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STATEMENT OF POSITION
OF THE
ATOMIC INDUSTRIAL FORUM, INC.

on

THE STORAGE AND DISPOSAL OF NUCLEAR WASTE

in the matter of

WASTE CONFIDENCE RULEMAKING

of the

U.S. NUCLEAR REGULATORY COMMISSION

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of)

PROPOSED RULEMAKING ON THE) PR-50, 51 (44FR61372)
STORAGE AND DISPOSAL OF)
NUCLEAR WASTE)

(Waste Confidence Rulemaking))

STATEMENT OF POSITION OF THE ATOMIC INDUSTRIAL FORUM, INC.

7 July 1980

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I. INTRODUCTION

By direction of its Board of Directors, the Atomic Industrial Forum (AIF) filed a notice on November 21, 1979 of its intent to be a full participant in the rulemaking proceeding on the storage and disposal of nuclear waste announced by the Nuclear Regulatory Commission (NRC) in a Federal Register notice of October 25, 1979. This statement is submitted pursuant to the AIF's filed intent and is believed responsive to NRC's initial notice as well as to the prehearing conference order issued by the Presiding Officer on February 1, 1980.

This statement was prepared by the AIF's Working Group on NRC Confidence Rulemaking. The Group is comprised of technical experts with many years experience in waste management and other areas of the nuclear fuel cycle.

The AIF has entered into this proceeding with the intent of contributing to the purpose of the proceeding, namely, "to assess generically the degree of assurance now available that radioactive waste can be safely disposed of, to determine when such disposal or off-site storage will be available, and to determine whether radioactive wastes can be safely stored on-site past the expiration of existing facility licenses until off-site disposal or storage is available."

A favorable finding will affirm on a generic basis NRC's confidence that radioactive wastes can be safely disposed of without undue risk to the health and safety of the public and the environment. Subsequent promulgation of a rule will remove the matter from individual licensing proceedings. But more importantly, it will allay the concerns of those members of the public who in the absence of such a finding have questioned the further development and use of nuclear power.

This statement is based on the premise that the Department of Energy (DOE) has the lead responsibility in this proceeding. This is consistent with the fact that the responsibility for high-level radioactive waste disposal lies with the federal government. Within the federal government, DOE is the agency that has been assigned that responsibility. This premise is also consistent with the fact that virtually all of the domestic research and development work that provides the technological base on which radioactive waste disposal relies has been conducted by DOE and its predecessor organizations, the Energy Research and Development Administration and the Atomic Energy Commission, and their respective contractor organizations. This statement, therefore, is intended to supplement the DOE statement submitted in this proceeding on April 15. It is generally supportive of the DOE statement except on the matter of scheduling where it is the AIF's observation that it should be possible to put into operation a waste repository in advance of DOE's earliest date of 1997. This statement is also intended to complement the submissions of other industry groups, e.g., the Utility Nuclear Waste Management Group-Edison Electric Institute.

This statement is consonant with a ruling of the Presiding Officer in his first prehearing conference order that only the disposal of spent fuel will be dealt with in this proceeding. The Presiding Officer said that waste from reprocessing should not be considered "in light of the Commission's suspension of its further consideration of reprocessing spent fuel from commercial reactors which followed the decision of the President on April 7, 1977 to defer indefinitely all civilian reprocessing of spent fuel."

Notwithstanding the intent to limit the scope of this statement, the AIF does not wish to be taken as waiving any rights by failing to preserve its position that some consideration needs to be given to reprocessed waste. Hence, we record the following observations:

> The energy content of the fissionable material in spent fuel, when used in today's reactors, represents, as noted by the AIF Study Group on Waste Management in its policy statement of October 18, 1978, "the equivalent of tens of billions of barrels of oil. In the breeder, the spent fuel resource is equivalent to trillions of barrels of oil. We believe it would be imprudent to forego this energy content until superior alternate energy supplies may become available. It is highly uncertain whether alternative non-nuclear energy sources can be developed on a time scale to affect significantly the need for efficient use of our nuclear resources."
>
> A second observation is that the disposal of spent fuel represents technologically an upper bound, i.e., the problems of heat dissipation and packaging integrity would appear to be more severe in disposing of spent fuel than in disposing of separated waste. Hence, any system accommodating adequate public health and environmental criteria for disposing of spent fuel would be more than adequate for disposing of separated waste. At the same time, the underlying technologies for the geologic disposal of both waste forms are essentially the same, as noted by the Interagency Review Group on Radioactive Waste Management (IRG) in its 1979 report to the President.
>
> A third and final observation is that the President has adopted a planning strategy, as part of a comprehensive radioactive waste management program announced on February 12, 1980, that will focus "on the use of mined geologic repositories capable of accepting both waste from reprocessing and unprocessed commercial spent fuel."

II. FINDINGS AND CONCLUSIONS

In considering the degree of assurance now available that spent fuel can be safely disposed of, the AIF has concluded:

- The amount of commercial spent fuel to be disposed of is well within manageable limits.

  The disposal of approximately 300,000 MTHM as discharged spent fuel generated in a once-through cycle by a peak of 400 GWe of installed nuclear power plant capacity will require through the year 2040 no more than five, and possibly no more than four, repositories of 2000 acres each. (Section III.1)

- The requisite technology is at hand.

  After careful and comprehensive review of available scientific and technological knowledge, the IRG reported: "Present scientific and technological knowledge is adequate to identify potential repository sites for further investigation. No scientific or technical reason is known that would prevent identifying a site that is suitable for a repository provided that the systems view is utilized rigorously to evaluate the suitability of sites and designs, and in minimizing the influence of future human activities. A suitable site is one at which a repository would meet predetermined criteria and which would provide a high degree of assurance that radioactive waste can be successfully isolated from the biosphere for periods of thousands of years." The IRG also said "it believes its technical findings to represent the views of a majority of informed technical experts." (Section III.2)

  The IRG findings are borne out in the peer review commentaries cited later in this statement. It is also borne out in the scope, direction and resolve of a number of developing waste management programs outside the U.S., all of which are based on the emplacement of high-level radioactive waste (mainly, separated waste from reprocessing spent fuel) in geologic repositories. Further, the confidence implied in the independent pursuit by most of the nations developing nuclear power in the geologic disposal of nuclear waste is confirmed in the findings of the recently completed International Nuclear Fuel Cycle Evaluation (INFCE). (Section III.2)

The environmental impact of the uranium fuel cycle, including the disposal of high-level waste, was exhaustively reviewed during the course of developing Table S-3, 10 CFR Part 51.20. Following the exchange of thousands of pages of written statements and answers to questions raised during many days of testimony before an NRC hearing board, it was concluded that existing technology can provide for safe geologic disposal with little or no environmental impact. That proceeding, based in large measure on NRC staff testimony, constitutes the most complete record that has been developed to date in the U.S. on this subject. (Section III.2.1)

- Spent fuel can be packaged and disposed of at less risk to the public than is involved in the handling and use of many non-radioactive materials routinely used in domestic commerce.

  For example, the amount of chlorine being produced today contains about 40,000 times as many potential lethal doses as all the spent fuel that would be discharged from the 50 GWe of currently operating nuclear power capacity. The amount of chlorine used over the next 60 years, provided it continues to be produced at today's rate will contain about 12,000 times as many potential lethal doses as all the spent fuel discharged over the same period from 400 GWe of installed nuclear power capacity. For the comparison to hold, all of the radioactivity in the spent fuel would have to be inhaled or ingested as would the chlorine. Although neither chlorine nor spent fuel will be handled in such manner as to permit such inhalation or ingestion, chlorine is much more accessible to man than spent fuel buried some 2000 feet underground. (Section III.3.1)

  In addition, the risks from the disposal of spent fuel discharged from the production of an assumed 10,000 GWe of nuclear power is significantly less than the risks from wastes that occur if coal is used to produce the same amount of electricity. Analyses indicate that postulated fatalities resulting from nuclear waste represent only 0.03% of the fatalities associated with a comparable coal-fired operation. (Section III.3.2)

- The shorter of the two schedules developed by the AIF indicates that it should be possible to have an NRC-licensed waste repository in operation within 10-1/2 years from the start of the site selection process.

This schedule assumes that adequate geologic characterization leading to site selection can be derived from vertical bore holes in contrast to exploratory shafts, in situ testing, and lateral drilling at depth. This is normal practice for underground excavation. Only after site selection and prior to construction authorization would site validation through extended subsurface exploration commence. (Section IV.1)

- The longer of the two schedules developed by the AIF allows 14 years from the start of site selection to operation which is 3 years shorter than the earliest schedule outlined in the statement that DOE has filed in this proceeding and 12 years shorter than the extended schedule contained in the DOE statement.

  The principal factors contributing to the longer AIF schedule are: the sinking of an exploratory shaft, in situ testing and lateral drilling at all candidate sites before a site is selected, additional time for licensing, and an extended construction schedule. (Section IV.2)

- A key to developing and maintaining any schedule is the institutional framework within which the program will be carried out. The institutional framework must include criteria and procedures for site selection, host state role, and federal regulatory approval of design, construction, operation and closure.

  Two recent developments reveal that positive steps are being taken to resolve institutional/political concerns. The first is the announcement by the President in a message to the Congress, dated February 12, 1980, of the "nation's first comprehensive radioactive waste management program." The second is the presentation on April 15, 1980 of DOE's statement in this proceeding. The DOE statement presents a comprehensive, stepwise program for implementing the President's policy. Taken together, these two developments provide a sound foundation for a finding of confidence from the standpoint of institutional and political considerations. (Section IV.4)

- Spent fuel can be safely stored on-site until (1) off-site storage becomes available, (2) off-site disposal becomes available, (3) the indefinite deferment of spent fuel reprocessing is rescinded, or (4) some combination of these alternatives can be effected.

The safety of spent fuel storage has been demonstrated for more than two decades without revealing any detectable degradation of the stored fuel. There appears to be no reason why spent fuel could not continue to be stored safely in water basins for periods well beyond what may be needed. (Section V.2)

Operating experience has demonstrated the capability to accommodate credible perturbations in operating conditions as well as to effect timely control and repair of pool hardware, including liners, in the event of accidental damage. (Section V.2)

The functional demands imposed on a spent fuel storage facility are well within the capabilities of today's technology. (Section V.2)

Spent fuel storage facilities are not particularly susceptible to degradation. (Section V.2)

- Based on the material set forth in this statement, the AIF has concluded that there is reasonable assurance that safe, off-site disposal and/or storage for spent fuel from any licensed facility will be available prior to the expiration of such licenses. AIF also concludes that, if necessary, such waste can be safely stored on-site until disposal and/or off-site storage is available.

On the basis of the above, AIF respectfully requests the Commission to exclude consideration of off-site disposal and/or storage, as well as extended on-site storage, from individual licensing proceedings. AIF further respectfully requests the Commission to confirm this action in the promulgation of an appropriate rule.

III. CONFIDENCE IN SAFE DISPOSAL

The initial question raised in this proceeding is: What is the assurance that spent fuel can be safely disposed of?

In addressing this question, it is logical to look first at the dimensions of the task, i.e., the amount of waste to be disposed of, next, at whether the accumulation of technological knowledge and experience indicates that the task can be accomplished, and finally, at the risk to public health and safety that would be involved.

III.1 Quantities Of Waste To Be Handled

The quantity of spent fuel to be disposed of first needs to be estimated in terms of the number of disposal sites that will be required. To put this information in perspective, the amount of spent fuel to be handled can be compared with the amount of waste that would be generated and would have to be disposed of if the same amount of electricity were generated by other means.

Projections of spent fuel discharges are subject to many assumptions and nuclear industry growth scenarios. Estimates prepared by government agencies and contractors (1,2,3) are not totally congruent, but they do bracket a range of expected spent fuel discharge quantities over the next fifty to sixty years. Based on these studies, a 10,000 GWe-year nuclear economy (10,000 reactor-years) through the year 2040 seems to be a reasonable basis upon which to forecast commercial high-level waste disposal requirements for the period. This cumulative nuclear generation projection is predicated on an assumed peak installed LWR capacity of about 400 GWe early in the next century, followed by a gradual capacity reduction to zero around 2040.

Assuming that 1 GWe-year requires the consumption of around 160 tons of U_3O_8, a total nuclear production of 10,000 GWe-years would consume about 1.6 million tons of U_3O_8. For a once-through fuel cycle, it appears that U.S. uranium resources could supply these requirements. U.S. Department of Energy estimates (4,5) of producible U_3O_8 at $50/lb indicate that domestic production capability, including reserves and probable potential resources, is approximately 1.8 million tons. Thus, an estimate of 10,000 GWe-years is a reasonable upper prediction of the amount of nuclear power that can be generated on a once-through fuel cycle based on consuming most U.S. resources.

This nuclear growth scenario will produce approximately 300,000 MTHM (metric tons of heavy metal) as discharged spent fuel through the year 2040. Assuming a reactor base of 60% PWR's (pressurized water reactors) and 40%

BWR's (boiling water reactors), this heavy metal tonnage would be contained in about 860,000 spent fuel assemblies (or single-assembly disposal canisters). If this same heavy metal tonnage were reprocessed to reclaim the uranium and plutonium values, the resulting high-level wastes could be solidified and packaged in about 100,000 HLW (high-level waste) canisters, assuming around three MTU equivalents could be contained within a 30x300 cm cylindrical canister.

The disposal requirements for the respective numbers of disposal canisters appears to be quite manageable. A composite reference underground waste repository(3,6) would occupy approximately 2,000 acres (about [illegible].1 square miles) and could store about 200,000 spent fuel canisters or 36,000 solidified high-level waste canisters. The total number of commercial high-level waste canisters could be accommodated by five waste repositories for a once-through fuel cycle or by three waste repositories for a U+Pu recovery fuel cycle. The parameters for this scenario are summarized in Table 1:

Table 1

Commercial High-Level Waste Repository Requirements

Bases: 10,000 GWe-Years Through Year 2040
300,000 MTHM Fuel Discharged

Fuel Cycle	Number of Waste Canisters	Reference Repositories	Occupied Area*	
			Acres	Square Miles
Once-Through	860,000	4.3	8,600	13.4
U+Pu Recycle	100,000	2.8	5,600	8.7

*This is underground area. The surface area required would be much smaller.

The land areas required for high-level nuclear waste repositories are comparatively small when one considers that, even for the larger requirement for a once-through fuel cycle, only about 13.4 square miles underground would be occupied by the repositories. Such a land requirement could be easily accommodated on a reserve such as the Hanford Reservation, which encompasses about 570 square miles. For example, if all the expected nuclear wastes were placed underground at the Hanford Reservation, they would rest under less than 3% of the area on this one federal reservation.

As stated above, the generation of 10,000 GWe-years by nuclear power stations will produce about 300,000 MTHM of spent fuel. The associated volume of the spent fuel canisters would be approximately 3.6×10^5 cubic meters. In contrast, the same quantity of electric energy generation from coal-fired power plants, based on waste generation projections from a modern 1,000 MWe coal-fired power plant,(7) would produce approximately 5.4×10^9 metric tons of ash and sludge residues. This ash would occupy about 3.9×10^9 cubic meters. This means that coal-fired power plants would produce about 11,000 times more waste on a volume basis than the equivalent nuclear power plants. In addition to these solid wastes, the coal-fired plants would also produce about 526 million metric tons of gaseous effluents, including SO_2, NO_x, and CO, but excluding CO_2.

The stack discharges from coal-fired plants also contain other contaminants. For example, the annual discharges to the atmosphere from a single 1,000 MWe coal-fired plant(7) contain about 3,000 metric tons of particulates, 190 metric tons of hydrocarbons, 6 metric tons of aldehydes, 3.3 metric tons of zinc, one metric ton of lead, and one metric ton of arsenic.

III.2 An Assessment Of The Technological Base

A key to NRC's finding that it has confidence that spent fuel can be safely managed and disposed of is its acceptance of the technology on which geologic emplacement must be based as being sound and sufficient. If waste repository operating experience were available, this experience could, of course, be used in lieu of an assessment of the technology. Lacking such experience, confidence to proceed with the design, construction and operation of a repository must be based on a combination of accumulated research and development data, peer review of expert opinion, and acceptance of a deliberate step-by-step approach that is sufficiently flexible to permit the identification and adoption of appropriate options as the program proceeds.

The DOE submission to this proceeding provides a full description of the research and development, experimental and field test data that has been accumulated to date and its applicability to the design,, construction and operation of a geologic repository. It spells out a deliberate step-by-step approach that provides ample flexibility to take advantage of new data as it is collected and to accommodate those changes that will provide improvements in the program as the work proceeds.

The purpose of the following discussion is to provide further documentation that those institutions and individuals that understand and have given serious consideration to the complexities of high-level radioactive waste management have expressed confidence that safe geological disposal is attainable and the preferred approach. Such documentation is to be found in the U.S. as well as in a number of other countries that are utilizing nuclear power and accordingly are faced with the same waste management problem.

III.2.1 The Situation In The U.S.

There is a substantial consensus in the technical community that sufficient technology exists to proceed with the disposal of spent fuel in a manner which is both safe and environmentally acceptable. An expanding data base indicates that isolation of highly radioactive material such as spent fuel can be satisfactorily accomplished in mined, deep geological formations. A Presidential committee, the IRG, has stated:(2)

> "The current rate of growth of relevant knowledge is very large. Confidence has now increased to the point where the majority of informed technical opinion holds that the capability now exists to characterize and evaluate media in a number of geologic environments for possible use as repositories built with conventional mining technology and that successful isolation of radioactive wastes from the biosphere appears feasible for periods of thousands of years."

This concept is generally recognized to provide not only technical feasibility, but also economic practicality and comparative safety.

This disposal concept is not new. As early as 1957, a committee of the National Academy of Sciences first proposed the burial of radioactive wastes in deep, geological stable rock formations.(8) Over the last two decades, extensive research and development programs (9,10) to develop the needed technology for the ultimate disposal of high-level waste have been conducted by national laboratories, universities and private industry. An overview of this intensive effort was provided by the American Physical Society:(11)

> "For all LWR fuel cycle options, safe and reliable management of nuclear waste and control of radioactive effluents can be accomplished with technologies that either exist or involve straightforward extension of existing capabilities...for normal operation of all fuel cycle options studied, potential radiation exposures from either wastes or effluents do not appear to limit deployment of nuclear power."

The NRC has likewise stated:(12)

> "For the management of radioactive wastes we appear to need neither a breakthrough in nuclear physics nor the development of dramatic new technologies. We do need to apply scientific and engineering knowledge within constraints set by openly determined societal goals."

The IRG concludes in its report(2) that mined repositories should be the concept selected for the first facility for high-level nuclear waste disposal. The U.S. Department of Energy and the U.S. Nuclear Regulatory Commission have developed risk assessment models(1,3) for geologic repositories. These studies have been supplemented by risk assessments conducted by the U.S. Environmental Protection Agency (EPA). The EPA's studies(13) indicate that the risks posed by conceptual geologic repositories are, in fact, well below those risks to humans due to common natural hazards.

In a recent comprehensive report on energy alternatives (CONAES Report), a select committee of the National Research Council considered the question of safe disposal of radioactive wastes.(14) Its assessment is generally that technology exists for safely isolating wastes; and that the major problems in implementing a program are in "overcoming several political and institutional barriers." Specifically, the CONAES Report states, "Our own conclusions and recommendations are essentially identical with those reached by the American Physical Society's study group on nuclear fuel cycles and waste management, with regard to the feasibility of radioactive waste isolation. Among other points, the study group notes waste isolation is feasible in salt and other media; that detailed technology for waste solidification, encapsulation, transport, and emplacement in mixed salt caverns is within the scope of existing knowledge; that confidence in geological isolation arises primarily from limitations on the rate of ion migration in underground formations; that continued investigation of geological and geochemical transport modeling is the most important current research topic; and that unreprocessed spent fuel should not be considered as waste, at least at this time."

It is also noted that Working Group 7 of the International Nuclear Fuel Cycle Evaluation (INFCE)(15) reviewed the management and disposal of wastes that arise from several nuclear fuel cycles. This group concluded in part:

> "The estimated contribution from waste disposal to collective dose commitment is small compared with that from natural background and of the same order of magnitude as that from other phases of the fuel cycle. In making this comparison, however, one should remember that most of the exposure from waste disposal would occur over a long time starting far in the future...
>
> "The cost of waste management and disposal is only a few percent of the value of the electricity generated and does not vary greatly between fuel cycles..."

This INFCE Working Group also commented:

> "Safety analyses and calculations of future doses are limited by the accuracy of available models to describe natural phenomena. However, the uncertainty is not such as to affect the conclusion that disposal can be carried out without undue risk to man or the environment..."

It is clear from reviewing the information base established for nuclear waste disposal that the associated problems are primarily political and institutional in nature -- not technological. The IRG Report(2) has outlined a method to establish a national political consensus through the implementation of a stepwise, technically conservative approach to the permanent disposal of nuclear waste. These steps provide a mechanism to create a coherent national nuclear waste program and fill the policy void which has created uncertainties in the public mind over whether or not a viable solution to the problem is indeed possible.(16) Public attitude toward nuclear waste management(17) is a key consideration in proceeding with site selection, design, construction and operation of a nuclear waste repository.

The best method for convincing the public that the technology exists is to expedite and proceed with a large-scale facility. It has also been observed(18) that "in the records of modern science and engineering...no single project or development...has been studied so thoroughly, before constructing the prototype, as the concept of building a geologic repository for nuclear wastes." The technology is ready -- the risks are acceptable.

The Nuclear Energy Policy Study Group(19) has stated:

> "...that nuclear wastes can be disposed of permanently in geological formations in such a way that there is very little prospect of material escaping into the environment. Moreover, even unlikely failures of repositories in the distant future would not have large consequences to human populations. This is true, independent of whether the wastes disposed of are spent fuel or the resolidified and transuranic wastes left after reprocessing and recycle."

An MIT report(20) also concludes that:

> "The risks posed by radioactive waste must be viewed in context and balanced against the benefits to be derived from activities which produce the waste and the consequences if those activities are stopped. Our security as a nation appears to rest in part on our nuclear deterrent, and the well-being of society depends on adequate energy. The world urgently needs practical alternatives to fossil energy, and nuclear fission has been demonstrated to be a practical way to generate electricity.
>
> "The central conclusion that emerges from this report is that institutions can be developed which will provide reasonable assurance of safe management of radioactive waste in the U.S. and elsewhere in the world."

When the NRC adopted Table S-3, 10 CFR Part 51.20(21) as a final rule on August 2, 1979, it did so only after having compiled a record that included thousands of pages of written statements and questions and answers and a voluminous transcript of testimony developed in eleven days of oral examination by a hearing board. It is the most extensive record compiled to date on the environmental impact of the nuclear fuel cycle, including the impact of reprocessing and waste management of both solidified high-level waste and spent fuel.

With respect to the treatment of waste management in that rulemaking, the Federal Register notice contained the following note: "The program of interim storage followed by geologic disposal is in broad outline the same waste management model considered in the original fuel cycle rulemaking, but the record developed in the present proceeding is far more extensive, particularly with respect to disposal."

Notwithstanding NRC's admonition that S-3 is to be used only for NEPA purposes to specify the environmental impacts to be considered in individual licensing proceedings as part of the environmental cost-benefit analysis for a power reactor, the following statements would appear to have a substantive bearing on this proceeding:

> "The technology for storing spent fuel elements under water in pools is well established; radioactive releases to the environment have in practice been extremely small and may be expected to remain small, even if pool storage is protracted by delays in establishing disposal facilities...
>
> "The staff assumed...that after the repository is sealed there would be no...release of radioactive materials to the environment...
>
> "With regard to this assumption of complete repository integrity, the Hearing Board identified as the major concern the question 'whether water might enter, dissolve the radioactive materials, and transport them to the biosphere.' The staff assumed such transport would not occur, for reasons summarized by the Board as 'in part based on the fact that the salt in which the waste would be buried would have existed for millions of years free of water except for a small amount of entrapped brine, and could be expected to continue to so exist. The site location would be one of low seismic and volcanic activity and with few resources important to man, so the probability of intrusion by nature or by humans would be small. Salt is plastic and would tend to heal some types of intrusions. Furthermore, if water were to reach the repository and dissolve the waste, natural barriers provided by media surrounding the salt would slow the

> rate of transport so that most of the radioactivity would decay before it would reach the biosphere.'...

III.2.2 The Situation Outside The U.S.

Some 40 industrialized nations outside the U.S. engaged in the development and use of nuclear power are also faced with managing nuclear wastes. Most of these nations are utilizing light water cooled reactors. It follows, then, that the spent fuel discharged from these reactors will be comparable to the spent fuel discharged from U.S. reactors. On the other hand, most of these nations are planning to reprocess their spent fuel. Hence, the ultimate waste form to be handled outside the U.S. will for the most part be solid, vitrified waste that has been produced from the separated high-level liquid waste coming from a reprocessing plant.

Some 17 countries are reported to be planning or developing high level radioactive waste disposal facilities: Austria, Belgium, Canada, Denmark, Federal Republic of Germany, France, German Democratic Republic, India, Italy, Japan, Netherlands, Pakistan, Russia, Spain, Sweden, Switzerland, and the United Kingdom. (22) Additionally, a number of international organizations, including the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (NEA/OECD), Commission of European Communities (CEC), Eurochemic, Nordic Council, etc., are also working on various waste management problems.

All 17 countries with waste management programs are looking to mined geologic storage as the preferred waste storage medium. Only two, Canada and Sweden, have given any serious consideration to the disposal of spent fuel; the other 15 countries are basing their plans on the ultimate waste form being vitrified solid waste. All 17 countries are planning on interim storage of either spent fuel or separated waste for a 25-30 year period prior to transfer to a geologic repository. The consensus of those countries that have done the most work in the waste management area is that an initial geologic repository will be completed in the 1990's. Therefore, in most respects, the elements of the problem to be resolved as well as the approach towards its resolution are similar, inside and outside the U.S.

The universal decision outside the U.S. to adopt mined geologic storage as the means of ultimate disposal is based on many years of study and experimentation by competent scientific and engineering personnel and institutions. It is a generally held consensus among this group that in a proper geologic medium, properly sited and having favorable geologic and hydrologic characteristics, the consequences to man from radioactive waste emplacement would be negligible even if the engineered protective package were to lose its integrity shortly after emplacement. Since most of the national programs have focused on immobilized waste (vitrified form), less information is available on the likely behavior of spent fuel in the same geologic media over the same time periods, but based on available scientific and technological evidence,(23) there is no less confidence in its negligible impact on the biosphere.

The following summary cites a few examples of specific waste management programs and activities underway outside the U.S.

III.2.2.1 Sweden

The very thorough Swedish KBS work(24,25) concludes that both vitrified waste encapsulated in lead and titanium or spent fuel encapsulated in copper canisters buried 500 meters underground in crystalline rock will adequately protect man for hundreds of thousands of years.(26,27)

The National Academy of Sciences(23) (U.S.) reported on January 16, 1980 on the adequacy of the technical data base supporting the KBS-II (unreprocessed spent nuclear fuel) conclusions on thick walled copper canisters enclosed in bentonite and on the availability of the requisite geological site. The report concluded: "...the effectiveness of this barrier to contain the radionuclides in spent fuel rods for hundreds of thousands of years has been adequately demonstrated, and the required properties for the less easily verifiable geologic barriers are therefore less stringent than in other disposal plans."

The Academy in another of its conclusions, assuming failure of the canister, stated: "...the retardations (from insolubility for uranium oxide pellets and by sorption and ion exchange on bentonite and on mineral surfaces) is expected to ensure that concentrations in moving groundwater will not reach unacceptable levels."

The significance of this KBS work is that it represents an upper bound. The protective measures assumed are believed to be much in excess of what is needed.

III.2.2.2 Canada

Canada has indicated its preference for deep geologic disposal in hard-rock formations although it is keeping its options open. Atomic Energy of Canada Limited is expected to select a demonstration site by late 1981. Construction of the facility is expected to be completed in the late 1980's. Both spent fuel and immobilized high-level waste are being studied. An assessment of engineered systems, including natural barriers, together with the results of the first "rough pathway analysis for disposal in hard-rock" have led to the general conclusion that multiple barriers can provide sufficient protection for man and the environment.(28) This statement assumes that assessments can be carried out "to evaluate the acceptability of the disposal project to the satisfaction of the scientific agencies and the general public."(29)

In a summary paper(30) the Canadian program states that since no decision has been made on fuel recycling, immobilization technology is being developed for both irradiated fuel and for separated wastes. The year 1982 is the target date for proving that this concept (burial in igneous rock formations about 500-1000 meters deep) is sound and for finding a technically suitable site. Completion and start of operations of this facility is projected for the early 1990's. Several areas in Ontario and Manitoba have been selected for study.

Of significance are the results of a Chalk River experiment where high level waste in nepheline syenite glass was buried in the ground in flowing groundwater. Extrapolation of measured dissolution rates indicated that it would take on the order of 100 million years for complete dissolution of the blocks.

III.2.2.3 Federal Republic of Germany

The Federal Republic of Germany is planning to reprocess its fuel and is therefore concentrating on solidified high-level waste. The French AVM process is being used as a reference for planning purposes, but interest has also been expressed in the PAMELA vitrification process (small beads in a metal matrix).(31) Salt domes have been chosen as the preferred geologic media and a site has been located at Gorleben in Lower Saxony.

Extensive testing is under way in the Asse rock salt mine which DWK purchased and has been using for storage of low and intermediate radioactive waste.(22)

A detailed plan for site investigations and repository design indicates the repository could be operating in the first half of the 1990's.(32)

III.2.2.4 France

France is reprocessing its spent fuel and is using its highly developed AVM technology for vitrifying separated high level waste.(33)

It has an adequate interim storage system for vitrified high level waste cylinders and is looking at rock salt, crystalline rocks and argillaceous materials for ultimate waste disposal. A rough schedule of 10-20 years is estimated for establishment of an experimental repository.(34,35)

The French "system" concept is similar to others, i.e., the "barrier concept." The first barrier is the glass matrix, followed by the canister, an adsorption medium and finally, the geologic medium itself.(35)

III.2.2.5 United Kingdom

The United Kingdom has already reprocessed high-level waste from more than 18,000 MTU of fuel. The high-level waste is currently being stored as a liquid. Two vitrification processes are being investigated, the United Kingdom FINGAL/HARVEST process and the French AVM process.(36) For geologic disposal, adequate sites of argillaceous materials, crystalline rocks and granites(37,38) are available.

A conceptual design for a hard-rock repository is underway. A demonstration facility is planned for the 1990's and a full-scale repository in the early 2000's.(39) The United Kingdom is also studying seabed disposal. In addition to the crystalline rock, argillaceous and evaporite formations have been selected for exploratory drilling. The United Kingdom is using the multiple barrier system concept and is aiming at containers having a life of 1,000 years.(22)

III.2.2.6 Switzerland

Switzerland is considering several media for a geologic repository. Granites appear to have the most promise but anhydrites, argillaceous formations and crystalline rocks other than granites are being considered. NAGRA, Switzerland's agency responsible for radioactive waste storage, has a target date of 1985 for identification, safety analysis and engineering of a specific site or sites. Expenditures of more than $125 million over the next five years are planned.(40,41)

III.2.2.7 Miscellaneous

Other countries having active waste management programs include:

- Belgium, which is developing a clay repository system located in the Boom clay formation at Mol.(42)
- Denmark, which is working on solidified high level waste disposal in salt domes and has scheduled its repository for operation by the year 2020.(22)
- Italy, whose program is based on burying separated solidified high-level waste in argillaceous sediments in Southern Italy. Operations in a test repository are expected to start in the mid-1980's.(22)
- The Netherlands, which has an active geologic waste isolation program concentrating on salt dome repositories sited on state owned properties.(22)

III.3 Risks To Public Health And Safety

To put in perspective the risk to public health and safety that would be involved in disposing of radioactive waste (spent fuel), it may be helpful to consider the following questions:

How does the toxicity of spent fuel compare with the toxicity of other materials used in domestic commerce?

What would be the limiting consequences of radioactivity from spent fuel emplaced in a geologic repository reaching man's food and water supplies?

How does the risk from the disposal of spent fuel compare with the risks faced by the average person from much more familiar activities?

The discussion below provides answers to these questions.

III.3.1 Toxicity Comparisons

There has been a great deal of publicity about the high toxicity of spent fuel. How does it compare with the toxicity of other substances that are commonly handled in the U.S.?

One approach would be to compare the total number of potential lethal doses of common chemicals used in the U.S. with the number of potential lethal doses contained in spent fuel. This comparison is shown in Table 2.(43) As shown, all of the chemical substances listed in terms of the number of lethal doses produced each year are more toxic than spent fuel. One should also consider the relative availability of these toxic substances to man. The chemicals listed are available to the public with essentially no controls, whereas the availability of spent fuel is restricted from the public by a number of legal, institutional and technological constraints.

Table 2

Number Of Potential Lethal Doses Contained In Various Toxic Substances

Based on 1980 Generation Rates

Toxic Substance	Number of Potential Lethal Doses
Spent Fuel (as discharged)	$1x10^{10}$
Spent Fuel (after 200 years of aging)	$1x10^{8}$
Chlorine Gas	$4x10^{14}$
Phosgene Gas	$2x10^{13}$
Hydrogen Cyanide	$6x10^{12}$
Ammonia	$6x10^{12}$
Barium	$9x10^{10}$
Arsenic	$1x10^{10}$

Nuclear critics often point out that spent fuel will remain toxic for a very long time. True, but barium and arsenic will retain their toxicity forever. Moreover, these materials will not be buried deep underground as will spent fuel; in fact, most of the arsenic is used as a herbicide and remains scattered around on the ground, largely in areas where food is grown. A further argument sometimes advanced is that toxic elements are already here on earth whereas the radioactivity in spent fuel is artificially produced. True again, but half of the arsenic used in this country is imported and therefore, "artificially" introduced into our domestic environment.

Given the fact that we must reduce our dependence on oil and gas (especially imported oil), our prime alternate energy source, other than uranium, for producing electricity is coal. In producing electricity from coal, the toxic gases and particulate matter emitted constitute hundreds of times more lethal doses of toxic material than the radioactivity in spent fuel.(44) Needless to say, the toxic wastes from coal burning are not buried deep underground, but rather are distributed in an uncontrolled manner throughout our environment.

In comparing toxicities, it should be recognized that the health effects of radiation are far better understood and quantified than are the health effects of chemicals. To be fairly certain that health effects are not being underestimated, toxicities assigned to chemical poisons should be multiplied manyfold, whereas those assigned to radioactivity are already chosen to represent a conservative upper bound, consistent with available scientific information.

III.3.2 Perspectives On Actual Risks

The fear is frequently expressed that the long lifetime toxicity of spent fuel precludes effectively keeping it isolated from man. Those expressing such concern assume that our political, economic, and social system may not survive for the thousands of years during which the toxicity in spent fuel will remain high. Such concerns, however, apply only to our environment here on the surface of the earth. The environment deep underground where spent fuel would be placed is very different. It consists essentially of rocks that have been in place for millions of years.

A recent study (45) derives the number of eventual health effects from buried high-level waste in a manner which relates the release of the waste to man's environment to known gradual dissolution of underground rocks into aquifers. If an atom of buried spent fuel is assumed to have the same probability of being leached out by ground water and eventually getting into food and water supplies as an atom of average rock already submerged in ground water (referred to as "reference rock"), the eventual consequences to human health would be about 0.0074 fatalities per GWe-year of nuclear power.* This total would not be reached for about 13 million years.

Under this postulated scenario, spent fuel discharged from the projected 10,000 GWe-years of nuclear power plant operation could result in 74 eventual fatalities. This total number of fatalities would occur over the 13 million years previously cited, inasmuch as this is the time estimated to release all the spent fuel material from the ground. One way to put this figure in perspective is to compare it with the health effects associated with natural background. The annual natural background dose in the United States is approximately 100 mrem. Utilizing the 1970 U.S. census figure of 200,000,000 people, an annual 20,000,000 man-rem figure is obtained. Based on the ICRP(47) and BIER(48) reports, there are 1 to 1.8 fatalities per 10,000 man-rem. Based upon this information, there will be 2,000-3,600 fatalities per year from natural background. Natural background fatalities over 13 million years will be 26-47 billion. Compared to these effects, the 74 deaths attributable to spent fuel disposal will be an infinitesimally small contribution.

Further, if we assume that the 10,000 GWe years of electricity provided by nuclear power were replaced by coal generation, we can compare the postulated fatalities of the two energy options. About 25 fatalities/GWe-year result from the wastes produced by coal-burning power plants. (49) Assuming this additional 10,000 GWe-years of coal plant operation, 250,000 fatalities would result. These are present fatalities, i.e., occurring during the next 60 years. The 74 fatalities from spent fuel disposal would occur over 13 million years. However, even assuming they occur in the next 60 years, they would represent only 0.03% of the fatalities associated with a comparable coal-fired operation.

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*The work reported in Reference (45) considered the burial of vitrified high-level waste which can be shown to result in approximately 10 times fewer fatalities. The results have been corrected to account for isotopic differences between spent fuel and high level waste. The 0.0074 fatalities does not include any contribution from uranium since it is being returned to the ground in a more secure condition. The 0.0074 fatalities per GWe-year compares with 0.00125 fatalities estimated by the NRC.(46)

Finally, another upper limit way to place these health effects in perspective is to derive what they mean in terms of reduction in life expectancy. To do this, however, requires an equilibrium levelized scenario of nuclear power. Thus, if spent fuel is discharged and buried from a continuous 400 GWe of nuclear capacity (over a time period comparable to the millions of years required for the buried waste to return to man's environment), the amount of radioactive waste returning to the biosphere millions of years in the future would result in a fatality rate of three persons per year. A fatality rate of three per year represents a reduction in life expectancy of 0.007 days or 10 minutes for the average American. This is the risk an overweight person takes in eating one extra slice of bread during his life, the risk to an individual in smoking one cigarette during his lifetime, the risk of one extra street crossing by a pedestrian every three years, and the risk of driving an extra 0.2 miles per year.

Further perspective on the 10 minutes of lost life expectancy from buried spent fuel may be gained by considering other factors that result in life expectancy reduction. The number of days in lost life expectancy due to other common risks(50) are:

Table 3

Lost Life Expectancy Due To Common Risks

	Days
Remaining unmarried (male)	3,500
Smoking one pack of cigarettes/day	2,200
A career as a coal miner	1,100
Being 20% overweight	900
Dropping out of elementary school	850
Being an unskilled laborer	700
Marrying an unskilled laborer	700
Construction worker - accidents only	300
Motor vehicle accidents	200
Use of alcohol	130
Accidents in the home	95
Suicide	95

Each of these dangers reduces life expectancy by many thousand times the 0.007 days of life expectancy we would lose from buried spent fuel.

Nuclear waste is clearly a trivial contributor to life's everyday dangers and is not deserving of the high degree of public concern and apprehension that it attracts. Many of the items in the above list could be substantially reduced by technological improvements. For example, motor vehicle fatalities could be reduced by impact absorbing guard rails, or better highway lighting and signs. But the principal avoidable dangers in our society are due to social and behavioral problems. They are what we should be worrying about if we want to reduce the hazards in our lives -- not nuclear waste.

IV. SCHEDULE FOR ESTABLISHING REPOSITORIES

The second question raised in this proceeding is: When will repositories for the disposal of spent fuel be available?

In an attempt to answer this question, the AIF has developed two reference schedules. Both schedules include site selection, design, and construction of an initial repository, it being assumed that less time will be required to bring subsequent repositories into operation. Both schedules are compatible with state-of-the-art waste management technology, proposed NRC licensing procedures, and current CEQ (Council on Environmental Quality) guidelines for the implementation of NEPA (National Environmental Policy Act). The geologic medium assumed in both schedules is bedded salt.

A variance of 3-1/2 years between the two schedules is primarily due to different assumptions on the time needed for site selection and facility construction. Reference Schedule I is consistent with the Government's objectives and believed achievable. It is the schedule of AIF's preference. Reference Schedule II is based on a more deliberately paced sequence of steps recommended by the IRG(2) and reflected in the radioactive waste management program outlined by the President.(51)

IV.1 Reference Schedule I

Reference Schedule I shows a total time span from start of the formal site selection process to repository operation of 10-1/2 years. The schedule allows 36 months for DOE site selection, 39 months from site selection to construction authorization, and 45 months for construction.

The schedule assumes that a SCR (Site Characterization Report) will be prepared in accordance with the proposed licensing procedures of 10 CFR Part 60.(52) A single SCR is planned to cover all candidate sites derived from the site screening process. Though the NRC staff has indicated only seven months are required for SCR review,(53) 12 months have been allowed to assure adequate time for state interaction. Following issuance of the FSCA (Final Site Characterization Analysis) by the NRC, 12 months are available before site selection to implement NRC comments into the site characterization program.

It is assumed that adequate geologic characterization of the site leading to site selection can be derived from surface exploration techniques such as vertical bore holes and geophysical tests, as opposed to exploratory shafts, in situ testing, and lateral drilling at depth. This approach is consistent with a proposed amendment to 10 CFR Part 51(54) which provides procedures for the review of alternate sites for nuclear power plants under NEPA. The proposed rule states:

> "Reconnaissance level information, i.e., information or analyses that can be retrieved or generated without the performance of new, comprehensive site-specific investigations, is normally adequate as a basis for identifying candidate sites and for selecting a proposed site.
>
> "While detailed site-specific baseline studies on the proposed site are required to support the remainder of the NRC's environmental review, these data normally add little to NRC's determinations regarding alternative sites. These detailed studies principally serve as a basis for decision-making regarding mitigative measures to reduce (on a practicable basis) any residual adverse environmental impacts. However, they also serve a secondary purpose in that they confirm judgments on likely adverse environmental impacts that are made using reconnaissance level data.
>
> "The rationale for the rule on reconnaissance level information proceeds from the premise that major adverse environmental impacts can normally be identified using this type of information. Therefore, the added costs of requiring detailed site-specific investigations and analyses on all candidate sites normally would not be justified with respect to any marginal improvement in environmental protection."

Based on current studies of geologic repositories, the rationale for requiring only reconnaissance level information for site selection of nuclear power plants seems to apply equally well to geologic repositories.

Following DOE site selection and prior to construction authorization, an exploratory shaft will be sunk at the selected site, and in situ testing and lateral drilling will be performed as required for validation of the site and to obtain information needed to complete the repository design. The 18-month period required for site validation is based on the WIPP (Waste Isolation Pilot Project) schedule for performing similar activities. Note that final site selection is validated during the licensing review process, which involves the NRC, the affected states and the public, and culminates with the issuance of the Construction Authorization.

Title I is assumed to start immediately following site selection and to extend for 12 months. This time period should be sufficient due to the lengthy conceptual design period preceeding Title I. The ER (Environmental Report) and SAR (Safety Analysis Report) are tendered to the NRC for licensing review at the completion of Title I. The

14-month NRC review period leading to the ES (Environmental Statement) and SER (Safety Evaluation Report) is consistent with an NRC staff estimate of 12 to 18 months.(53) It is further assumed that ACRS (Advisory Committee on Reactor Safeguards) review is not required.

The schedule also assumes that for public lands the Department of Interior will not request legislation for permanent land withdrawal until an NRC staff finding of site suitability has been completed. Consequently, the DOE request for land withdrawal is not initiated until the NRC staff has completed its environmental review and issued the Environmental Statement.

Reference Schedule I is based on an estimated 45-month construction period followed by 6 months for facility checkout. The 45-month construction period is 5 months longer than the construction period currently scheduled for WIPP. Public hearings are not assumed to be necessary at the operating license stage since all major issues should have been addressed and resolved prior to the start of construction. However, if public hearings are considered necessary, the SAR update and operating license review can be scheduled earlier in the construction phase.

IV.2 Reference Schedule II

Reference Schedule II shows a total time span from start of the formal site selection process to repository operation of 14 years. The schedule allows 60 months for DOE site selection, 45 months from site selection to construction authorization, and 54 months for construction. The principal differences between this schedule and Reference Schedule I are outlined below.

Reference Schedule II assumes completion of the NRC/State review of the SCR before site characterization is initiated. It also assumes that a validation program consisting of sinking an exploratory shaft, in situ testing, and lateral drilling will be performed for each candidate site during the characterization period and before a site is selected. The early SCR preparation and review, and the site validation program during site characterization adds two years to the period before site selection.

Reference Schedule II also adds 6 months to the SAR review period to allow for review by the ACRS. Finally, the schedule increases the construction period by 9 months and allows time for public hearings at the OL (operating license) stage.

All of the above changes are consistent with the schedules proposed by the IRG(2) and the President's Waste Management Program.(51) However, as was stated earlier, the AIF believes a much shorter schedule can be realized without jeopardizing this country's waste management objectives. Reference Schedule I would not only satisfy such objectives, but would result in significant savings in both dollars and effort.

IV.3 Relationship To DOE Schedule

The DOE schedules for development of the first HLW (high-level waste) repository range between 17 and 26 years,(55) whereas the AIF proposed schedules range between 10-1/2 and 14 years. The major differences between these schedules are best illustrated by the comparison of estimated durations of major activities shown in Table 4.

The DOE schedules are believed to be extremely conservative. Consequently, very high confidence should exist that these schedules can be achieved even considering the uncertainties associated with the institutional considerations discussed below. On the other hand, the AIF Reference Schedule I is believed to be realistically achievable based upon today's knowledge of nuclear waste disposal technology, NRC regulatory requirements, and procedures for compliance with NEPA.

Table 4

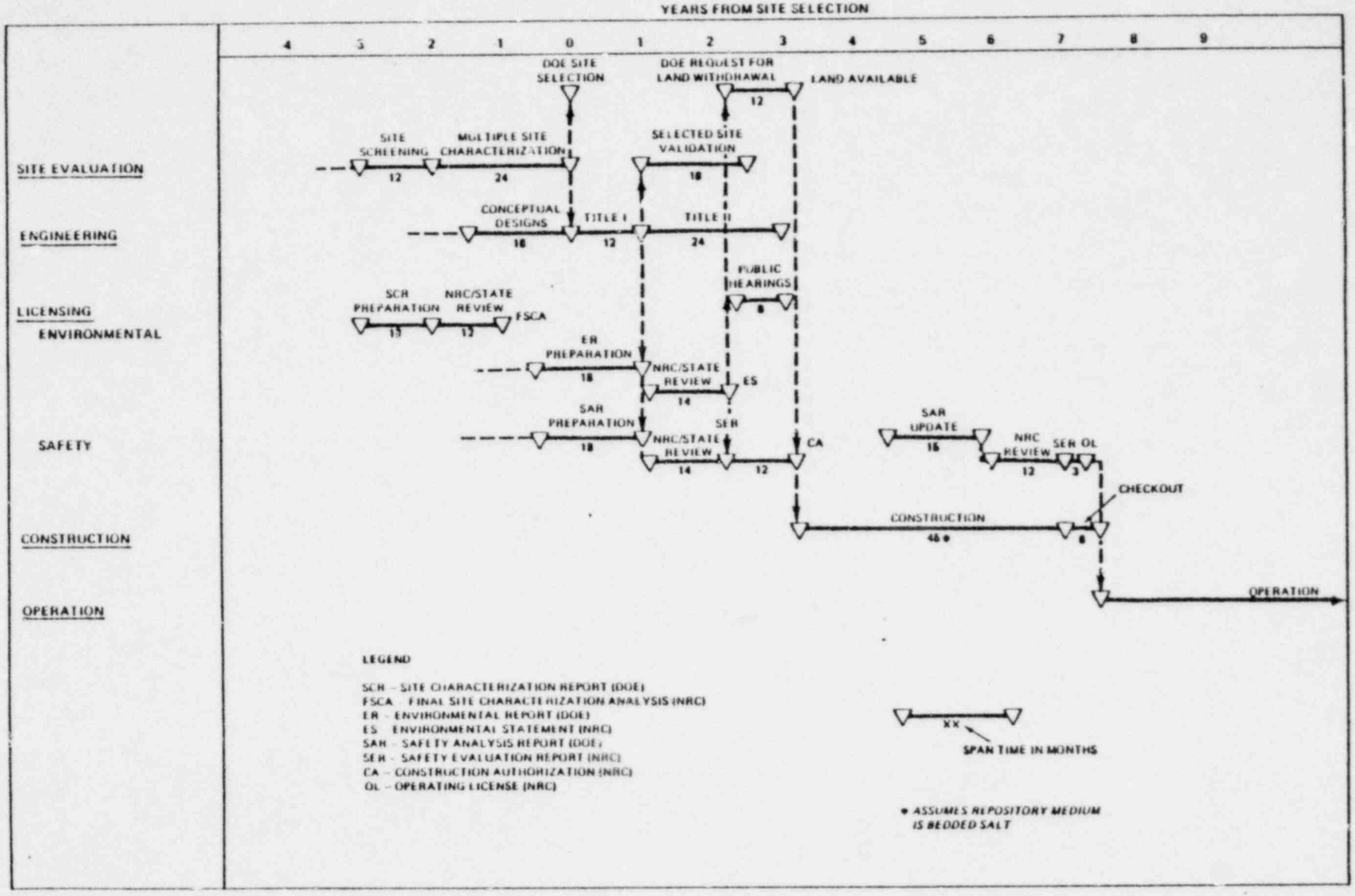
Durations Of Major Activities In Repository Development Schedules

	Duration, Months			
	AIF		DOE	
Activity	Reference I	Reference II	Reference	Extended
Site Selection Decision	36	60	81	126
Preliminary and Detailed Design	36	36	75	84
Application Preparation (including PSAR & ER)	18	18	27	36
Regulatory Review (from Application to CA)	26	32	48	60
Construction	45*	54*	63-96**	75-108**
Checkout Tests	6	6	6	9
Total Duration	126*	168*	205-238**	284-317**
(First Repository Operation Date)	(1991)	(1994)	(1997-2000)	(2004-2006)

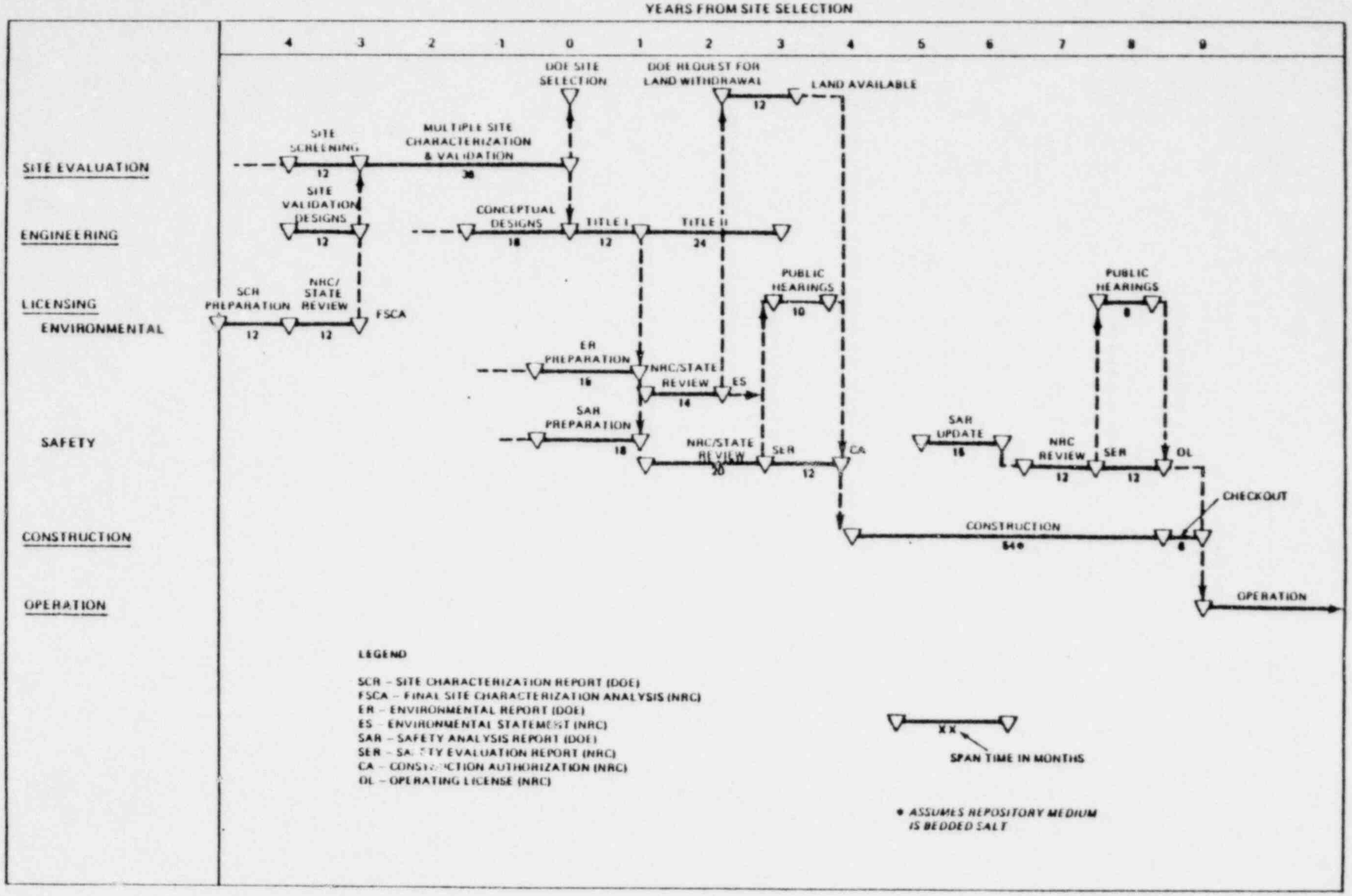
* Assumes repository medium is bedded salt.

**Depends upon mineral type selected. Shorter duration is based on bedded salt. Longer duration is based on hard rock.

REFERENCE SCHEDULE I FOR HLW REPOSITORY DEVELOPMENT



REFERENCE SCHEDULE II FOR HLW REPOSITORY DEVELOPMENT



LEGEND

SCR – SITE CHARACTERIZATION REPORT (DOE)
FSCA – FINAL SITE CHARACTERIZATION ANALYSIS (NRC)
ER – ENVIRONMENTAL REPORT (DOE)
ES – ENVIRONMENTAL STATEMENT (NRC)
SAR – SAFETY ANALYSIS REPORT (DOE)
SER – SAFETY EVALUATION REPORT (NRC)
CA – CONSTRUCTION AUTHORIZATION (NRC)
OL – OPERATING LICENSE (NRC)

** ASSUMES REPOSITORY MEDIUM IS BEDDED SALT*

IV.4 Institutional Considerations

As expressed above, there are no major technological obstacles to siting, building and operating a repository. Nonetheless, in assessing the bases for a finding of confidence that the nation will actually have an operating repository in the next two decades, NRC will no doubt consider institutional/political matters, including criteria and procedures for site selection, host state role, and federal regulatory approval of design, construction, operation and closure. Two very recent developments reveal that positive steps are being taken to resolving institutional/political concerns. These developments take the form of the President's program(51) submitted to the Congress on February 12, 1980* and the presentation, on April 15, 1980, of DOE's prepared statement(55) in this proceeding. The DOE statement presents a comprehensive program to implement the President's policy. Taken together, we conclude that these major initial steps provide a sound foundation for a finding of confidence from the standpoint of institutional and political considerations. With rational implementation (including legislation, NRC criteria and state concurrence), NRC can have a high degree of confidence that these programs will result in one or more waste repositories in operation by the end of the century despite the presently controversial nature of siting and repository approval. This finding is bolstered by the recognition that the technical aspects associated with permanent storage of high-level nuclear wastes are presently susceptible to solution using known technology in modest extrapolations without major breakthroughs.

Independently of Administration initiatives, the Congress has introduced a number of pieces of proposed legislation that clearly indicate the intent of the Congress to see the waste management problem resolved. Such action also reveals the confidence of the Congress that the problem can be resolved. Because of the

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*President Carter announced that he is "establishing this Nation's first comprehensive radioactive waste management program." The President's proposal sets forth guidelines for the development of a comprehensive national program for the management of "all types of radioactive wastes" to be implemented by the Department of Energy and other federal agencies, and providing for an "effective role" for state and local governments.

variety of legislative proposals suggested, no single policy has yet been distilled from these Congressional initiatives. It now seems likely, however, that such a distillation will be prompted by the initiative taken by the Administration, using the President's plan as a point of reference. It seems equally likely that the Congress will take steps to shorten the schedules outlined in the Administration's program so as to assure the operation of a high-level radioactive repository by the mid-1990's.

V. INTERIM STORAGE

The third and final question raised in this proceeding is: Can spent fuel be safely stored on-site past the expiration of existing facility licenses until off-site disposal or storage is available?

Having already addressed the schedule for a disposal repository, what now needs to be considered is the integrity of on-site and off-site storage. Since spent fuel has been safely stored on-site at some facilities for as long as 20 years without revealing any detectable degradation of the spent fuel or of the basins in which it has been stored, the question really goes to the safety of long-term storage, i.e., for periods appreciably longer than initially contemplated.

A near-term alternate to the repository is the interim storage of spent fuel at away-from-reactor (AFR) facilities. The issue here is the same as for the repository: When will such off-site storage be available? We have reviewed the DOE statement(55) on this question and concur with its conclusion that use of either existing facilities (Morris, West Valley or Barnwell) or construction of new large AFR's can be timely with respect to the needs for such facilities.

The corollary question in this proceeding: If disposal or off-site storage will not be available until after the expiration of the licenses of certain nuclear facilities, can spent fuel be safely stored on-site until such disposal is available? The information presented is focused mainly on those concerns that might arise due to the extension of the storage period.

Based on our analysis and reviews of the operating experience that has been accumulated over the past 30 years, we conclude that spent fuel can be safely stored on-site in the spent fuel pool for decades - sufficiently long to permit either permanent disposal facilities or appropriate interim off-site facilities to become available under the longest schedules contemplated for such facilities.

V.1 Background On Spent Fuel Storage

An extensive background of experience in the storage of spent nuclear fuel in water-filled pools has been accumulated during the last 30 years both in the U.S. and overseas. This experience has been presented in the DOE submission to this proceeding(55) and is summarized as follows:

> "The technology of water pool storage of spent fuel is not only available but is well established through more than 30 years of work at government and industrial facilities. Dry storage of spent fuel by several different techniques has been the subject of

> a significant level of research, development, and demonstration, and promises to be a technically viable alternative to water pool storage. Thus, there are a number of technically suitable alternative methods of spent fuel storage in existence at the present time.
>
> "The regulatory framework, industry standards, and design requirements for the water pool storage of spent fuel currently exist.
>
> "The licensing of water pool storage of spent fuel has been practiced routinely by the Commission and its predecessor agency for nearly 20 years and is being practiced at the present time.
>
> "Zircaloy-clad spent fuel has been stored under water for periods of up to 20 years and stainless steel-clad fuel has been so stored for periods up to 12 years, with no evidence of degradation as a result of such storage. Studies of the corrosion aspects of water pool storage indicate that there are no obvious degradation mechanisms which operate on the cladding at rates which would be expected to cause failure in the time frame of 50 years or longer. Moreover, in the unlikely event that severe deterioration of the cladding were to develop, the spent fuel could be encapsulated to provide the necessary integrity for indefinite storage."

Each operating nuclear power plant contains a spent fuel storage pool that has been designed in accordance with appropriate codes, standards and NRC requirements.(56,46)

The Safety Analysis Report for the plant reviews the safety of storage in the spent fuel pool and the operating license permits the storage of fuel of specified design in the pool for periods of time up to the duration of the operating license. Initially, it was believed this storage period would be short and that spent fuel would be shipped to a reprocessing plant within a year or so after discharge.

In recent years, many utilities have applied for license modifications to increase the capacity of their spent fuel pools by installing high capacity storage racks. Licenses for such modifications have been requested by 55 reactors, and as of March 6, 1980(57) such amendments had been granted for 34 reactors. Each of these amended licenses has been based on a revised safety analysis for the specific plant. Each modification has been carried out in accordance with the applicable NRC guides and codes and standards. The NRC has noted, with respect to the licensing of the expansion of the capacity of spent fuel pools:(56)

> "Each of these applications was evaluated on an individual basis with findings in each case that:
>
> > At-reactor spent fuel storage can be increased;
> >
> > The actions can be taken with no sacrifice of public health and safety; and
> >
> > The environmental impact of the proposed increased at-reactor spent fuel storage was negligible.
>
> "It should be kept in mind that increased at-reactor spent fuel storage involves only aged fuel (at least one year since discharge) which has orders of magnitude less hazard potential than fuel freshly discharged from a reactor."

Thus, it can be concluded that a significant background of experience in the design, construction, safety review, and licensing of spent fuel storage pools at reactor sites has been amassed over the last 30 years. A well-defined methodology, defined by approved codes, standards, and design practices, is in place that assures a safe facility, engineered to meet specific site requirements, can be built and operated.

V.2 Operating Experience Of Spent Fuel Storage Facilities

The storage of spent fuel in water-filled pools has been practiced in the United States and elsewhere for many years. The performance of spent fuel in these pools has been monitored over extended periods, and these observations demonstrate that the storage of spent fuel is safe and presents minimal risk to the public. Summaries of this experience base are presented in several documents(46,58,59) and need not be repeated here. However, the following observations are pertinent:(58)

> "Fuel handling experience in the U.S., going back to 1959, has not revealed any instance where Zircaloy-clad, uranium oxide fuel has undergone corrosion or other chemical degradation in pool storage....This favorable experience is corroborated by experience in other countries with the following maximum pool residence for Zircaloy-clad fuel as of late 1977:

Canada	14 years
United Kingdom	11 years
Belgium (MOL)	10 years
Japan	9 years
Norway	7 years
Sweden	5 years

> "Spent fuel with cladding defects has been stored, handled, and reprocessed without substantial problems. Case histories summarizing experience with defective fuel have been documented. Methods have been developed to deal with defective fuel, including closed canisters for isolating the fuel, and hoods to channel any released gases to the pool building ventilation system. In the U.S. these measures are seldom needed. The large majority of defective U.S. bundles are stored on the same basis as intact fuel. Two aspects account for the variable storage characteristics of the defective fuel: (a) the fuel rod releases its gaseous radioactive inventory to the reactor coolant when the defect develops; additional gaseous releases in the pool are small; (b) exposed UO_2 pellets are quite inert to pool water and have degraded very little in pool exposures of several years."

> "Degradation mechanisms from exterior and interior fuel rod surfaces have been assessed. General corrosion rates are summarized -- indicating that under pool storage conditions the corrosion rates are very low."

Specifically, the extrapolated corrosion rates indicate less than 0.1% penetration of the clad at 100 years for Zircaloy-clad fuel.

> "There is a general consensus from the assessments that no mechanism has emerged which offers a threat to fuel cladding integrity for storage over a period of a few decades. In some cases, the assessments are based on short-term data or are inferred from behavior of similar systems. However, in summary, the corrosion assessment leads to the conclusion that fuel bundle materials are corrosion resistant and the pool storage environments are relatively benign. While some slow degradation mechanism cannot be fully ruled out, it appears to be unlikely."

Several evaluations of the overall risk of the use of nuclear fuel (and coal) for power generation show, first, that nuclear power is comparatively safe, and, second, that fuel storage has the least risk of any part of the fuel cycle. These comparative risks are shown in Table 5:(46)

Table 5

Comparison Of Potential Excess Mortality Of Nuclear Versus Coal Power Generation Per 0.8 GWY(e)

Fuel Cycle Component	Nuclear	Coal
Resource Recovery (mining, drilling, etc.)	0.32	0.3-8.0
Processing	0.073-1.1	10
Power Generation	0.13-0.3	3-100
Fuel Storage	≈ 0	≈ 0
Transportation	0.01	1.2
Reprocessing	0.057-0.065	---
Waste Management	0.001	≈ 0
Totals	0.59-1.7	15-120

Based on the extensive experience base, including many evaluations and observations, it is concluded that the storage of spent fuel from light water reactors is a fully developed technology that is very safe and presents little risk to the public. The NRC concluded in its final GEIS on the Handling and Storage of Spent LWR Fuel:(46)

> "The storage of LWR spent fuel in water pools has an insignificant impact on the environment, whether such pools are at reactor sites or away therefrom....The technology of water pool storage is well developed....Radioactive waste that is generated is readily confined and presents little potential hazard to the health and safety of the public."

V.3 Consideration Of Extended On-Site Storage Of Spent Fuel

The previous sections have shown that, based on extensive experience, the storage of spent LWR fuel in water-filled pools is an established technology that presents very little risk to the public. This conclusion is based on extensive experience and presents a base for the evaluation of the safety of spent fuel storage in reactor pools for an extended period after the expiration of the license of certain reactors. The following sections discuss the pertinent factors that need to be considered in an evaluation of extended on-site storage.

V.3.1 Period Of Storage On-Site

One of the purposes of this proceeding is to consider the supposition that off-site storage may not be available until after the expiration of an operating license. It is possible that some fuel might be stored on-site for a period of up to two or three decades after the expiration of a reactor's license. It does not, however, appear to be necessary to consider longer time periods since so many options are available for off-site storage or disposal within that time frame, even when considering the longest schedules and contingencies. Appropriate facilities could be made available within a 6-10 year period.

Thus, we suggest that a realistic estimate of the time period for consideration of extended storage at a specified licensed facility need be no longer than two to three decades after shutdown of the facility and, in practice, will most likely be much shorter.

V.3.2 Spent Fuel Properties

The requirements placed on a spent fuel storage system to assure safety of storage and to avoid unacceptable releases of radioactivity to the biosphere are determined primarily by the characteristics of the spent fuel and, to a lesser extent, by site-related considerations. Methods for designing spent fuel storage systems to meet these requirements are well-defined and proven as previously referenced. Essentially, all the spent fuel characteristics that define the requirements of a safe storage system are at their peak values immediately upon discharge from the reactor and decrease with time. The properties of spent fuel that need to be considered when evaluating the safety of extended storage are nuclear reactivity, heat generation, and contained radioactivity. These characteristics are considered in the following sections.

V.3.2.1 Nuclear Reactivity

Upon discharge from the reactor at the end of its useful life, spent fuel is considerably less reactive than unirradiated fuel. However, all spent fuel storage facilities are designed to safely store fresh fuel at the maximum reactivity for which the facility is licensed. The reduced reactivity of spent fuel affords a significant added margin of safety during storage.

Assurance of subcriticality for spent fuel storage arrays is relatively simple and straightforward since the fuel reactivity does not change significantly during storage and ample safety margins are employed. The stored fuel assemblies are substantially subcritical individually and storage arrays can readily be maintained in a subcritical condition by limiting the extent of neutron interaction among the fuel assemblies in the storage array. The control of neutron interaction is accomplished by combinations of well-demonstrated methods that are based on absorption of neutrons in the basin water, in structural materials employed in the storage array or in strong neutron absorbers incorporated in the storage array. Maintenance of subcriticality throughout an extended storage period requires only that the mechanisms employed to limit neutron interaction be shown to remain effective under all credible conditions that might be encountered.

V.3.2.2 Heat Generation

Following discharge from the reactor, the heat of radioactive decay declines rapidly as shorter-lived fission products decay away. By the time the spent fuel has aged for a year, the decay heat rate is reduced to approximately 0.5% (a factor of 200) of that at the time of shutdown. Ten years after discharge, the decay heat rate of the spent fuel has reduced another tenfold (or a factor of 2000). Since the prolonged storage of spent fuel will be concerned primarily with fuel aged appreciably more than a year, the cooling requirements will be relatively modest. This results in low temperatures within the fuel and at the fuel clad surface and assures that any system designed to safely handle freshly discharged fuel can easily accommodate aged fuel.

V.3.2.3 Contained Radioactivity

Spent fuel is highly radioactive. This radioactivity, however, decreases rapidly with time in a manner comparable to the decay of heat. The radioactivity inventory in spent fuel as a function of time is shown in the following table.(56)

Table 6

Radioactivity Present In Spent Fuel
Megacuries Per Metric Ton Of Uranium Charged To Reactor

Decay Time - Days After Discharge	0	160	365	3,650
Fission Product Nuclides	165	4.25	2.06	0.523
Actinides and Their Daughter Elements	20.7	0.081	0.075	0.048
Light Elements & Fuel Element Construction Materials	0.213	0.060	0.027	0.003

As shown in Table 6, the fission product nuclides are predominant. However, 98.8% of this activity decays away within the first year. For freshly discharged fuels a principal concern is the 8-day I-131 which is absorbed by plants, animals and humans, particularly in natural iodine deficient inland locations. However, since the quantity of I-131 present in discharged fuel is reduced by a factor of about a million in the first 160 days of decay, it is not a major concern for the long-term storage of spent fuel.

Several of the fission product nuclides are of concern during long-term storage such as Kr-85, Cs-137, and others. However, all evidence shows that the risks of release of these nuclides is small and is decreasing with time after discharge.

V.3.3 The Extended Storage Environment

V.3.3.1 Potential Inventory

Typically, nuclear reactors are licensed to operate for 30-40 year periods. The storage capacity of the spent fuel pool at currently operating reactors, and those under construction, varies considerably because of the numerous expansion plans that have been developed in recent years. However, a range of 5-20 annual discharges encompasses the capacity of all current reactor pools. Thus, for a reactor to operate for 40 years, it may be necessary that on-site storage be expanded or that fuel be shipped to off-site storage facilities. The shipped fuel will generally be the oldest fuel; however, there may be some exceptions to this.

At the time of termination of an operating license, a reactor pool may then have up to 20 annual discharges in storage, including one full core that has recently been discharged. The rest of the fuel will have been aged for a span of one to twenty years.

V.3.3.2 Extended Storage Operations

The operational requirement during extended storage will be to maintain the status quo, i.e., to continue all those procedures and systems which are normally required to assure safe storage of spent fuel during the earlier operation period. Some slight modifications in operating procedures might be appropriate, such as increased inspection of stored fuel and systems.

V.3.3.3 Continuity Of Reactor Services

Continued storage of fuel at a reactor will require the continuity of certain services and facilities required for safe operation of the spent fuel storage system. The important facilities and services include: (1) heat removal systems, (2) water purification systems, (3) ventilation and air filtration, (4) electrical supply, (5) security and safeguards, and (6) pool maintenance and operation. These services are on-site and the demand on them will be well within the design capacity of the plant.

V.4 The Safety Of Extended Storage

A safety analysis of extended storage needs to consider any failure mechanisms that might result as a function of the extended time period when fuel is in the pool. The only failure mechanisms which cannot be considered as insignificant are those arising from gradual degradation of the fuel cladding, or those arising from some gradual failure of the pool liner or of any component failures that might be essential to continued heat removal. It is also necessary to consider any incremental risks due to a loss of security, i.e., sabotage.

V.4.1 Fuel Cladding Failure

A thorough assessment of operating experience to date(58,59) shows that failure of fuel cladding due to corrosion is extremely slow in water-filled pools. In fact, external corrosion of the cladding is shown to be almost insignificant over a time period of several decades. Some failure of cladding during an extended period of storage from other mechanisms such as hydriding, fission product attack, stress corrosion, etc., cannot be fully ruled out.

However, the conditions in the storage pool are benign, temperatures are much lower than in the reactor, and any degradation of the cladding is expected to be small over a storage period up to 50 years or more.(58,59,60) Thus, no sudden rash of failures would be expected in the pool.

A clad failure in relatively old fuel is comparatively insignificant relative to a clad failure in freshly discharged fuel. The I-131 will have decayed. The principal effect of any clad failure would be the release of the mobile portion of the Kr-85 contained in the gas plenum of the failed rods.

The NRC has observed:(56) "Experience at the NFS West Valley reprocessing plant with chopping fuel, in preparation for dissolution, showed the release of krypton from spent fuel was marginally observable on their krypton stack monitor; almost all of the krypton was retained in the fuel until its dissolution. This experience indicates that even the rupture of a number of fuel elements in the storage pool would not cause a release of Kr-85 in sufficient quantities to be measurable off-site."

As noted earlier, the storage of spent fuel with cladding defects has produced no substantial operating or safety problems. During extended storage, the problems from clad failures would be even smaller because of the decreased radioactivity of the aged fuel. If necessary, failed fuel can be encapsulated in closed canisters which will provide a complete isolation of the exposed fuel from the environment. The technology for such encapsulation is well developed and has been used in a number of instances.

V.4.2 Affects On Storage Facilities

Reactor plant fuel storage facilities, including retrofitted high density fuel storage racks, have typically been licensed for the same design life as the reactor power plant, which is predominantly 40 years. The implicit assumption supporting this action has been that all spent fuel would be removed from the facility at the time of plant decommissioning. The possible need for extension of the 40-year design life for the fuel storage facility has only recently been identified.

In evaluating the consequences of extending the facility design life, it is convenient to separate the active systems components such as pumps, valves and heat exchangers from the passive, stationary structural components comprising the major portion of the facility. In the case of the active systems components, the original designs provided for relatively simple removal and replacement since such components are likely to need replacement or repair during the normal design life. Extending the design life of the facility is not, therefore, limited by the active systems components.

The possible sources of design life limitations for the stationary structural components include: (1) structural fatigue, (2) irradiation damage, (3) corrosion effects, and (4) general material degradation-pool structure. Each of these effects is evaluated below.

V.4.2.1 Structural Fatigue

Structural fatigue failures can occur either as a result of vibration, a cyclical loading operating cycle or thermal cycling. The only vibration sources that can be identified for a fuel storage facility are the short duration effects of a seismic event. The seismic stress limits imposed upon the structures ensure that fatigue failures will not result, even if the structures are subjected to several severe earthquakes. Stray vibration effects caused by adjacent mechanical equipment and piping systems do not present a problem because of the very large mass of the pool structure and pool water. The fuel storage facility is not subjected to any significant cyclic loading.

The fuel storage facility will be subjected to a low level of thermal cycling as a result of annual discharges of hot fuel. However, the thermal inertia of the large mass of concrete and water ensure that the thermal transients are slow and, consequently, the thermal stress cycles are of very low magnitude.

V.4.2.2 Irradiation Damage

The only significant irradiation effects in a spent fuel pool are the gamma emissions from the spent fuel. Neutron emissions are at a very low level. The gamma emissions will have a negligible effect on steel and concrete structures. Therefore, no problem in extending the facilities design lives is anticipated, especially since the extension would be for continued storage of old fuel at relatively low irradiation levels.

V.4.2.3 Corrosion Effects

Spent fuel storage pools are normally lined with welded stainless steel sheet. The majority of fuel storage racks are also of welded stainless steel construction with some facilities having aluminum alloy racks. Pool water is demineralized (in the case of PWR's with boron added). PWR pools are slightly acidic (pH of 5-6) and BWR pools are neutral (pH of 7). Design temperatures are 120°-125°F for normal operations and 150°F for abnormal operations. At these conditions, corrosion rates for spent fuel pool materials are extremely low and would not inhibit extension of the design life.

V.4.2.4 Structural Material Performance

Pool structures consist of massive poured-in-place reinforced concrete structures. In most plants these reinforced concrete pool structures are housed within a building protecting the structure from the external environment.

Reinforced concrete dams, bridges and buildings have been subjected to much more severe environmental effects (temperature cycling, corrosion atmospheres and cyclic loading) for several decades without suffering significant damage. It is anticipated, therefore, that degradation of the pool structure would in no way prevent extension of the design life of a fuel storage facility.

V.4.2.5 Security

The security of spent fuel from sabotage, or diversion, has been evaluated and has been determined to be a very low risk. The level of consequences that might result from credible sabotage scenarios is very low.(61) Protection against sabotage during normal, licensed operation of the reactor is provided by armed guards, intruder detection systems, and other procedures in accordance with appropriate federal regulations.

During an extended storage period, maintenance of the same security systems will be necessary; however, assuming such systems are maintained, the probability of sabotage events will not change appreciably during the duration of extended storage. The consequences of sabotage can be expected to decrease slightly because of the decrease in radioactivity and heat generation as the spent fuel ages.

VI. CLOSING REMARKS

Based on the material set forth in this statement, the AIF has concluded that there is reasonable assurance that safe, off-site disposal and/or storage for spent fuel from any licensed facility will be available prior to the expiration of such licenses. AIF also concludes that, if necessary, such waste can be safely stored on-site until disposal and/or off-site storage is available.

On the basis of the above, AIF respectfully requests the Commission to exclude consideration of off-site disposal and/or storage, as well as extended on-site storage, from individual licensing proceedings. AIF further respectfully requests the Commission to confirm this action in the promulgation of an appropriate rule.

VII. REFERENCES

1. U.S. Department of Energy. Management of Commercially Generated Radioactive Waste, Draft Environmental Impact Statement, DOE/EIS-0046-D. April 1979.

2. Interagency Review Group on Nuclear Waste Management. Report to the President, TID-29442. U.S. DOE, March 1979.

3. U.S. Nuclear Regulatory Commission, Division of Waste Management. Information Base for Waste Repository Design Vols. 1-7, NUREG/CR-0495. Prepared by the Analytical Sciences Corporation. March 1979.

4. Uranium Industry Seminar, Grand Junction, Colorado, U.S. Department of Energy, October 16, 17, 1979.

5. "DOE Ups U Estimates." Nuclear News, p.46-47. 21(7)1978.

6. Office of Nuclear Waste Isolation. National Waste Terminal Storage (NWTS) Conceptual Reference Repository Description (CRRD), draft, ONWI/SUB/79/E512-01600.16. Columbus: Battelle Memorial Institute, September 1979.

7. Testimony of M.I. Goldman, NUS Corporation, GESMO Utility Group. Hearings held by U.S. Nuclear Regulatory Commission, Docket No. RM-50-5. GESMO Hearing Board, March 4, 1977.

8. Committee on Waste Disposal. "Disposal of Radioactive Waste in Salt Cavities, Appendix F." Disposal of Radioactive Waste on Land, Pub. 519. Washington, D.C.: National Academy of Sciences, National Research Council, 1957.

9. Office of Waste Isolation. Technical Support for GEIS: Radioactive Waste Insolation in Geologic Formations (Vols. 1-24), Y/OWI/TM-36. Oak Ridge: Oak Ridge National Laboratory, 1978.

10. U.S. Energy Research and Development Administration. Alternatives for Managing Wastes from Reactors and Post-Fission Operations in the LWR Fuel Cycle (Vols. 1-5), ERDA-76-43. Prepared by Battelle Northwest Laboratories, May 1976.

11. American Physical Society. "Report of the Study Group on Nuclear Fuel Cycles and Waste Management." Reviews of Modern Physics. 50(1/Part II)1978.

12. U.S. Nuclear Regulatory Commission, Division of Fuel Cycle and Material Safety. Proposed Goals for Radioactive Waste Management, NUREG-0300. May 1978.

13. U.S. Environmental Protection Agency, Ad Hoc Panel of Earth Scientists. State of Geological Knowledge Regarding Potential Transport of High-Level Radioactive Waste from Deep Continental Repositories, EPA/520/4-78-004. Prepared by Arthur D. Little, Inc. June 1978.

14. Committee on Nuclear and Alternative Energy Systems. Energy in Transition 1985-2000, final report. Washington, D.C.: National Academy of Sciences, National Research Council, 1979.

15. INFCE Waste Management and Disposal, Report of Working Group 7, January 1980, IAEA, Vienna.

16. Brown, G.E., Jr. Nuclear Waste Disposal Policy: A Case History of Change and Uncertainty. Washington, D.C.: Atomic Industrial Forum, January 1979.

17. Porkorny, G. "Public Attitudes Toward Nuclear Waste Management." Workshop on the Management of Spent Fuel and Radioactive Wastes. Atomic Industrial Forum. (Washington, September 1979).

18. Carter, N.E. "Nuclear Waste Disposal: A Problem with a Solution." Workshop on the Management of Spent Fuel and Radioactive Wastes. Atomic Industrial Forum. (Washington, D.C., September 1979).

19. Nuclear Energy Policy Study Group. Nuclear Power: Issues and Choices. Sponsored by the Ford Foundation; administered by the MITRE Corporation. Cambridge: Ballinger, 1977.

20. Willrich, M. Radioactive Waste Management and Regulation, MIT-EL-011. Cambridge: Massachusetts Institute of Technology, Energy Laboratory, 1976.

21. U.S. Nuclear Regulatory Commission. "Licensing and Regulatory Policy and Procedures for Environmental Protection; Uranium Fuel Cycle Impacts from Spent Fuel Reprocessing and Radioactive Waste Management, proposed 10 CFR Part 51." 44 Federal Register 45362, August 2, 1979.

22. Harmon, K.M. et al. Summary of Non-United States National and International Radioactive Waste Management Programs, 1980, PNL-3333. Prepared by Pacific Northwest Laboratory. U.S. DOE, March 1980.

23. Committee on Radioactive Waste Management, Subcommittee for Review of the KBS-II Plan. Review of the Swedish KBS-II Plan for Disposal of Spent Nuclear Fuel. Washington, D.C.: National Academy of Sciences, National Research Council 1980.

24. *Handling of Spent Nuclear Fuel and Final Storage of Vitrified High-Level Reprocessing Waste*. Stockholm: Karnbranslesakerhet, 1977.

25. *Handling and Final Storage of Unreprocessed Spent Nuclear Fuel*. Stockholm: Karnbranslesakerhet, 1978.

26. *Copper as an Encapsulation Material for Unreprocessed Nuclear Waste: Evaluation from the Viewpoint of Corrosion*, KBS technical report 90. Stockholm: Karnbranslesakerhet, 1978.

27. Devell, L. et al. "Disposal of High-Level Waste or Spent Fuel in Crystalline Rock: Factors Influencing Calculated Radiation Doses", IAEA-SM-243/55. *International Symposium on the Underground Disposal of Radioactive Wastes*. International Atomic Energy Agency & Organisation for Economic Co-Operation and Development. (Helsinki, July 1979).

28. Hatcher, S.R. et al. "Development of Deep Underground Disposal for Canadian Nuclear Fuel Wastes", IAEA-SM-243/167. *International Symposium on the Underground Disposal of Radioactive Wastes*. International Atomic Energy Agency & Organisation for Economic Co-Operation and Development. (Helsinki, July 1979).

29. Lyon, R.B. & Rosinger, E.L.J. "Safety Assessment for Deep Underground Disposal Valut Pathways Analysis", IAEA-SM-243/169. *International Symposium on the Underground Disposal of Radioactive Wastes*. International Atomic Energy Agency & Organisation for Economic Co-Operation and Development. (Helsinki, July 1979).

30. Rummery, T.E. & McLean, D.R. "The Canadian Nuclear Fuel Waste Management Program." *Workshop on the Management of Spent Fuel and Radioactive Wastes*. Atomic Industrial Forum. (Washington, D.C., September 1979).

31. Salander, C. "The Present Status of "Entsorgung" of Nuclear Power Plants in the Federal Republic of Germany." *Workshop on the Management of Spent Fuel and Radioactive Wastes*. Atomic Industrial Forum. (Washington, D.C., September 1979).

32. Rothmeyer, H. "Site Investigations and Conceptual Design for the Mined Repository in the German Nuclear Entsorgungs-Zentrum", IAEA-SM-243/48. *International Symposium on the Underground Disposal of Radioactive Wastes*. International Atomic Energy Agency & Organisation for Economic Co-Operation and Development. (Helsinki, July 1979).

24. Handling of Spent Nuclear Fuel and Final Storage of Vitrified High-Level Reprocessing Waste. Stockholm: Karnbranslesakerhet, 1977.

25. Handling and Final Storage of Unreprocessed Spent Nuclear Fuel. Stockholm: Karnbranslesakerhet, 1978.

26. Copper as an Encapsulation Material for Unreprocessed Nuclear Waste: Evaluation from the Viewpoint of Corrosion, KBS technical report 90. Stockholm: Karnbranslesakerhet, 1978.

27. Devell, L. et al. "Disposal of High-Level Waste or Spent Fuel in Crystalline Rock: Factors Influencing Calculated Radiation Doses", IAEA-SM-243/55. International Symposium on the Underground Disposal of Radioactive Wastes. International Atomic Energy Agency & Organisation for Economic Co-Operation and Development. (Helsinki, July 1979).

28. Hatcher, S.R. et al. "Development of Deep Underground Disposal for Canadian Nuclear Fuel Wastes", IAEA-SM-243/167. International Symposium on the Underground Disposal of Radioactive Wastes. International Atomic Energy Agency & Organisation for Economic Co-Operation and Development. (Helsinki, July 1979).

29. Lyon, R.B. & Rosinger, E.L.J. "Safety Assessment for Deep Underground Disposal Valut Pathways Analysis", IAEA-SM-243/169. International Symposium on the Underground Disposal of Radioactive Wastes. International Atomic Energy Agency & Organisation for Economic Co-Operation and Development. (Helsinki, July 1979).

30. Rummery, T.E. & McLean, D.R. "The Canadian Nuclear Fuel Waste Management Program." Workshop on the Management of Spent Fuel and Radioactive Wastes. Atomic Industrial Forum. (Washington, D.C., September 1979).

31. Salander, C. "The Present Status of "Entsorgung" of Nuclear Power Plants in the Federal Republic of Germany." Workshop on the Management of Spent Fuel and Radioactive Wastes. Atomic Industrial Forum. (Washington, D.C., September 1979).

32. Rothmeyer, H. "Site Investigations and Conceptual Design for the Mined Repository in the German Nuclear Entsorgungs-Zentrum", IAEA-SM-243/48. International Symposium on the Underground Disposal of Radioactive Wastes. International Atomic Energy Agency & Organisation for Economic Co-Operation and Development. (Helsinki, July 1979).

33. Bonniaud, M.R. & Frejacques, M.C. *High-Level Radioactive Waste and Vitrification*, *Commissariat a l'Energie Atomique*. Included in a letter dated March 21, 1980 to Carl Walske, Atomic Industrial Forum.

34. Sugier, N. *La Gestion Des Dechets Radioactifs en France*. *Commissariat a l'Energie Atomique, Department des Programmes*. Included in a letter dated March 21, 1980 to Carl Walske, Atomic Industrial Forum.

35. Sugier, A. *Main Lines of the French Policy in the Field of Nuclear Waste Management*, *Commissariat a l'Energie Atomique, Department des Programmes*. Included in a letter dated March 21, 1980 to Carl Walske, Atomic Industrial Forum.

36. "Inquiry Report Supports BNFL Reprocessing Plant." *Energy International*. 15(5)1979.

37. Royal Commission on Environmental Pollution. *Nuclear Power and the Environment*. B. Flowers, Chairman. *London: Her Majesty's Stationary Printing Office*, 1976.

38. Mather, J.D. et al. "Geological Criteria and Site Selection for High-Level Radioactive Waste Repositories in the United Kingdom", IAEA-SM-243/29. *International Symposium on the Underground Disposal of Radioactive Wastes*. International Atomic Energy & Organisation for *Economic* Co-Operation and Development. (Helsinki, July 1979).

39. Griffin, J.R. et al. "Geological Disposal of High Level Radioactive Waste Conceptual Repository Design in Hard Rock", IAEA-SM-243/93. *International Symposium on the Underground Dsposal of Radioactive Wastes*. *International Atomic Energy Agency & Organisation for* Economic Co-Operation and Development. (Helsinki, July 1979).

40. Issler, H. et al. "Concept and Realization Programme for Final Storage of Nuclear Waste in Switzerland", IAEA-SM-243/160. *International Symposium on the Underground Disposal of Radioactive Wastes*. *International Atomic Energy Agency & Organisation for* Economic Co-Operation and Development. (Helsinki, July 1979).

41. Nuclear Fuel, McGraw-Hill Publishing Co., February 4, 1980.

42. *Disposal of Radioactive Wastes in Canisters (Overview and Current Status of this Issue in the Specific Case of Belgium)*. International Atomic Energy Agency & Organisation for Economic Co-Operation and Development, nd.

43. Cohen, B.L. "High-Level Waste from Light Water Reactors." Reviews of Modern Physics, p.1-20. 49(1)1977.

44. U.S. Environmental Protection Agency. Radiological Impact Caused by Emissions of Radionuclides into the Air in the United States, EPA-520/7-79-006. 1979.

45. Cohen, Bernard L., "Analysis, Critique, and Reevaluation of High-Level Waste Repository Water Intrusion Scenario Studies", Nuclear Technology, Vol. 48, April 1980, pp 63-69.

46. U.S. Nuclear Regulatory Commission, Office of Nuclear Materials Safety and Safeguards. Handling and Storage of Spent Light Water Power Reactor Fuel, Generic Environmental Impact Statement, NUREG-0575. August 1979.

47. Advisory Committee on the Biological Effects of Ionizing Radiation. Considerations of Health Benefit-Cost Analysis for Activities Involving Ionizing Radiation Exposure and Alternatives, (BEIR II), EPA 520/4-77-003. Supported by U.S. Environmental Protection Agency, Office of Radiation Programs. Washington, D.C.: National Academy of Sciences, National Research Council, 1977.

48. International Commission on Radiological Protection. "Radiation Protection", ICRP Publication 26, adopted January 17, 1977. Annals of the ICRP 1(3)1977. Oxford: Pergamon Press, 1977.

49. Cohen, Bernard L, 1976, "Impact of the Nuclear Energy Industry on Human Health and Safety", American Scientist, 64(5), 550.

50. Cohen, B.L. & Lee, I.S. "Catalog of Risks." Health Physics. 36(707)1979.

51. Presidential Message to Congress, February 12, 1980. "Comprehensive Radioactive Waste Management Program." Weekly Compilation of Presidential Documents. 16(7)1980.

52. U.S. Nuclear Regulatory Commission. "Disposal of High-Level Radioactive Wastes in Geologic Repositories; Proposed Licensing Procedures, Proposed 10 CFR Part 60." 44 Federal Register 70408, December 6, 1979.

53. Minutes from the Nuclear Regulatory Commissioners' meeting held on November 19, 1979. (Proposed 10 CFR Part 60).

54. U.S. Nuclear Regulatory Commission. "Licensing and Regulatory Policy and Procedures for Environmental Protection; Alternative Site Reviews, Proposed 10 CFR Part 51." 45 Federal Register 24168, April 9, 1980.

55. U.S. Department of Energy. Statement of the Position of the U.S. Department of Energy; In the matter of Proposed Rulemaking on the Storage and Disposal of Nuclear Waste. (Waste Confidence Rulemaking). April 1980.

56. U.S. Nuclear Regulatory Commission. Handling and Storage of Spent Light Water Power Reactor Fuel, Draft Generic Environmental Impact Statement, NUREG-0404. March 1978.

57. Williams, J.P., Update on Summary Information--Spent Fuel Modifications, rev. 29, memorandum, CD-LIS-5607. Rockville: NUS Corporation, 1980.

58. Johnson, A.B., Jr. Utility Spent Fuel Operating Experiences, PNL-SA-6863. Richland: Pacific Northwest Laboratory, April 1980.

59. Johnson, A.B., Jr. Behavior of Spent Nuclear Fuel in Water Pool Storage, BNWL-2256. Richland: Battelle Northwest Laboratories, September 1977.

60. Vesterlund, G. & Olsson, T. "Degradation Mechanism During Pool Storage and Handling of Spent Power Fuel." ASEA-ATOM, reprint RB 78.29. January 1979.

61. U.S. Department of Energy. Storage of United States Spent Power Reactor Fuel, Draft Environmental Impact Statement, DOE/EIS-0015D. August 1978.