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**STORAGE OF SPENT FUEL
FROM THE NATION'S NUCLEAR REACTORS**

- STATUS, TECHNOLOGY, AND POLICY OPTIONS -

**State of Nevada
Agency for Nuclear Projects/
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INTRODUCTION

Since the beginning of the commercial nuclear electric power industry, it has been recognized that spent nuclear reactor fuel must be able to be readily removed from the reactor vessel in the plant and safely stored on-site. The need for adjacent ready storage is first for safety. In the event of an emergency, or necessary maintenance that requires the removal of irradiated fuel from the reactor vessel, cooled reserve storage capacity for the full amount of fuel from the reactor core must be available. Also, the uranium fuel in the reactor eventually reaches the point where its heat generation is below the planned efficiency for steam production which drives the turbines and generators. It then must be replaced by fresh uranium fuel, with the "spent fuel" elements being removed to a safe and convenient storage location near the reactor vessel. Spent fuel and full core reserve capacity is maintained at the reactors in the form of spent fuel pools, in which the irradiated fuel is stored beneath about a 20 foot cover of water that is cooled to remove the heat still being generated by radioactive decay, primarily of the fission products.

After a period of a few months to a few years, the heat generation reduces to the point that, with properly designed radiation shielding and either active or passive cooling, the spent fuel can be stored out of the fuel pool in various types of casks or vaults, which can be located either at or away from the reactor site.

The federal nuclear waste repository program, even without delays in the current schedule of disposal becoming available in 2003, will result in a large percentage of the 111 existing operable commercial reactors requiring expansion of their spent fuel storage capacity. How that need can and will be met raises issues of both technology and policy that will be reviewed in this report.

STATUS OF SPENT NUCLEAR FUEL STORAGE

The Congress in adopting the Nuclear Waste Policy Act of 1982 recognized the growing need for spent fuel storage resulting from continuing reactor operation and an increasing number of reactors (all ordered prior to 1978) being brought into operation. Even though the 1982 Act laid out a schedule for deep geologic repository disposal of spent fuel to begin in 1998, it was already recognized that the available spent fuel storage capacity and full core reserve at some operating plants would be exceeded by that time.

This known shortage of spent fuel capacity resulted from the expectation, until the mid-1970's, that the spent reactor fuel would, after a short storage period, be removed off-site to a reprocessing facility, and extended at-reactor spent fuel storage would not be necessary. It was at this time that interest, developing since the mid-1950's, in geologic disposal of the highly radioactive wastes from reprocessing heightened, but with an added emphasis on use of this mode for commercial spent nuclear reactor fuel disposal as well, in order to avoid the need to expand at-reactor pool storage capacity.

First, difficulties in developing an acceptable reprocessing facility, then a 1976 estimate that a repository would be available in the mid-1980's, followed by later 1976 and 1977 Presidential prohibitions on reprocessing (to curtail nuclear weapons proliferation), and finally the economic infeasibility of commercial reprocessing when the ban was lifted in 1981, left many reactors short of spent fuel storage capacity to meet their expected needs. Figure 1 illustrates the nuclear fuel cycle with and without reprocessing. Note that both cycles result in waste generation, but with the reprocessing option, the resultant wastes are associated with the reprocessing facility, rather than being in the form of spent fuel building up in reactor storage.

The 1982 Nuclear Waste Policy Act provided three options for

Figure 2-1. The Nuclear Fuel Cycle Without Reprocessing of Spent Reactor Fuel.

Source: NRC (1976b 3-21).

Figure 2-2. The Nuclear Fuel Cycle with Reprocessing. The uranium and plutonium extracted from spent reactor fuel are recycled into new fuel.

Source: NRC (1976b 3-5).

assuring that operating reactors would not be forced to shut down prior to the end of their planned lifetime, due to the lack of an available federal spent fuel disposal facility prior to 1998. First, the Act established that spent fuel storage at the plant site was the responsibility of the owner utility, but it did make financial and technical assistance available, on a cooperative demonstration basis, to develop technologies for on-site dry storage, and permitted fuel from a limited number of particularly needy reactors to be sent to federal facilities for use in a research and development program for dry cask storage. Second, the Act authorized a Federal Interim Storage Program (FIS) to provide a storage facility for up to 1,900 metric tons of spent fuel to utilities able to demonstrate that they could not provide, when needed, adequate storage to be able to maintain continued orderly reactor operation. Such utilities would be required to pay their share of the full facility cost. And third, the Secretary of Energy was directed to study the need for and feasibility of a Monitored Retrievable Storage (MRS) facility, and propose to Congress, by mid-1985, one or more such centralized storage facilities which would be paid from the Nuclear Waste Fund, the same ratepayer fee fund established by the Act to fund the geologic repository disposal program.

Since passage of the 1982 Act, the cooperative demonstration program for dry cask storage has resulted in both the successful licensing and at-reactor use of dry casks and above-ground

modules, on a limited basis. This may well be seen in the future as one of the more significant advances brought about by the Nuclear Waste Policy Act in response to industry's recognition of its own growing need for expanded spent fuel storage capacity. During this same period of time, there has been considerable advance in research and use of dry casks in Japan, Germany, and France.

There have been no utility initiatives, and likely will be none, for a Federal Interim Storage facility. The Monitored Retrievable Storage program has experienced a notable political failure in designating a proposed facility site in Tennessee. Meanwhile, about one half of the utilities with reactor storage pools have either re-racked within the pools - a modification that allows closer spacing of stored fuel assemblies - or are planning for re-racking. Also, some rod consolidation research and experiments have been undertaken, but, for a number of technical and financial reasons, this approach to increasing spent fuel storage capacity without pool expansion currently does not appear to be viewed by the majority of utilities as a viable option.

The 1982 Act's provisions for interim spent fuel storage were based on the assumption that a federal geologic repository for spent fuel disposal would be available by 1998. By 1987, the DOE repository siting program was essentially stalled, primarily because of political reaction in many affected states to the DOE's

apparent political bias in candidate site selection. The MRS siting program was also caught up in the political backlash for similar reasons. In an attempt to "save" the program, the Nuclear Waste Policy Act was amended in a manner that was intended to expedite and reduce costs of site selection for a geologic repository. The Congress recognized the fact that a significant and growing number of reactors would need expanded spent fuel storage, even though the expedited program was to provide a federal disposal facility which DOE then said could be available by 2003 for initial receipt of waste. Thus, five years of lack of progress in repository and MRS site selection became translated into an additional five-year demand on discharged reactor fuel storage.

The 1987 amendments to the Nuclear Waste Policy Act resulted in the naming of a single site, at Yucca Mountain, Nevada, to be characterized as a candidate repository site, with candidate sites in Texas and Washington removed from further consideration. It also established a Monitored Retrievable Storage Review Commission to report to Congress on the "need for a monitored retrievable storage facility as a part of the Nation's nuclear waste management system." Further amendment of the Act set the date for the MRS commission's report to Congress for November 1989. Meanwhile, the 1987 amendment had also authorized the DOE to site, construct and operate one MRS subject to conditions related to both the MRS Commission's report and recommendations,

and specific progress milestones in siting a geologic repository. The DOE's site selection, construction and operation of the MRS could not proceed without concurrent site approval and NRC construction authorization for a repository. The DOE expressed confidence that, by staying on schedule for opening a repository in 2003, it could have an MRS available for spent fuel receipt in 1998.

The 1987 amendments to the Act also provided for Presidential appointment of a Nuclear Waste Negotiator whose charge was to seek out States or Indian Tribes willing to host a repository or MRS facility, based upon Congressional adoption of the negotiated agreement between the Nuclear Waste Negotiator and the potential host. The 1987 amendment is written in a manner such that an MRS host agreement is not subject to the repository progress linkages that are imposed if the DOE initiates MRS siting following Congressional receipt of the MRS Commission report. This provision, according to DOE, could result in an MRS becoming available for spent fuel receipt earlier than 1998; however, to date, the President has not named a Nuclear Waste Negotiator, and equally important, no State or Indian Tribe is known to have expressed a willingness to host an MRS.

Progress in beginning characterization of the Yucca Mountain repository site has been slow, and it is clear that DOE's schedules for beginning major on-site work and investigations in

1989 will not be met. This greatly reduces confidence in a repository becoming available for spent fuel receipt in 2003, and likely will result in delays of unknown duration in meeting the progress milestones to which the DOE's MRS siting, construction and operation program is statutorily linked, if it is approved by Congress. Such delay and uncertainty creates a further spent fuel storage burden on the utilities of unknown duration and magnitude.

There is also the possibility that the Yucca Mountain Candidate Repository Site will either be disqualified or otherwise removed from consideration for a repository. This could occur at any time during the site characterization program, which DOE now plans to continue through 1995. If this occurs, the Act requires DOE to recommend further action to the Congress for a spent fuel disposal program. In this event, under the 1987 amendments, a DOE-sited MRS is unlikely to be realized, even if approved by Congress.

The DOE has recently reported its estimates of additional at-reactor spent fuel storage capacity requirements under various scenarios of waste acceptance at a repository, and at an MRS prior to repository availability, or in the event of no repository becoming available during the design life of existing and under-construction reactors. In the case of the linked MRS-Repository system accepting waste as scheduled by DOE, first at an MRS in 1998, and then at a repository in 2003, low and high estimates of

the number of reactors requiring additional storage capacity are 51 and 68. The total number of reactors generating and storing waste at that time ranges from a low of 107 to a high of 115. It is interesting to note that if the federal waste acceptance system is delayed even five years, until 2003, the number of reactors requiring additional spent fuel storage would increase to a range of from 73 to 101. If there were no repository system available during the life-time of the reactors, all of the reactors would require expanded storage capacity, resulting in an industry-wide additional spent fuel storage capacity requirement of 32,090 to 42,450 metric tons of uranium. Figure 2 illustrates the effects of alternative spent fuel acceptance scenarios on cumulative additional spent fuel storage requirements for commercial nuclear power reactors.

Figure 3 shows the geographic distribution of the additional spent-fuel storage capacity requirements in the case of repository spent fuel acceptance beginning in 2003 without an MRS in the waste acceptance system. Spent fuel currently stored in operable commercial reactor pools, some of which have already been re-racked in as many as three incremental steps, amounts to about 15,000 metric tons at 108 reactors. It is estimated that by 1995 there will be nearly 35,000 metric tons of spent fuel stored at 111 commercial reactors.

FIGURE 2

Figure 3-4. Effects of alternative spent-fuel-acceptance schedules on the cumulative aggregate additional-storage requirements.

Source: DOE/RW-0220

FIGURE 3

Figure 3-6. Distribution by State of the maximum additional-storage requirements for the reference spent-fuel acceptance case.

Source: DOE/RW-0220

SPENT FUEL STORAGE TECHNOLOGY

As discussed above, the numerous available and developing technologies for expanded spent fuel storage, both at-plant and off-site, provide the basis for technical and policy options to meet the known need for an uncertain capacity and duration of additional spent fuel storage prior to the availability of a disposal facility, whenever that might be. On-site technologies, coupled with the now commonplace re-racking of existing spent fuel storage pools, can meet the need for safe, feasible and economical storage for an indefinite period of time at any capacity level necessary, while avoiding public controversy over the risks of transporting spent fuel to an off-site "temporary" storage facility. Additional capacity in dry storage can be added incrementally as required by needed expansion and the economies of scale. Furthermore, if problems develop over time with the storage technology chosen, new technology can be installed, with the spent fuel being transferred from the original to a replacement storage container.

It is generally accepted that the construction of new spent fuel storage pools at the reactors is not a favorable option to pursue. This results from factors such as the initial high capital cost for a fixed (rather than incrementally expandable) storage capacity, ongoing high operational and maintenance requirements which affect safety and costs, potential licensing difficulties that could impact continued reactor operation, additional low-

level radioactive waste generation during operation, and long lead-time in implementation.

The DOE, in its 1989 Final Dry Cask Storage Study report (DOE/RW-0220) which was required of the DOE by the 1987 amendments to the Nuclear Waste Policy Act, described a number of on-site dry storage technologies that are either in use now, or have been sufficiently studied to be considered potentially viable designs. The designs described, almost all of which provide passive storage, are metal casks, dual-purpose (storage and transport) metal casks, concrete casks, horizontal concrete modules, and modular concrete vaults. A brief summary of these designs and their status is presented below.

On Site Storage Technologies

Metal Casks: These passively cooled cylindrical casks that can be constructed of various types of metal and internal radiation shielding, are approximately 16 feet long, 8 feet in diameter, have a capacity of 21 to 33 spent (pressurized water reactor) fuel rods amounting to 9 to 14 metric tons of uranium, and have a gross weight of 100 to 125 tons. The casks can be stored outdoors at the reactor site in either a horizontal or vertical configuration. Metal casks are commercially available and six of them are now in use by Virginia Power, which obtained a dry storage license from the NRC in 1986. The utility plans to add two to three metal storage casks per year to meet expanded spent fuel

storage requirements. Aside from licensing the specific cask design, site specific licensing issues that were resolved with the NRC included pad design, security and safeguards, leak detection, potential seismic effects on the pad and casks, loading and transportation procedures at the reactor site, occupational exposure of plant workers, and cask maintenance.

Dual-Purpose Casks: Having a similar appearance to the metal casks described above, these metal containers are designed to serve as both storage and transportation casks for spent fuel. They have been approved for use in the Federal Republic of Germany, and the NRC certification process has begun in the U.S., with a demonstration program soon to begin as part of the certification process. Cask licensing issues have a significantly broader scope than the metal casks described above because of the planned use of the casks in transportation as well as storage, while site specific licensing issues would be essentially the same. Incentive to pursue dual-purpose cask development is not great at this time because the Department of Energy has not specified the engineering interface requirements for an integrated spent fuel transportation and management system.

Concrete Casks: Designed to be built of reinforced concrete with a metal liner, these casks are similar in dimension to the metal cask. Although the gross weight is about 90 tons (compared to 100 to 125 tons for metal casks), the spent fuel capacity of

9 (pressurized water reactor) spent fuel rods is significantly less than the metal cask. One utility reportedly has expressed an interest in this cask type, and a topical report is being prepared for review by the NRC staff. A significant design licensing issue will involve the concrete and its allowable operating temperature to assure its continued integrity.

Horizontal Concrete Modules: The horizontal concrete storage modules (Figure 4) are designed to contain sealed stainless steel canisters which, depending upon the design, hold from 7 to 24 spent (pressurized water reactor) fuel assemblies in a helium or nitrogen atmosphere to prevent spent fuel oxidation. One commercial application of this technology of increasing interest has been licensed by the NRC for eight modules, and another of somewhat differing design and greater capacity is under consideration. As with the concrete cask, the integrity and allowable operating temperature of the concrete will be an added licensing issue in the design evaluation.

Modular Concrete Vault Storage: This, the most complex of the storage technologies reviewed by the DOE report, involves storing spent fuel rods, contained within carbon-steel canisters, in a concrete vault structure under a nitrogen or air atmosphere (Figure 5). While additional units can be coupled to the original structure, the design size for the initial storage structure is about the size of a reactor spent fuel storage pool. An

FIGURE 4

Figure 4-4. The generic horizontal modular storage system (NUHOMS).

FIGURE 5

Figure 4-5. Conceptual design for a modular vault storage system.

Source: DOE/RW-0220

application of this design has been used in the United Kingdom, but no U.S. utility is known to be planning for its use. The NRC has reviewed and approved one design for this technology, provided nitrogen is employed as the cover gas to give greater assurance of safety at the expected operating temperatures. Site specific licensing issues for the NRC are expected to be similar to those of other on-site dry storage technologies.

Off-Site Storage

Federal Interim Storage (FIS): Since there is no current indication of utilities seeking implementation of the FIS provisions of the Nuclear Waste Policy Act, the planning for such a facility remains at the conceptual stage. Such a facility could be located at existing reactor sites or on federal sites, and the available technologies already discussed, ranging from new spent fuel pool storage facilities to any of the various dry storage technologies, could be employed for the limited storage capacity authorized by the Act. It is not anticipated that there will be any utility initiative to develop FIS prior to the January 1, 1990 expiration of the Act's authorization for such a facility.

Monitored Retrievable Storage: Various dry spent fuel storage technologies have been evaluated by DOE for potential use at an MRS, should such a facility be developed. In general these consist of differing configurations of above-ground and in-ground bunkers, and vaults or silos for large-scale modular storage and ready

retrievability of spent fuel. Design constraints are largely those of safety and efficiency of operation, and cost of development.

The storage technology selected will also depend upon the range of functions the MRS is intended to perform. The 1982 Act appeared to envision the MRS as a "lag storage" facility to fill a temporary interim storage need should waste receipt at a repository be delayed for a short period of time beyond the intended 1998 availability of federal spent fuel disposal capability. The 1987 amendment to the Act has generally adopted the DOE's more recent thinking regarding integrating the MRS into an overall waste management and disposal system. Within this context, the MRS could serve, as originally intended, simply as lag storage, or it could perform additional functions which may include rod consolidation and sealed packaging of spent fuel for transportation and direct emplacement into a repository, both of which functions could also be performed at a repository surface facility. The Act, however, prohibits the siting of an MRS facility in Nevada as long as the Yucca Mountain Site remains the proposed repository site.

It is generally agreed that from a standpoint of safety, technological feasibility, and licensability, any of the spent fuel storage technologies discussed above could be employed to meet the current and future need for expanded spent fuel storage capacity, and could be implemented in an incremental manner that

is responsive to the persistent uncertainty about the future availability of spent fuel disposal. Policy considerations, public acceptability and optimization of safety and cost factors will likely continue to dominate the public and private decisions concerning how spent fuel from commercial nuclear reactors will be stored during the indefinite interim period which now prevails prior to the availability of federal spent fuel disposal. As will be discussed later, the U.S. Nuclear Regulatory Commission staff has found reason for confidence that interim storage can be accomplished safely for a period of up to 100 years.

SPENT FUEL STORAGE POLICY OPTIONS

The Nuclear Waste Policy Act of 1982 and its 1987 amendment both emphasize the federal Monitored Retrievable Storage option for additional spent fuel storage, although neither mandates that such a facility be constructed. The 1982 Act requires that DOE present a detailed MRS proposal to the Congress for consideration. The 1987 amendment conditionally authorized siting, developing and operating an MRS, but also established the MRS Review Commission to report to Congress on the need for an MRS as part of a national integrated nuclear waste management and disposal system.

As discussed above, the 1987 amendment also created a number of linkages between MRS development and progress in the repository program. If the Nuclear Waste Negotiator is not successful in

finding a willing host for an MRS and gaining Congressional approval of the proposed federal/host agreement, the Secretary of Energy may begin the site selection process for an MRS as soon as the MRS Commission forwards its report to Congress. However, the Secretary may not finally select an MRS site until he has recommended a repository site for Presidential approval, following completion of characterization of a candidate site. If Yucca Mountain remains the proposed repository site, the DOE's schedule calls for such a recommendation in 1995. The 1987 amendment requires that the NRC condition the license for the development of a DOE selected MRS in the following ways:

- a) construction of the MRS may not commence until the NRC has issued an authorization for beginning construction of a repository (which DOE has scheduled for 1998);
- b) MRS construction, or receipt of spent fuel at an MRS, must cease if repository construction ceases, or the NRC revokes the repository license;
- c) the MRS may not store more than 10,000 metric tons of waste prior to the beginning of waste acceptance at a licensed repository (which DOE has scheduled for 2003); and
- d) the amount of waste at an MRS may not exceed 15,000 metric tons at any one time.

DOE management, with apparent utility support, proposed these restrictive linkages between the MRS and repository progress to

Congress for two primary reasons. The first was to assure that the political and other pressures to meet schedules in the siting and development of a repository would not be relaxed in response to the availability of a temporary federal nuclear waste storage facility. And second, the intent was to allay the long-expressed fears of many public interest groups that the availability of an MRS facility would result in its becoming a de facto repository, and terminal disposal would not be realized. Clearly the storage capacity limitations relate to the existing inventory of spent fuel at operating reactors. The limitations were intended to assure that the MRS could not be viewed as an alternative to a disposal facility because its capacity would be insufficient for spent fuel in excess of that generated through 1987. As noted earlier, none of the schedule linkages and restrictions apply to an MRS developed as a result of successful efforts by the Nuclear Waste Negotiator in siting a Congressionally approved storage facility. The reasoning supporting this lapse is open to speculation, since it was never justified by the Congress, nor was it discussed by witnesses in Congressional oversight hearings.

As pointed out in the above section on spent fuel storage technology, numerous apparently acceptable options are available to meet the utilities' need for additional spent fuel storage at their reactors. Some of these technologies have already been licensed for use at specific reactors. Others are in a design approval stage, and still others remain in the design process.

A number of real and perceived impediments have frustrated, to some extent, additional spent fuel storage, other than re-racking, being planned for reactor sites. Not the least of these is the Act's requirement that on-site storage is the responsibility of the reactor owner. As these impediments become better understood and progress is made in evaluating approaches and options for their resolution, it appears that the response of the utilities is becoming one of increasing interest in at-reactor storage, rather than in a federal MRS, although testimony to the MRS Commission from the utilities, with a few notable exceptions, continues to show some support for MRS development. This changing perception of the value of the MRS to the utilities could be due to the fact that numerous utilities are approaching, or have arrived at the point in time when they must decide how to meet their inevitable need for additional spent fuel storage, in light of the fact that there is no certainty regarding when storage and disposal might become available through a federal waste management system.

A major concern of the utilities in planning for additional at-reactor spent fuel storage is related to receipt of the needed NRC approvals for construction, or installation, and operation of added facilities at the licensed reactor site. The utilities' concerns center on the possibility of intervenors obstructing the license proceeding by reopening reactor site issues that may then

jeopardize the reactor's continued NRC authorization for operation. The Nuclear Waste Policy Act anticipated this concern in its direction to DOE for implementing the dry cask research and development cooperative demonstration program. The DOE is to adhere to the "objective of establishing one or more technologies that the [Nuclear Regulatory] Commission may, by rule, approve for use at sites of civilian nuclear power reactors without, to the maximum extent practicable, the need for additional site-specific approvals by the Commission." To this end, the NRC published a Proposed Rule on May 5, 1989 (FR Vol. 54, No. 86, p. 19379) for use of dry casks at reactor sites based upon a general license for current reactor licensees. This would authorize use of NRC certified casks at reactor sites without additional site specific reviews, if certain existing site data from the original reactor license application are successfully evaluated against the specifications of the selected approved casks. Four commercial dry cask designs are named in the Proposed Rule as having received 20 year (renewable) use certifications from the NRC. It is expected that a Final Rule adopting this concept will be approved by the NRC, and that additional designs will be certified as they are presented to, and reviewed by the NRC.

There is indication that States which have statutory or other impediments to at-reactor dry storage facilities being installed, may remove them since there is no certainty that federal alternatives will be available when needed by some older reactors.

The State of Michigan, for example, has adopted legislation that removes the prohibition against spent fuel storage other than in approved underground pools, and allows expansion of on-site storage. Wisconsin has also acted on this matter. Other states with similar controls will likely follow suit if faced with the only alternative being early shut-down of operating nuclear power reactors.

The DOE's strong and continued support of the MRS program currently has the effect of being an impediment to utilities planning to install additional on-site spent fuel storage, because of the uncertainty of whether, and under what conditions, the Congress might adopt the DOE's position into policy. The DOE's early dedication to developing an MRS in Tennessee resulted in a political failure, to the extent that the 1987 Nuclear Waste Policy Amendments Act ordered that, if the Secretary of Energy pursues MRS siting, he must reinstitute the site screening process as directed by the amendment, rather than simply readopt the earlier selected Clinch River, Tennessee, site. In a May, 1989, statement of position to the MRS Commission, the DOE still strongly supports construction of an MRS, but with an initially simplified mission which essentially is to serve the original "lag storage" intent of the 1982 Act, although the options of rod consolidation and further waste packaging and handling could be added in later planning. This uncertainty regarding the MRS and its role, as well as other persistent DOE waste system design

uncertainties have also contributed to dampening utility interest in on-site rod consolidation as a storage expansion measure.

The core of the DOE's MRS position is as follows: "The DOE supports the development of an MRS facility as an integral part of the waste management system because an MRS facility would allow the DOE to better meet its strategic objectives of timely disposal, timely and adequate waste acceptance, schedule confidence, and system flexibility. [...] Recognizing the difficulty of the DOE-directed siting through national or regional screening, the DOE prefers an MRS facility that is sited through the efforts of the Nuclear Waste Negotiator, especially if the siting negotiations lead to linkages that allow the advantages of an MRS facility to be more fully realized. Even if such revised linkages are not achieved, however, the DOE supports the development of the MRS facility."

The DOE's support for the MRS comes with the acknowledgement that it will add significantly to the cost of the federal waste management and disposal program for civilian spent fuel. In the case chosen by DOE for analysis, which includes a DOE sited MRS, available in 2000, followed by waste receipt beginning at a repository in 2003, the additional cost to the ratepayer supported Nuclear Waste Fund would be \$2.1 billion. And this would be for the most simplified "lag storage" MRS. But the DOE claims that if the projected \$400 million cost to utilities for the increment of

additional on-site storage that this plan would void is subtracted, then the net additional cost to the ratepayers to deploy the MRS is only \$1.7 billion. Of course, if the repository is delayed beyond 2003, or an MRS with a greater scope of waste handling and packaging activities is built, and the Act's linkages between the MRS and repository remain, net costs will continue to rise due, in part, to the need for additional utility paid on-site storage. Also, a fallacy of the DOE's net additional cost calculation approach is the fact that the ratepayers are supporting the Waste Fund, from which the MRS would be paid, but also likely will pay the utilities to build the needed additional on-site storage. Therefore, with the money coming from the same source, the difference is only whether it is dedicated to a more costly MRS, which is still subject to the uncertainties of repository siting and licensing and the real costs of MRS development, or invested at the reactor site in increments as additional storage is needed.

The DOE also has calculated the net additional cost of an MRS if it is sited by the Nuclear Waste Negotiator, and if a repository is delayed until 2013, ten years later than now planned by DOE. By taking advantage of no constraining linkages between MRS and repository development, and having an MRS available in 2000 that has no imposed capacity limitations, the DOE has calculated the additional net ratepayer cost for the (lag-storage) MRS is still \$1.3 billion greater than at-reactor storage.

Costs of the federal waste management and disposal program are becoming a matter of significant interest to the ratepayers, state utility regulators, the utilities, members of Congress, and others. The ratepayers have paid over \$4.5 billion to the Nuclear Waste Fund, with more than \$2.2 billion having been spent by DOE since the fee fund was established by the 1982 Act. Of real interest in the debate over how additional spent fuel storage requirements will be met is whether the ratepayers are "getting their money's worth," and whether they are being treated fairly. An added cost to the ratepayer for unanticipated, but needed additional spent fuel storage capacity because the federal system is unable to provide spent fuel receipt at the time committed results in the ratepayers essentially paying twice for the same service. The value received and fairness of this effect is one that is of growing interest to state utility regulators, who may find the need to determine, on a prudence basis, whether the additional costs should be allowable in the utility rate base, or borne by the owners and stockholders of the utilities. Pursuant to the Act, and subsequent successful litigation brought by the utilities, the utilities, themselves, are the only consumers of power generated from nuclear reactors who are not subject to fee payments to the Nuclear Waste Fund.

In its MRS Position Paper, the DOE lists a number of factors as being nondiscriminating in making the choice between including

an MRS in the waste system or relying on continued at-reactor spent fuel storage. These factors are health and safety, environmental impacts, socioeconomic impacts, and transportation impacts. Aspects of elements on this list may be debatable as to their lack of consequence in decision-making, and each factor may, in fact, require further examination in determining cost implications and other considerations relevant to choices regarding the means by which timely and safe additional spent fuel storage can be achieved.

Following its public hearings, and in preparation for developing its November, 1989, report to Congress on the need for an MRS, the MRS Commission outlined four generic strategies it will evaluate in arriving at its report recommendations. These are stated by the MRS Commission as follows:

1. At-reactor storage until the repository is ready to accept spent fuel (no MRS);
2. Hybrid system with a mix of at-reactor storage and MRS storage at regional MRS facilities until the repository is ready to accept spent fuel (mix of at-reactor and one or more MRSs);
3. Storage at a central facility until the repository is ready to accept spent fuel (MRS only); and
4. Processing and storage at a central facility until the repository is ready to accept spent fuel (multi-function MRS).

The Commission's February, 1989, announcement goes on to say that each generic strategy option will be evaluated with regard to the following factors:

1. Overall safety and environmental impacts;
2. Effect on safe, efficient preparation of spent fuel for safe, permanent disposal (impact on repository design and construction; waste preparation; waste package design, fabrication, and standardization);
3. Transportation impacts (will include consideration of dual purpose and universal casks);
4. Flexibility and reliability of the national nuclear waste management program;
5. Economic efficiency;
6. Effects on public confidence in the national nuclear waste program;
7. Likelihood of meeting applicable regulatory requirements;
8. Likelihood of adverse impacts on reactor operations;
9. Equity of the system (e.g. regarding distribution of costs and benefits); and
10. Likelihood that DOE will be able to meet its contractual obligations [to begin accepting commercial reactor spent fuel in 1998].

The MRS Commission in announcing this strategy and evaluation approach has made clear its receptiveness to the spectrum of

public testimony it received during its nationwide public hearings. It also appears to have identified the set of policy options available to not only recommend for or against an MRS, but to address the larger question of how to create a safe, effective and efficient, and acceptable capability to store commercial reactor spent fuel for whatever period of time is necessary prior to the availability of spent fuel disposal.

The State of Nevada, in its January 9, 1989, testimony before the MRS Commission, concluded with the following statement of position:

"Given the number of options available in spent fuel storage technology, and the current policy that requires the utilities to bear the cost of at-plant interim storage, while the cost of an MRS would be paid from the Nuclear Waste Fund, the Commission should consider policy options that go beyond the current assumption of an all-or-nothing MRS policy configuration. More specifically, one might consider a policy that permitted the use of the Waste Fund for all types of interim storage, and then require each nuclear utility to commit itself, by some near future date, to what interim storage technology it prefers, and will, in fact employ, including an MRS if it is available by a date certain, and has a known storage capacity that is not linked to progress on a waste disposal facility. In this way, the utilities, as a group, may assist in determining the need for an MRS facility once the obvious cost, schedule and capacity disincentives have

been removed from their consideration. If enough utilities commit to use of an MRS to make it cost effective, this, in a way, becomes a system cost optimization decision. The overall system that would result from a mix of interim storage modes could then be analyzed to assure that on a system basis, the level of safety is acceptable.

"It is our recommendation that the Commission's report to Congress include analysis of spent fuel storage options that involve policy revisions to become achievable, such as those discussed here. The realities of the need for interim storage are sufficiently compelling that the nation's policy must result from consideration of the broadest and least inhibited set of options."

There are two lingering issues regarding the nation's policy to close the nuclear fuel cycle through development of a geologic repository system. Both involve considerations of interim spent fuel storage prior to the availability of a disposal facility. The first is in the realm of what has become known as "waste confidence." The Nuclear Regulatory Commission, in 1984, adopted a statement of "confidence" that safe and acceptable nuclear waste disposal capability would become available shortly after the turn of the century. This statement of confidence, and its mandated periodic review, at five year intervals, was intended to serve as a justification to continue to permit the operation, planning and further development of the commercial nuclear industry, even

though there was no available facility for terminal disposal of the nuclear waste (spent fuel) produced by the industry. In developing its 1989 waste confidence review position, the NRC staff, and the NRC's Advisory Committee on Nuclear Waste (ACNW), have recommended two modifications to the NRC Waste Confidence Findings. One is that "at least one mined geologic repository will be available within the first quarter of the 21st century." This modification is intended to recognize the continued delays in the federal nuclear waste repository program, and the possibility that the proposed Yucca Mountain repository site will not be found suitable for repository development, and a new program will have to be initiated.

The second significant proposed finding is that, "if necessary, spent fuel generated at any reactor can be stored safely and without significant environmental impact for at least 100 years." The stated technological basis for this finding of an extended period of confidence in spent fuel storage, beyond the earlier adopted 30 years, is three-fold: a) the reliability of hardware and engineering structures; b) no failure modes of significant concern for storage pools or dry casks; and c) if a repository is available by 2025, 100-year storage will not be required for any reactors.

The Nuclear Regulatory Commission, after hearing the recommendations of its staff and the ACNW, issued for a 90-day

public review period, a proposed revision of its Waste Confidence Decision on September 28, 1989, that is somewhat less far-reaching than that recommended by its staff and the ACNW. The two proposed revised findings are stated as follows:

- The Commission finds reasonable assurance that at least one mined geologic repository will be available within the first quarter of the twenty-first century, and that sufficient repository capacity will be available within 30 years beyond the licensed life for operation of any reactor to dispose of the commercial high-level radioactive waste and spent fuel originating in such reactor and generated up to that time;

- The Commission finds reasonable assurance that, if necessary, spent fuel generated in any reactor can be stored safely and without significant environmental impacts for at least 30 years beyond the licensed life for operation (which may include the term of a revised license) of that reactor at its spent fuel storage basin, or at either onsite or offsite independent spent fuel storage installations.

If either this proposed position, or that recommended by NRC staff and the ACNW, is adopted as a new Waste Confidence Rule by the Nuclear Regulatory Commission, it will provide the MRS Commission and the Congress increased security in recommending and adopting interim spent fuel storage policy without the fear of inhibiting or foreclosing the nuclear power option in the nation's electrical energy generating sector. Furthermore, it can provide

additional needed incentive to have the federal repository siting and development program proceed on a less schedule-driven and more conservative and scientifically motivated path in evaluations of a site's waste isolation capabilities.

It is also interesting to note that, if spent fuel is stored for a period of about 100 years (or even as little as 30 to 50 years) prior to disposal, its characteristics of radioactive decay make it a material that is considerably easier to deal with in developing a geologic repository in which there can be greatly improved confidence in its capability for safe waste isolation. The radioactivity of the spent fuel, in a 100 year period after discharge from the reactor, is reduced by approximately two orders of magnitude, from about 2 million curies per ton to about 30,000 curies per ton. Also, the heat generation of the spent fuel, after about 100 years of storage, is reduced by about thirty-fold, greatly reducing the uncertainties in planning for and analyzing the waste isolation performance effects of heat loading in a geologic repository. Furthermore, if the spent fuel is stored at the reactors for an extended period of time, these same two factors serve to greatly reduce transportation risks (and possibly some costs) when it is finally shipped from the sites. Obviously, this advantage in transportation does not accrue if relatively young spent fuel is removed from the reactor sites to an MRS.

The other lingering issue in waste management and disposal

policy considerations that may influence interim storage decisions is the utilities' desire to terminate ownership, and thus responsibility for their spent fuel inventories as soon as possible after its discharge from the reactor. In light of the long-standing federal commitment to receive and dispose of the nation's commercial high-level nuclear wastes, it is understandable that the utilities would want this to take place as soon as possible for reasons of capital and operational cost containment, as well as safety and liability. An outgrowth of this business-driven objective is the often stated, but not necessarily compelling, notion that we, the generation who created these highly dangerous wastes, have a responsibility to finally solve the problems of their disposal, rather than passing the unresolved problems on to future generations. Given the current state of lacking technological readiness to safely site, operate and finally seal a geologic repository, and our current confidence that existing technology is capable of providing long-term, safe interim storage of spent fuel and high-level radioactive wastes, a reasonable conclusion might be that to rush to less-than-sure geologic disposal is both dangerous and irresponsible. In pursuing such hasty action, we might actually be passing a greater problem - radioactive contamination escaping a failing repository - on to future generations. The utilities and consumers have reaped the benefits of nuclear power, and thus may be in the position of now having to shoulder the burden of the waste products generated for a longer period of time than planned or desired should this be

determined to best serve the nation's interest in optimizing safety and cost in finally closing the nuclear fuel cycle.

CONCLUSION

Passage of the Nuclear Waste Policy Act of 1982 created an atmosphere of optimism among governmental and private sectors in this nation that the problem of closing the nuclear fuel cycle through early development of a geologic repository was soon to be resolved. The prevailing rhetoric leading to passage of the 1982 Act was that if a repository is not available very soon, nuclear power reactors may have to shut down prematurely due to lack of spent fuel storage space and full core reserve capacity.

Since 1982, feasible technologies have developed rapidly for expansion of spent fuel storage at the reactors, and the option of off-site spent fuel storage is technologically achievable as well. Utilities and the NRC are now clearly stating that there is no "spent fuel emergency," and that additional, extended storage can be made available without compromising public safety.

It is becoming increasingly evident that the 1987 amendments to the Nuclear Waste Policy Act have done little to improve the possibility that geologic disposal of commercial spent fuel will be available as scheduled by DOE. And, there is declining confidence that it will become available anytime in the near

future, given the scientific and technological problem associated with the proposed Yucca Mountain repository site, as well as the inherent problems associated with making a credible determination of the site's suitability, when it is the only site under consideration.

The DOE and the utilities have clearly demonstrated that, even if the DOE repository program meets its optimistic schedules for repository siting, licensing and development, there will still be an unavoidable significant need among the nuclear utilities for expanded and extended spent fuel storage. The consequence of long delay or the abandonment of the Yucca Mountain site is that the known requirement for additional spent fuel storage capacity may be further expanded and extended. While this appears to be inconsistent with current nuclear waste policy objectives, it is these very policy objectives that require re-examination in the light of existing realities.

There is reason to continue to evaluate the option of geologic disposal, through an objective research and development approach, rather than through a schedule-driven advocacy of the suitability of a politically selected site. However, there is also a compelling current need to develop policy that assures safety and security in meeting the assured need for additional spent nuclear fuel storage. And that policy must arise from the realistic understanding that a safe and acceptable geologic

disposal facility cannot be achieved immediately simply because some interest sectors desire that to be the case. History and experience have taught us that in the nuclear arena, a conservative and scientifically deliberate approach is required in both policy development and actions undertaken.

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