration factors in aquatic environments?
3. How does ERDA evaluate the economic consequence of accidental releases that would restrict agricultural operations?

BACKGROUND

The use of nuclear fuel sources, as well as other energy sources, is associated with environmental interactions, most of which are either well known or predictable. Both aquatic and terrestrial ecosystems are affected to various degrees.

Relatively large volumes of water are required for cooling purposes. Depending upon cooling water intake structural design and location, the effects upon entrained aquatic life are highly variable, with mortalities ranging from 10 percent for well designed and sited once-through systems to as much as 100 percent for low consumption closed systems. In addition, heated water, metallic corrosion products, low-level radioactive wastes, and water treatment chemicals may be discharged to surface water ecosystems. Where evaporative cooling is employed, the same pollutants are discharged at lower volumes and temperatures but at greater concentrations than with once-through cooling.

The use of large, evaporative cooling towers results in the atmospheric dispersion of large volumes of heat, moisture, salts, and a variety of chemicals which interact with the terrestrial environment as well as the atmosphere. This is true for both nuclear and fossil plants, but nuclear requires more cooling for the same power and, also results in the release of low levels of radioactivity y. Released either to receiving waters or atmosphere, these interact with man and either directly with terrestrial or aquatic ecosystem components or indirectly through a synergism with other plant releases, such as heated plumes (aquatic or atmospheric) metals, and chlorine. Depending upon the type of meteorologic or hydrologic transport of these low-level radioactive products, they are available for uptake, cycling, and concentration within biological food chains which include man.

Since ERDA's Plan envisions many new nuclear energy sources, adequate resources must be devoted to the associated environmental problems. The environmental study program, however, appears to shift emphasis from nuclear to fossil power. This is reasonable because nuclear environmental and health hazards are probably better understood than those from other sources, although many uncertainties remain even here.

Specific data deficiencies also exist, such as the biological cycling of low-level ionizing radiation within various aquatic ecosystems, Studies are needed to assess the patterns of accumulation and resultant effects on the aquatic community, as well as any resultant hazards to man.

Another area for research concerns localized accidental releases around operating nuclear reactors and reprocessing facilities. Insufficient effort has been devoted to the specific economic, sociological, and radiological impacts that apply to the population groups involved. In particular, there is need for a better understanding of remedial measures available and their resultant cost/value relationships.

9. Plutonium Toxicity

ISSUE

The toxicity of plutonium may pose a serious threat to a plutonium-based nuclear option, such as the LMFBR or plutonium recycle in light-water reactors.

SUMMARY

Suggestions have been made recently that plutonium may be much more hazardous than had been previously believed to be the case. Though these claims have been specifically denied by the British Medical Council, to ERDA scientists, and many other scientists and scientific groups, the issue remains a lively one requiring a more definitive resolution than exists at present.

QUESTIONS

1. How much effort is ERDA planning to devote to resolution of the question of toxicity of plutonium?
2. What is the evidence that land contaminated by plutonium can be restored to a usable condition?

BACKGROUND

Plutonium is a very hazardous material; for example, the maximum permissible concentration of the isotope Pu-239 in the air, when the plutonium is in the form of insoluble plutonium oxide, is about 6 x 10^{-14} microcuries per ml or 100 x 10-20 gin/ml. Nevertheless, other materials (such as the botulism virus) are much more toxic per gram than plutonium. Fortunately, plutonium is not readily absorbed by the gastrointestinal tract or by the food chain.

Inhalation of radioactive discharges from nuclear facilities is the more likely mode of significant plutonium ingestion. This results in deposition in sensitive lung tissues with possible ultimate development of lung cancer. The maximum permissible lung body burden is 1 6 nanocuries; however, various critics of the nuclear energy program have argued that this body burden is too high by a large factor.

The position of the nuclear energy community and of the majority of qualified experts in the biomedical community is that currently allowed levels are safe. Primary evidence for this conclusion is that, despite man having dealt with plutonium on a large scale for over 30 years, no case of lung cancer in man can be attributed to plutonium. In particular, some 25 workers at Los Alamos received as much as 10 times the occupational dose limit to the bone, yet some 30 years later none of these people has suffered ill effects. Critics claim that these findings are not in conflict with their position because the doses were not received in the most dangerous manner,

10. Waste Disposal

ISSUE

Satisfactory handling of nuclear fission wastes appears to be technologically feasible, although it has yet to be demonstrated. Other problems exist, mainly societal and institutional, which greatly influence the nature of the demonstration required.

SUMMARY

Spend fuel discharged from a reactor contains radioactive fission products which must be isolated from the biosphere for approximately 700 years as well as actinide elements (uranium, plutonium, americium, curium, and other heavier elements) which are radioactive for hundreds of thousands of years. Because there are no chemical reprocessing plants currently operating in the United States, spent fuel elements from nuclear powerplants are stored temporarily in water basins at the powerplants. Commercial facilities are being designed and constructed, however, to receive the spent elements and remove almost all of the uranium and plutonium, which can be recycled into new fuel, while the residue must be disposed of in solidified form. Several options for this exist, each with different short and long-term economic and societal costs and benefits, If the wastes are sequestered without further separation, the long-term radioactivity between 700 and about 1,000,000 years of the approximately 1 $meter^3$ per reactor-year is several times that of natural pitchblend ore; but if diluted to the original volume of mined uranium ore, the radioactivity is less than that of the ore. If the actinide elements are also removed during reprocessing and recycled and “burned out” in the reactor itself, the toxicity after 700 years is essentially negligible thereafter.

Projected costs for almost all the water disposal options are small compared to the total value of associated power produced.

QUESTIONS

1. What program exists to evaluate the hazards and options associated with nuclear wastes and at what level is this program funded?
2. What are the expected total hazards from the various main options for nuclear waste disposal?
3. What reservations does ERDA have concerning the disposal of solid waste in salt formations (as at Carlsbad, N. Mex.)?
4. How does the scheme for burning out the long-lived transuranic elements in a reactor compare with other options?
5. What is to be done about the so-called alpha wastes (e.g., plutonium-contaminated tools, gloves, etc.) where the activity per unit volume is low, but the volume is so large that total activity is comparable to the high-level wastes?

BACKGROUND

For permanent disposal of wastes, present options are as follows:

. Disposal of wastes as presently envisaged to be processed in sites with very high integrity up to 700 years or so, with integrity at longer times striven for, but not essential to guarantee, The present disposal-in-salt schemes seem satisfactory provided obvious mistakes such as susceptibility to intrusion of ground water are avoided.

- Better removal of the long-lived radioactive wastes; specifically, the 0.50/0 remaining plutonium, plus the bulk of americium, curium, etc., which are now normally left in the wastes, The impact of such extra separation on the total fuel cycle cost is uncertain, but quite possibly modest, The separated long-lived wastes would then have to be burned out by reinsertion into operating nuclear reactors (fast reactors would be best). If this option were developed, the long-term storage problem would be virtually eliminated, and the shorter-term storage problem would become even more straightforward.

- Disposal of untreated wastes in hitherto relatively unconsidered locations: for example, burial in ocean floors, Many of these geologic regions have been stable for many millions of years, and modern deep ocean drilling techniques have improved substantially in the last several years.

Presently contemplated chemical reprocessing methods for spent fuel elements are expected to remove 99,50/0 of the plutonium and uranium and little of anything else; this procedure represents the best macroeconomic profitability because of the value of these materials for recycling. Substantial quantities of radioactive heavy elements americium and curium with half-lives of 10,000 to 25,000 years would remain with the fission products, whose half-lives are less than 50 years. Since ten half-lives reduce the original activity by a factor of a thousand, which is usually a safe level, 700 years' isolation is adequate for the fission products as contrasted with 200,000 years for the heavy elements,

Inclusion of a further reprocessing step, which would remove these heavy elements from the fission products, appears feasible, Because the heavy elements are small in volume, they can probably be returned to a fast reactor to be fissioned, at which point they become normal fission products. Thus arises the question of present costs versus far future benefits.

In any event, the wastes must have low leachability y. This can be assured via well developed waste technology. Evidence that such low leachability can be achieved, even without any processing or conversion to solid form, is provided by some ancient "natural reactors" in Gabon which have been under study by French scientists. Neither plutonium nor other long-lived wastes were found to have migrated appreciable distances since ancient geologic times, as evidenced by the fact that their final decay products are spatially coincident with the remaining uranium.

11. Safeguards for Nuclear Materials

ISSUE

Safeguards must be adequate to prevent the theft or loss of fission materials, with subsequent clandestine construction of nuclear weapons.

SUMMARY

Only about 20 pounds of reactor grade plutonium oxide, or comparably small quantities of other fissionable materials, are required to make a crude nuclear bomb. Furthermore, the information needed to design and construct nuclear weapons is readily available. Preventing diversion of small amounts is difficult because fissionable material must be processed and handled in multiton quantities annually. Plutonium, which is already produced in large quantities in light-water reactors, is an even larger component of the LMFBR fuel cycle, While it is widely agreed that pas t safeguards practices have been inadequate, a number of measures are under consideration to improve the safeguarding of nuclear materials in the United States. There are important international aspects to the problem, however, since, once diverted, the materials are rather easily concealed and transported.

QUESTIONS

1. What extra safeguards are needed to protect plutonium from being stolen from fuel fabrication and reprocessing plants by heavily armed gangs?
2. Is ERDA studying or developing new safeguard techniques?
3. To what extent would the safeguard problems be eased if the entire nuclear power program were shifted from uranium-plutonium to thorium-uranium?

BACKGROUND

The information needed to design and construct crude nuclear weapons is available, as are the associated nonnuclear materials required. Dozens of nations have the skills and facilities necessary to build reliable atomic bombs. Some, but not all, nuclear weapons experts assert that small groups of people, conceivably even individuals, could construct a crude bomb which, although inefficient, could be transported in an automobile and would be highly destructive. Furthermore, modest workshop facilities would suffice. Such a crude bomb might have the power of 100 tons of TNT and, if exploded in a densely populated city area, might kill more than 100,000 people under some circumstances.

The only ingredient not readily available for such weapon construction is the nuclear fissionable material required. A few tens of pounds of plutonium or highly enriched uranium are needed, the exact amounts depending on the chemical form and the degree of dilution of the fissionable isotope with nonfissionable isotopes. Such plutonium or enriched uranium is used or produced in most fission power reactors.

Plutonium is also a potentially toxic material. If dispersed in the form of small particles in the atmosphere with sufficient concentration, inhalation might lead to many eventual deaths from cancer. The potential threat in populated areas should be compared with the corresponding threat of dispersal of highly poisonous chemical or biological agents, except that physical effects are not generally visible for several decades. Thus, the primary threat as a terrorist weapon is psychological.

In addition to the countries which already have nuclear weapons, 15 others operate power reactors which produce plutonium. By 1985, the number will be at least 50. The plutonium produced will be in the irradiated fuel rods and, therefore, will be in too dilute a form for a bomb. These rods will also contain highly radioactive and dangerous fission products whose radiation will play an effective "self protecting" role so that clandestine theft and handling would be very difficult. This situation changes when the fuel elements are reprocessed and the plutonium is separated from the other elements; several countries have or are constructing nuclear fuel reprocessing plants,

The International Atomic Energy Agency (IAEA) in Vienna has the responsibility for safeguards to detect the diversion of nuclear materials from peaceful purposes in nations that are parties to the Treaty of Non-Proliferation of Nuclear Weapons or have otherwise agreed to have their civilian nuclear materials under international safeguards. The responsibility for applying physical security safeguards to prevent theft or diversion of nuclear material by clandestine groups belongs to the individual countries involved.

In the United States, the present physical security for civilian nuclear materials, though strengthened substantially during the last 2 years, may still be inadequate to prevent theft by heavily armed groups with adequate resources and motivation comparable to the Brinks gang, NRC is presently studying new regulatory actions which involve "the principle of containmerit, " in that all potentially explosive fissionable material will be handled in areas circumscribed by well-defined barriers. A limited number of channels for the flow of materials through the barriers and other channels would be continuously monitored.

Some of the new safeguard measures under consideration are:

- Collocation of fuel reprocessing and fuel fabrication plants.
- Dilution of the separated plutonium by uranium at the output stages of reprocessing plants. To produce explosive fissile material chemical separation would then be required, and the weight of the material which must be stolen would be increased by a factor of about 100,
- "Spiking" of the plutonium with dangerous radioactive materials. Massive shielding would be required for all subsequent handling.
- Limited "spiking" of the plutonium with radioactive materials to make detection easier by monitoring systems.
- Use of specially designed vehicles or heavy containers for shipment.
- Establishment of a Federal protective service to safeguard nuclear materials in transit,

It is estimated that the cost of implementing these extra safeguards, although high, would increase the cost of the nuclear electric power by no more than 15 percent,

12. Siting

ISSUE

Nuclear Regulatory Commission policy changes for siting could influence reactor and supporting system design.

SUMMARY

The Energy Reorganization Act (ERA) of 1974 calls for the Nuclear Regulatory Commission (NRC) to report to the Congress on the clustering of nuclear reactors and supporting facilities in "nuclear parks. " Nuclear parks offer several advantages: easier safeguarding of fissionable material, lower unit construction cost, probably increased safety, and less disruptive construction (since the work force is stable), Disadvantages include higher vulnerability in the event of war, creation of heat islands, and increased expense of transmitting power from the remote site. If nuclear park siting becomes a general practice, certain technical problems would require more serious study and resolution: electrical transmission of extremely large blocks of power; the simplification of transport systems between reactor and chemical plant; the incorporation of interim waste disposal facilities on the nuclear park site; and the design of different reactor systems that are better suited to park siting, Though siting policy and the possibility of nuclear parks is largely the responsibility of NRC, the matter is so vital to the entire future of the nuclear energy enterprises that ERDA should be strongly involved in the development of the concept from the beginning.

QUESTIONS

1. If nuclear parks siting is required, how would this affect (a) the ERDA safeguards program; (b) the types of reactors ERDA develops; (c) the transport systems ERDA develops; and (d) the climatological effects program of ERDA?
2. Is ERDA planning to examine the social and institutional implications of nuclear parks?
3. Does ERDA believe that breeder reactors and their subsystems should be confined to nuclear parks?

BACKGROUND

When large-scale nuclear energy began in the United States during World War II, nuclear reactors and their chemical plants were confined mainly to nuclear parks: Hanford, Wash,; Savannah River, S, C,; Oak Ridge, Term,; and Idaho Falls, Idaho, In the ensuing 30 years, this original practice has been replaced by scatter-siting, The reactor has not been viewed as part of a system, but as a replacement for the boiler in a conventional steam plant.

With increasing popular concern about nuclear energy, the idea of nuclear park siting has received increasing attention as a means of answering some of the objections to nuclear energy. The feasibility of nuclear parks is now being studied under the auspices of NRC, and it is not clear what role ERDA ought to play in the clarification of the problem. There are some react or configurations— MSBR, the coupled HTGR-GCFR, ‘and possibly the LMFBR—that might better be located in parks than in isolation.

Nuclear park siting would carry with it many institutional implications: utilities might have to cooperate to support such large enterprises; the generation of electricity would tend to be separate from its distribution; and land use planning over a very longtime would be required. The impact on reactor design and selection is such that the possibility should be considered in present nuclear R&D programs and planning.

13. Uranium Resources

ISSUE

The lack of precision in present uranium resource estimates and questions as to the rate of expansion of uranium production capability make resource-related issues difficult to address.

SUMMARY

Since the adequacy of the domestic uranium resource base has an important bearing on ERDA’s and utilities’ nuclear strategy, and especially on the timetable for breeder reactor development, a much more precise evaluation is needed then is presently available or anticipated. To keep pace with the Nation’s energy needs as projected by ERDA, substantial expansion of domestic uranium production over the next 25 years will be required. This entails long leadtimes, major capital expenditures, and in the relatively near term, large exploration effort and ore-body development. The long time, perhaps 10 years, required for the development of a new mine-mill complex, together with the existence of competing investment opportunities, may require the creation of a relatively low-risk investment climate through loan guarantees, accelerated depreciation regulations, and assured uranium markets. Market prices have increased dramatically during the 1973-75 period from $7 per pound of U_3O_8 to about $30, and there is no reason to expect an early end to the seller’s market,

QUESTIONS

1. Is the National Uranium Resource Evaluation (NURE) adequately funded to meet the need for the identification of assured reserves for the next 30 years?
2, What is ERDA’s program for obtaining uranium resource information for its data base which is held in the private sector?
3. What incentives are needed, if any, to stimulate substantially greater exploration and development of mining and milling operations to insure the future availability y of fuel supplies?
4. How does ERDA evaluate the impacts of dependence on foreign sources of uranium, exportation of domestic uranium, and the participation of foreign interests in domestic resource development.

BACKGROUND

The adequacy of the domestic resource base has an important bearing on ERDA R, D&D strategy—in particular, the timetable for breeder reactor development and application. Also, utility perception of the resource base may condition the pace of utility commitments to nuclear power in the prebreeder era, As matters now stand, information needed for a definitive assessment of the domestic resource base is lacking, and expert opinion on the question of its extent is divided. ERDA's NURE program, initiated in 1973 and targeted to be completed by 1980, represents the first attempt to develop a comprehensive analysis of domestic uranium resources and hopefully will bring the question of adequacy into clearer focus. Work being carried out by the U.S. Geological Survey (USGS) will contribute additional insights, but is by no means clear that the sum of the ERDA, NURE, and USGS activities can or will provide all of the answers needed.

To keep pace with ERDA requirements projections, the domestic uranium production industry will have to expand at a very substantial rate, For example, ERDA's so-called "medium low" projection defines the growth in annual requirements as follows:

Year	Tons of U_3O_8
1975	10,000
1980	19,000
1985	37,000
1990	61,000

These figures assume recycle of uranium and plutonium, starting in the late **1970's.** Requirements would be about 25 percent higher than indicated here without recycle.

In 1974, the domestic industry produced 13,000 tons of U_3O_8. It is estimated that a 25,00()-ton per year production level could be realized if the domestic industry were to proceed with mine/mill ventures to exploit ore bodies already largely developed. Significant expansion beyond that level hinges on the results of exploration effort and ore-body development in the years immediately ahead, The leadtimes entailed are appreciable, and the capital requirements are substantial.

An appreciable part of the upward price movement of uranium since 1973 is a necessary and long overdue adjustment from an artificial uranium price economy to one that provides a reasonable incentive for supply industry expansion. At the same time, some portion doubtless reflects the existence, since mid-1973, of a strong sellers' market atmosphere, in which the quantities of low-cost reserves which suppliers have placed on the market are limited in relation to the quantities utilities would like to purchase.

During the interval to the end of the century, the typically projected annual ore production requirements will increase by a factor of roughly 10, which is more than twice as fast as the most rapid growth phases of other significantly large mining industries (such as copper) in the United States. The general resource shortages in the next few decades should provoke caution in the expectations that the required exploration crews, drill rigs, mine-mill investment capital, miners, and geologists will become available as needed,

The following factors are also potentially significant in affecting whether adequate fuel supplies will be available, and they merit attention in any coordinated national energy strategy:

- The recent occurrence of increased delays and costs in exploration and development activities because of new State and Federal environmental protection requirements [such as the NEPA statement).

- The need for improved geological models and exploration equipment (such as more sensitive, lightweight, airborne gamma-detectors).

- The abandonment of mines depleted of currently economical ore.

- The increased ore requirements which will be imposed if the ERDA-announced plan to increase the tails assay of the U.S. enrichment plants is implemented, if Pu-recycle is indefinitely delayed, or if the HTGR is not eventually commercially successful,

14. Uranium Enrichment

ISSUE

Expansion of uranium enrichment capacity is required to meet domestic requirements and foreign commitments for LWR and HTGR fuel.

SUMMARY

Enriched uranium fuel is needed in light-water reactors (LWR) and high temperature gas-cooled reactors (HTGR). The existing ERDA diffusion plants are being upgraded and expanded, but their capacity will be exceeded within a decade if presently contemplated nuclear powerplant construction occurs. ERDA policy calls for development of new production facilities by the private sector, but the financial risks may be too great without some form of Federal economic assurance. Among the risks involved in the financing of new plants is the possibility that new technology, such as the gas ultra-centrifuge or laser separation, might render a new diffusion plant obsolete. A related management question concerns the proposal to allow the U-235 content of the enrichment plant by-products material ("tails") to increase, thereby producing increased enriched uranium output at the expense of greater natural uranium input.

QUESTIONS

1. What financial and technical arrangements are required to bring a private enrichment plant on line at an early date?
2. How and when will ERDA make its centrifuge and laser isotope separation technology available to industry, and what effect will this have on the development of a centrifuge enrichment industry?
3. What are the implications for nuclear weapons proliferation in the advanced enrichment technologies?

BACKGROUND

Before the mid-1980's, ERDA will have upgraded U.S. enrichment capacity to support the generation of approximately 320,000 megawatts of electricity (MWe) if other fuel-cycle factors develop favorably. This capacity has already been unconditionally committed (208,000 MWe domestic and 107,000 foreign), and there are conditional foreign contracts already in hand that could increase the load by another 14,000 MWe. There is a clear need, therefore, for additional enrichment capacity to be completed by 1985, and perhaps earlier if other fuel-cycle factors develop less favorably than presently anticipated. These factors include delayed plutonium recycle, lower U_3O_8 production capability and higher LWR capacity factors. Enrichment capacity can be easily expanded by increasing the tails assay. This means that a given batch of uranium is not wrung out as hard as possible, but is replaced by new richer feed sooner.

The proposed change of enrichment tails from

0.2 to *0.3* percent U-235 would increase the existing enrichment capacity by 20 percent. The drawback is that the incoming feed of uranium must be increased by a similar factor, The enrichment cost would decrease, while the increased feed requirement would stimulate increased exploration and ore production. Opponents of this proposal argue that it represents false economy, in that it effectively reduces the long-term uranium supply for the LWR and HTGR, and that uranium production capacity already will be strained in the period when enrichment capacity will become critical.

The need to begin construction of a new enrichment plant is urgent, since construction time is estimated (by the National Petroleum Council) at 9 years for private construction, 6 to 7 years for the Government. Financial backing for an additional diffusion plant has so far been unavailable to industry because of several factors: high cost, about $3,5 billion for a $9-million separative work unit per year plant; the presently low pricing by existing ERDA facilities; and the threat of early obsolescence induced by the gas ultra-centrifuge and laser isotope separation. Possible Government assurances to induce industrial participation are guaranteed price for the product, guaranteed construction loans, and a change in pricing policy for enriched uranium from existing plants.

Of the new technologies, laser isotope separation is a promising concept but not yet even at the pilot-plant stage and there is no assurance of increases. Both this and the centrifuge process promise such substantial reductions in costs, as well as in the minimum scale for economical operation, that they represent a potential international threat through the clandestine production of nuclear weapons materials, As with gaseous diffusions, much of the information related to both processes is classified.

Gas centrifuge technology is well advanced, but a large-scale commercial plant has not yet been constructed. A major advantage to this process is its substantially lower electric power consumption, about 10 percent of that by a comparable diffusion plant. A Western European consortium has developed the process, and plants have been built in the Netherlands and the United Kingdom, Although classified, this technology is presumably available to the United States under bilateral agreements. In addition, the United States has a classified centrifuge program which is generally believed to be superior to the European technology and may be at the stage to support production plant construction.

15. Fuel Recycle

ISSUE

Fission fuel recycling capability is needed for the orderly development of nuclear power.

SUMMARY

Spent nuclear fuel assemblies still contain much valuable fuel material, The discharged fuel can be reprocessed to recover the usable fuel material, which can then be recycled through a reactor, There are four basic reasons for recycling the fuel: (a) the recycled fuel reduces the demand for new uranium that would have to be mined and refined; (b) recycling, desirable for LWR's, is an economic necessity for HTGR's, LMFBR's, and other advanced reactor designs; (c) lower power-generating costs should result; (d) the chemical processing which is part of recycling is also an integral part of some of the more promising waste disposal schemes,

Recycling is, however, beset by several problems. First, a reprocessing, a refabrication, and a radioactive waste disposal industry must be constructed and operated. Second, safeguards and transportation must be developed to protect the material adequately. Third, the economic advantage of recycling in LWR's is small at best although the spend fuel still contains material that can produce a large amount of energy.

The central point is whether ERDA's budget is adequate to develop the necessary recycling capability or whether adequate incentives can be provided to industry to provide this capacity,

QUESTIONS

1. What are the implications for resource economics and safeguards if recycle is further delayed?
2. What safeguards programs will ERDA support for reprocessing plants, plutonium shipment, and mixed-oxide fuel fabrication?

BACKGROUND

During the last decade, major emphasis in the nuclear field has been in reactor development and in the "front-end" of the fuel cycle. This emphasis was necessary to transform raw uranium ore into fuel *that* could be used in the reactors. The "back-end, " consisting of reprocessing, refabrication, and radioactive waste disposal, was not stressed; the AEC may have felt that these operations should be developed by private industry or that there was no urgency involved.

The arguments for recycling center on the conservation of uranium resources, the anticipated economic savings, radioactive waste handling, and the economic necessity for recycling in HTGR's, LMFBR's, and other advanced reactor designs, The lifetime 1,000 MWe LWR requirement for yellowcake (U_3O_8) is 5,400 short tons with no recycling, or 3,800 short tons with recycling. This results in a uranium savings of 30 percent over the reactor lifetime, For reactors

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other than LWR's, the economic savings are substantial; even for the LWR, recycling fuel is expected to offer an economic advantage. A recycle industry will definitely be needed in the future if a reactor concept other than the LWR is deployed, since the economic advantage of these advanced reactors hinges on the ability to recycle fuel.

Three companies—Nuclear Fuel Services, Allied-Gulf Nuclear Services, and General Electric—entered the reprocessing business, but presently no plant is operating, even though all three companies have contracts for reprocessing spent nuclear fuel in the *1970's*. General Electric practically completed their plant at Morris, Illinois, but found that certain advanced design features limited the throughput to noneconomic levels; they are now evaluating possible courses of action and hope to make a decision by the end of 1975.

The Nuclear Fuel Services plant operated from 1966-72 and reprocessed about 600 metric tons of fuel. Since 1972, the plant has been shut down to upgrade its radioactivity control systems and to consider designs to increase throughput, An application for a construction permit to carry out this expansion has been submitted, and the plant could be operational in the *1980's* if the licensing process is continued. The Allied-Gulf Nuclear Services plant, which is 95 percent complete in its basic structures, is now awaiting its operating license. Similarly, large-scale commercial refabrication plants are not operating, although several private pilot plants are in operation.

Because of substantial cost increases associated with newly implemented regulations, high construction cost escalation, and risk allowances to cover future uncertainties, the recycle of LWR fuel has lost much of its economic attractiveness. However, spiraling costs for raw uranium and for enrichment may change the economic picture.

ERDA, in a report (ERDA-33) on the problems of the fuel cycle, reviews this situation. They are concerned that a number of key process steps in the reprocessing plants are still undemonstrated, such as conversion of plutonium nitrate to solid form accept able for shipment, increased safeguards, waste solidification and packaging for shipment to storage/disposal facilities, and the removal and packaging of certain radionuclides from process streams to meet site effluent limits,

16. Public Understanding

ISSUE

Public understanding of the energy problem, and especially of the nuclear option, receives minor emphasis in the ERDA Program.

SUMMARY

The energy problem is complex, and increased efforts must be directed toward better public information programs. Within the past several years, public anxiety, confusion, and doubts have increased, and the energy problem is widely perceived as a "contrived situation. " More effort must be directed toward better understanding of energy options so that well-informed energy decisions can be made by the public. One of ERDA's tasks is to create and encourage ". . . the development of general information to the public on all energy conservation technologies and energy sources. . ." In addition, the ERDA Administrator, in conjunction with the FEA Administrator, is directed to disseminate such information through the use of mass communications. (Section 103. i' of Public Law 93-577.)

QUESTIONS

1. What type of program, with what budget level, will ERDA use to increase the public understanding of energy options?
2. How does ERDA envision the promotions of nuclear power being handled in the Government as compared to the development, and how will the agencies involved coordinate their roles?

BACKGROUND

There is great uncertainty among the public about the energy options that are being selected, but little effort seems to be directed toward the development and dissemination of information on energy issues. The nuclear field is poorly understood, even by otherwise well-educated people, and nuclear technology is widely mistrusted among the public. The task of providing adequate information for informed choices is formidable.

Another source of public concern may be the outgrowth of military needs. Although the nuclear industry has matured and has largely divorced itself from its military origin, the problem of safeguarding fissionable material to prevent illicit weapons production retains military implications. This subject is treated in more detail in Issue Paper 11 on "Safeguards. "

In addition, past practices of the AEC may be partially responsible for public mistrust. The former agency tended to be secretive and did not always respond fully to public requests for information. Reports and internal memoranda were suppressed, and the Commission's dual role of promoter and regulator resulted in criticism of the agency's objectivity. Understandably, the public is suspicious when a topic is surrounded by secrecy. A more basic problem is that the very technical, complex nature of nuclear science and technology prohibits easy explanations to seemingly simple questions.

Although most people who are knowledgeable in the nuclear field favor the continued development of commercial reactors and believe that both reactor safety and nuclear safeguards questions are resolvable, there are some experts who disagree and who advocate a slowdown or cessation of reactor procurement. The controversy is complicated by the fact that most pro-nuclear experts, of necessity, are employed in the industry, by ERDA, or in university programs partially dependent on ERDA. As a result of the lack of scientific consensus, the concerned layman may be at a loss for an informed judgment. The advantages and problems of nuclear power compared to other options must be thoroughly aired for the public to make rational choices,

17. Controlled Fusion

ISSUE

Great care must be exercised to ensure that the ERDA-controlled fusion program does not expand at a rate so fast that proper attention is not given to the different physics problems of controlled fusion and that development of new concepts is not prematurely abandoned.

SUMMARY

The advantages of successful fusion power are great; fusion research needs should receive high priority, but success is not yet assured by any future date. For example, it appears necessary to scale present experiments up to larger machines in order to maintain an effective program. While these next generation devices are being conservatively designed, they are still experimental. In addition, even though the science may scale to larger sizes, technological, engineering and economic considerations may or may not permit exploitation of a given concept for practical fusion power.

This uncertainty has two practical consequences. First, since no clear or complete path to fusion power now exists for any fusion concept, and since fusion is one of the few major long-term energy options, no fusion scheme should presently be abandoned unless it can be shown fairly convincingly to be unproductive. Second, in order to establish proper priorities in the face of this uncertainty, a more or less continual assessment of fusion concepts and prospects must be maintained; otherwise the program may evolve into either uncritical support of unfeasible concepts or unwarranted and premature concentration on a single concept.

QUESTIONS

1. What program does ERDA have to assess prospects for fusion and to readjust the program priorities?
2. What are ERDA's present views about the prospects for successful fusion via tokamak, magnetic mirrors, theta pinches?
3. Will ERDA be prepared in due course to request funding for "test reactors" for more than the one promising concept, or does it plan to weed the prospects down to only one before that time?
4. What is the present support for tokamak, mirror and theta pinches, laser fusion, and less-advertised schemes?
5. In the light of our past experience in building "big-machine" facilities, are the schedules realistic?
6. In view of the lack of assurance as to laboratory success, how does ERDA rate fusion as an option to either the breeder or solar energy'?

BACKGROUND

Wit hint he next century controlled fusion could provide the world with an abundant, essentially inexhaustible supply of energy with a manageable impact on the environment, but the scientific demonstration that controlled fusion can provide an economical source of power is expected to require a series of large and costly devices.

The successful development of commercial electric power by controlled fusion requires the solution of extremely difficult scientific and engineering problems. In the magnetic confinement concept, the principal scientific problems concern confining and heating a deuterium and tritium plasma to reach conditions of net energy release, There are several potential difficulties which may limit the ability to achieve a stable configuration of the plasma and to effectively supply energy to bring the plasma to thermonuclear temperatures. Many of these problems have been identified on the present generation of experimental devices,

Among the magnetic systems which have been studied experimentally over the past 2 decades, the tokamak concept has been the most successful, Because of this, the ERDA fusion plan is based primarily on rapidly developing this approach. The program calls for scaling up the tokamak device in a series of progressively larger machines leading to the construction of an experimental device which can demonstrate that significant energy can be produced by controlled fusion. The latter device, the Tokamak Fusion Test Reactor (TFTR), is projected to cost $215 million.

Although tokamaks have not displayed any behavior which would definitely preclude successful fusion power reactors, there is still uncertainty as to whether these devices can be scaled up to the required size and power generation conditions. There is considerable feeling, however, that larger machines are considered in light of the need to keep several options open for development of controlled fusion. The major difficulties will arise when deciding how to proceed beyond the TFTR stage, to the Experimental Power Reactor (EPR) phase. The ERDA fusion plan is pursuing two other lower priority magnetic confinement schemes besides the tokamak, and it is not reasonable to assume that a separate EPR could or should be financed for all three. This is to say nothing, of course, of other concepts which may develop as a result of unforeseen breakthroughs. Therefore, ERDA must take extreme care in the coming few years to ensure that they have not abandoned other paths to controlled fusion prior to a complete evaluation of their potential.

18. Technologies for Fusion

ISSUE

New technologies, which will be critical to fusion's successful development through the 1980's, requires a long time to develop and will require rapidly increasing effort with time.

SUMMARY

Many critical technological problems relate to more than one fusion concept. Some typical critical areas where much work needs to be done are:

(a) Materials and material combinations resistant to high energy neutron bombardment from the fusion reaction.

(b) Economical storage of large amounts of electrical energy to operate pulsed fusion devices.

(c) Very large superconducting magnetic systems needed for all but laser fusion schemes.

(d) Diffusion of tritium fuel into and out of reactor materials.

QUESTIONS

1. How are energy storage requirements likely to affect the range of fusion concepts that can be developed?

2. How do requirements for new materials compare with previous programs, such as fission reactor development and rocket propulsion?

BACKGROUND

Present materials with high-temperature strength need to be perhaps 10 times as resistant to radiation damage by high-energy neutrons for use in a fusion reactor. Experience shows that new exotic materials require many years to bring to the application stage, even when substantial development funds and intellectual effort are applied; 10 to 20 years is not uncommon. The long time is required not only because the basic metallurgical research depends on new ideas, but because tests may require several years under simulated operating conditions. Fission reactor technology will not provide much support, because fusion requirements are more severe.

The energy storage devices are large by electrical standards (10 to 100 megajoules), but small by chemical standards (1/2 to 5 pounds of gasoline). However, the output is required rapidly in electric form, so conventional storage schemes do not suffice: capacitors are too expensive except in a few critical applications; superconducting magnetic energy storage is untried, and means of coupling out the energy are presently unsatisfactory; and rotating machinery is generally slow. This energy storage problem may limit the options for fusion, and the limits are uncertain.

The problem of large superconducting magnetic systems can be well illustrated by considering a conceptual design for a large tokamak reactor. It may have a magnetic field of *100,000* gauss *(10* tesla), in a doughnut-shaped device whose outer diameter will be at least 15 meters. This is like a subway tunnel made into a tight loop; the force from the magnetic field is about *6,000* pounds per square inch, 3 times that in present pressurized water reactor pressure vessels. Furthermore, this huge doughnut has inlet and outlet pipes which also give magnetic perturbations that increase the local stress. All this stress must be carried by reinforcing material at superconducting temperatures (perhaps 4 degrees above absolute zero) where most materials are brittle, not ductile. Practical structures in this size and magnetic field range will require years to develop, and the cost cannot yet be estimated.

Tritium, and deuterium and lithium are the fusion fuels for the first generation of reactors. The tritium must all be generated by interaction of high energy (14 MeV) neutrons in a surrounding breeding blanket of lithium, which would be about 1 meter thick. For each fusion reaction, one hopes to generate about 1.25 new tritium atoms (a fusion reactor is in this sense a breeder). But of the fusion fuel put into the reactor, only a small fraction, perhaps 5 percent, is expected to react per pass, while the rest escapes via an “exhaust” (yet to be realistically designed for any fusion concept) where it must be captured and returned to fuel storage with virtually no loss.

A major difficulty is that tritium is a hydrogen isotope, and like ordinary hydrogen diffuses very readily into and through materials, gets trapped in the metallurgical structure (grain boundaries), and is difficult to recover.