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MEMORANDUM FOR: Samuel J. Chilk, Secretary

FROM: Fuel Cycle Rulemaking Hearing Board
Michael L. Glaser
Dr. John H. Buck
R. Beecher Briggs

SUBJECT: CONCLUSIONS AND RECOMMENDATIONS OF THE HEARING BOARD REGARDING THE ENVIRONMENTAL EFFECTS OF THE URANIUM FUEL CYCLE, DOCKET NO. RM 50-3

The Hearing Board has completed its conclusions and recommendations regarding the environmental effects of the uranium fuel cycle, Docket No. RM 50-3. Accordingly, we are submitting them to the Commission as an attachment to this memorandum.

We wish to call to the attention of the Commission the additional comments we have made with respect to the record in this reopened rulemaking proceeding. Such comments are set forth in section IV of the attachment, at pages

FUEL CYCLE RULEMAKING
HEARING BOARD

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Attachment

cc: Chairman Hendrie
Commissioner Gilinsky
Commissioner Kennedy
Commissioner Bradford
Commissioner Ahearne

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CONCLUSIONS AND RECOMMENDATIONS
OF THE HEARING BOARD
REGARDING THE ENVIRONMENTAL EFFECTS
OF THE URANIUM FUEL CYCLE

DOCKET NO. RM 50-3

CONTENTS

I. Introduction

The history of this rulemaking proceeding has already been discussed extensively by the Commission in its Notice of Reopened Hearing[1/] and in our recent Report to the Commission[2/] so that we need not repeat it here. It is sufficient to say that judicial review[3/] of the original fuel cycle rule (the so-called Table S-3) while approving the overall approach and methodology leading to its adoption "found that the rule was inadequately supported by the record insofar as it treated two particular aspects of the fuel cycle -- the impacts from reprocessing spent fuel and the impacts of radioactive waste management".[4/] The Commission's response to the court's decision resulting in this rulemaking hearing has been fully discussed in our Report to the Commission (pp. 7-16).

1/ Notice of Reopened Hearing in the Matter of Amendment of 10 CFR Part 51 - Licensing of Production and Utilization Facilities (Environmental Effects of the Uranium Fuel Cycle) dated May 20, 1977.

2/ Report of the Hearing Board to the Nuclear Regulatory Commission Regarding the Environmental Effects of the Uranium Fuel Cycle, Docket No. RM 50-3, August 31, 1978.

3/ Natural Resources Defense Council, Inc. v. NRC, 547 F.2d 633.

4/ Commission Notice of Reopened Hearing, May 20, 1977 at p. 2.

Based on the record of this reopened proceeding to date, we now present our recommendations for modification of the present Table S-3. We emphasize that our findings and recommendations must be read in light of our discussion of the staff's models and assumptions in our Report previously submitted to the Commission (see fn. 2, supra).

We note that in reaching its conclusions on the environmental impacts from reprocessing and waste management the staff utilized a number of models of facilities and systems for reprocessing and waste disposal. The staff included in these models assumptions of time factors for certain steps in the processes and choices of methodology based on its understanding of current technologies. We will first discuss whether the staff's models for reprocessing and waste management are reasonable and then give our recommendations for modifications in Table S-3.

II. Board Findings on Staff Models

In our consideration of the staff's models we have been guided by the following statements of the Court, made in its judicial review of the original fuel cycle proceeding:

> NEPA's requirements for forecasting environmental consequences far into the future implies the need for predictions based on existing technology and those developments which can be extrapolated from it. NRDC v. NRC, supra, n. 3, 547 F.2d at 639-40.

> Where important changes in the state of the art or other major uncertainties are in the offing, meaningful assessments of future environmental impacts might be facilitated by making two alternative estimates: one based only on existing technology and another which takes into account developments which may reasonably be anticipated. Id. at 640, fn. 13.

> Finally, we reject the related argument that plenary consideration of alternatives was necessary in this proceeding. We agree with the Commission that this may be deferred until action is proposed to license particular disposal facilities. For purposes of this proceeding, provided a sufficiently conservative and credible assessment of a particular waste disposal method is used, it is not material that another method might turn out to be even more desirable. * * * Of course, we do not exclude the possibility that limited consideration of certain alternatives (e.g., the consequences of not proceeding at all) may be necessary to meaningful judgments in a proceeding such as the present. Id. at 653, fn. 57.

A. Reprocessing[5/]

For the reprocessing alternative, the staff assumes that the spent fuel, after 150 days cooling at the reactor, will be shipped to a model reprocessing facility. In the model facility the fuel elements will be sheared into small pieces, and the uranium, plutonium and fission products will be dissolved in nitric acid leaving behind the cladding hulls and hardware. The uranium, plutonium and fission products will then be separated into three liquid fractions by the Purex solvent extraction process. The uranium will be converted to uranium hexafluoride that satisfies the purity requirements for recycling in an enrichment plant. The plutonium, containing about five percent of the fission products in order to make diversion more difficult, will be converted to plutonium oxide and packaged for disposal in a Federal repository.

The high level liquid waste (HLLW), containing the bulk of the fission products, will be stored for up to five years in tanks. Such wastes will then be calcined to a solid and formed into massive glass in a spray-calciner and in-can melter for disposal.

5/ As noted on page 4, *supra*, our discussion here must be read in conjunction with our previous Report to the Commission (see fn. 2, *supra*) and detailed references given in that discussion are not repeated here.

Most of the other radioactive wastes at the reprocessing site will be contaminated with plutonium and other transuranium (TRU) nuclides to the extent that they will have to be disposed of in a Federal repository. The combustible wastes will be incinerated. Incinerator ash, other dispersible solids, and aqueous concentrates will be mixed with cement or other solidification agents and packaged. Cladding hulls, hardware and other noncombustible solid wastes will be appropriately packaged for disposal.

Our review of the record indicates that no significant issues were raised regarding the staff's choice of processes in its model for the reprocessing. While some of the participants in this proceeding would have selected different processes or equipment, none actually contended that the staff's choices were impractical. Substantial issues were raised concerning whether the staff had made a conservative analysis of the performance of its model reprocessing facility; whether the capacity and capacity factor of the model are warranted; whether the radioactive releases and occupational exposures are conservative; and whether reprocessing is economically feasible.

1. Design Capacity of Model Reprocessing Facility

The staff's model facility is specified to have the capacity to reprocess 2000 MTHM/yr[6/] when operating with a capacity factor of 0.8. The staff assumed that such a facility would reprocess spent fuel from 57 model reactors. Each model reactor was specified to have a capacity of 1000 MWe, to have a capacity factor of 0.8 and to discharge 35 MT/yr of spent fuel with a burnup of 33,000 MWD/MT.

Although the only commercial experience in this country with reprocessing of spent uranium oxide fuel from LWR's was obtained from the 300 MT/yr (1 MT/day) Nuclear Fuel Services (NFS) plant, the Barnwell plant (Allied Gulf Nuclear Services) has been built with a capacity of 1500 MT/yr (5 MT/day). Exxon Nuclear has applied for a permit to construct the Nuclear Fuel Recovery and Recycling Center (NFRRC) designed for an ultimate capacity of 2100 MT/yr (7 MT/day). The United States government plants at Hanford and Savannah River, which reprocess low burnup uranium metal fuels by use of the Purex method, have capacities of 14 to 30 MT/day.

6/ MTHM = metric tons of heavy metal (uranium and plutonium), MTU = metric ton of uranium, and MT = metric ton are assumed to be equivalent terms in this discussion.

According to the staff, the model facility is intended to be representative of plants built after Barnwell. Three model facilities, in addition to Barnwell and NFRRC, would be required to reprocess the fuel from the 268 LWR's expected to be operating or under construction in the early 1980's. In view of the industry's trend toward larger plants, the fact that much of the technology is in use on a larger scale in the United States government plants, the potential supply of spent fuel, and other factors in the record before us, we find that 7 MT/day is reasonable choice of capacity for the staff's model facility.

2. Components of the Reprocessing System

Some of the components and systems included in the model facility have not been operated in a radioactive environment on a 7 MT/day scale. Foremost among these are the head-end process consisting of a shear and dissolver, the centrifugal contactor in the first stage of the Purex process, the facility for converting fission-product-contaminated plutonium nitrate into plutonium oxide, the incinerator for combustible TRU waste, and the process for solidifying HLW.

a. Shearing

A shear and dissolver in the NFS facility operated at the plant design capacity of 1 MT/day for extended periods. However, difficulties with the head-end process, mostly with the shear and maintenance of the shear, was one of the major reasons for the capacity factor of the NFS plant being only 0.33 as compared with the expected 0.8. A shear and dissolver system having a capacity of 5 MT/day has been installed at Barnwell. The shear is reported to have operated well in cold (non-radioactive) tests. Improvements in the design and in the equipment for maintenance, intended to overcome the difficulties experienced at NFS, have been incorporated in Barnwell.[7/] A shear of similar capacity is being developed for the NFRRC. Moreover, special attention is being given to maintenance. Two shears are included in the design to enable the plant to reprocess at a rate of 7 MT/day. A program for developing an improved shear and maintenance system is beginning at the Oak Ridge National Laboratory under the sponsorship of the Department of Energy.

7/ A similar shear has been used recently to shear oxide fuel elements for reprocessing in the La Hague plant in France. Apparently, difficulties have been experienced with maintenance of that shear, but it is not known how the provisions for maintenance compare with those installed at Barnwell.

Clearly, the solutions to the problems of shearing fuel elements experienced at NFS have not yet been demonstrated. However, the record here indicates that the head-end processing at Barnwell and NFRRC will be much improved over that at NFS. Use of two or more units per plant may be necessary to obtain a capacity of 7 MT/day and an adequate capacity factor, but nothing offered in the record suggests that the problems are so unique or difficult that they will not yield to good engineering and additional experience.

b. Centrifugal Contactors

Centrifugal contactors have been used in France and at Savannah River with good results. If the reliability of centrifugal contactors should prove to be inadequate, conventional pulse columns could be substituted. However, in order to reduce the degradation of the organic solvent, such a change might require that, before reprocessing, the spent fuel decay more than the 160 days assumed by the staff. Decay time before reprocessing is discussed at pp. 17-18, infra.

c. Conversion of Plutonium Nitrate

Processes for converting plutonium nitrate, highly decontaminated of fission products, to plutonium oxide and for handling the oxide in glove boxes are well developed. Leaving the plutonium highly contaminated with fission products to discourage theft means that these operations will have to be carried out remotely in hot cells. Although such a change is not trivial, the extensive experience with hot cell operations should make such a change achievable with moderate development. If the development should prove to be unexpectedly difficult, highly purified plutonium nitrate might be converted to the oxide and other means used to prevent theft or to contaminate the plutonium oxide just before it is packaged.

d. Incinerators

There is little question that incinerators can be built and operated on the scale required for a 7 MT/day reprocessing facility. Whether such a unit can be operated and maintained satisfactorily to burn waste containing TRU and fission product nuclides is in the process of being demonstrated. The staff chose this process over others for the model facility because it reduces the volume, removes combustible material from waste to be sent to a geologic repository, and it is conservative in that it produces higher environmental impacts than would be produced by other possible alternatives. If this method proves to be impractical, there are alternative methods for handling the waste and for reducing concerns about flamability.

e. Solidification of High Level Wastes (HLW)

Although to the present no HLW from the reprocessing of LWR spent fuel has been solidified, the spray-calciner in-can melter process has been extensively developed over many years. The development has included the processing on a 1 MT/day scale of simulated waste containing representative levels of fission product heat generation. The process has been tested with non-radioactive simulated waste on a 9 MT/day scale in a recently completed engineering test apparatus. The results of this program give ample reason to conclude that the development can be completed to provide satisfactory equipment and process for the model facility.

We find that equipment is presently available or can reasonably be expected to be developed for operating a facility of 2000 MT/yr capacity. We now consider whether the 0.8 plant factor is reasonable or necessary and the effect on the environmental impacts if that plant factor were not achieved.

3. Facility Capacity Factor

The NFS plant operated with a capacity factor of only 0.33. The United States Government plants are reported to operate with a downtime of 20 to 25 percent which implies a capacity factor of 0.75 to 0.8. Because of improvements incorporated in Barnwell and the fact that Barnwell will reprocess only LWR fuels, we find reason to conclude that the capacity factor at Barnwell will be substantially higher than at NFS. Unquestionably problems will be encountered and it may take some time to achieve satisfactory operation. We also assume that no administrative barriers to high capacity factors will be imposed.[8/] However, we believe it reasonable to expect that a model facility, following Barnwell and taking advantage of lessons learned there, would achieve a still higher capacity factor. Nonetheless, we find no precedent in experience with fuel reprocessing facilities to support an assumption that the capacity factor would actually be as great as 0.8 over the 30-year life of a facility.

8/ One such barrier, suggested by one of the participants in this proceeding would be to require that operation be interrupted in order to establish a plutonium balance for each batch of reprocessed fuel ($\sim$ 35 tons). (Testimony of Pohl and Resnikoff, Appendix A, pp. 146-147.)

For the purpose of Table S-3, the important assumption is that a model facility will reprocess fuel from 57 model reactors. The annual impacts of operation of the reprocessing facility are divided by 57 to obtain the annual impact attributed to each reactor in the Table. The record shows that the staff was conservative in assuming that the model reactor would discharge 35 MT/yr of spent fuel with a burnup of 33,000 MWD/MT. A realistic discharge rate would be about 30 MT/yr with a burnup of 31,000 MWD/MT or 29 MT/yr if the burnup were 33,000 MWD/MT.[9/] A model reprocessing facility operating with a capacity factor of 0.7 could reprocess the spent fuel discharged at these rates from 57 model reactors.

We find an adequate basis in the experience with government plants for assuming that commercial reprocessing facilities following Barnwell will be able to achieve capacity factors as high as 0.7. We find, therefore, that the staff's model facility would be able to reprocess spent fuel from 57 reactors. The staff has also used a reasonable basis for estimating those impacts such as land committed which depend on plant size. By assuming that the model facility would have to operate with a capacity factor of 0.8 (35 MT/RRY) the staff has used a basis that should

9/ See our Summary Report, p. 28.

result in overestimates of impacts such as consumption of water and energy and releases of chemical effluents all of which depend primarily on the amount of spent fuel reprocessed per RRY.[10/]

If it developed that the reprocessing facilities were unable to achieve a capacity factor as high as 0.7 some of the impacts (primarily those determined by size and number of facilities) would increase. However, except for the releases of radioactivity, most of the impacts of reprocessing are only a small fraction of the total values of environmental impacts in Table S-3. Large changes in capacity factor or plant size would not have much effect on the total impact values in Table S-3.[11/]

The Board finds that the capacity and capacity factor of the staff's model facility provide a reasonable basis

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10/ RRY - Operation of the Reference (or Model) Reactor for one year.

11/ Only in the cases of land temporarily committed, amount of natural gas consumed, and releases of radioactivity in gaseous effluents do the impacts of fuel reprocessing constitute as much as 10 percent of the total impact values in Table S-3. The values for land temporarily committed for reprocessing is about one-third of the total only because it was not prorated over the life of the facility as it was for other components of the fuel cycle. The consumption of natural gas and release of radioactivity are governed primarily by the quantity of spent fuel reprocessed per RRY and should not be much affected by plant size or capacity factor.

for its analysis of the environmental impacts of spent fuel reprocessing. No participant here has taken issue with the staff's values for natural resources used, chemical effluents, or thermal effluents. We find that the impact values are reasonable and in most instances are overestimates of the impacts that would actually occur.

4. Staff's Values for Releases of Radioactive Nuclides

The record shows that several factors in the staff's analysis of radioactive releases tend to cause the results to be overestimates of the releases that would actually occur.

a. Level of Fuel Burnup

Assuming the reprocessing of 35 MT/RRY with a burnup of 33,000 MWD/MT rather than the realistic value of 30 MT/RRY with a burnup of 31,000 MWD/MT causes the releases to be overestimated by a factor of 1.2.

b. Time to Start of Reprocessing

The staff assumed that the spent fuel would be reprocessed after 160 days decay. Considering the rate at which spent fuel will be accumulated and the time when reprocessing plants are likely to be operating, it is obvious that for many years to come the spent fuel will decay for five years or more before being reprocessed. This is unimportant for nuclides having long half lives, but iodine-131 (8-day half life) would have decayed away, ruthenium-106 (368-day) would be reduced by a factor of about 30, and tritium and krypton-85 would be reduced by a factor of 1.3 or more. Overall the longer decay would reduce the number of curies of radioactivity and the heat from radioactive decay by a factor of about 8.

c. Reprocessing Plant Effluents

All the radioactivity released to the environment from the reprocessing facility will be in gaseous effluents. The gas streams which would be expected to contain appreciable amounts of iodine or other semi-volatile materials and radioactive aerosols are treated by one or more of the processes such as scrubbing, sorption and filtration in order to capture almost all the radioactive material. In present and past reprocessing facilities, excess process water, containing a low concentration of radioactivity, has been discharged into local rivers and streams. In the staff's model facility, the excess water will be vaporized into the atmosphere and the vaporizer concentrate will be recycled to the plant waste system. Whether the excess water is discharged into streams or into the atmosphere is immaterial to this proceeding. The vaporization process will not reduce the amount of tritium that is released. That extra step can, however, be expected to reduce the amount of strontium and cesium and other less volatile radionuclides which would otherwise be released in the aqueous effluent from the plant.

d. Releases of Tritium, Krypton-85 and Carbon-14

For purposes of Table S-3, the staff has assumed that all the tritium, krypton-85 and carbon-14 in the spent fuel is discharged to the environment. No party in this proceeding contends that the staff has underestimated the releases of these three nuclides. We find that the 18,000 ci release of tritium from reprocessing is an over-estimate by a factor of 1.2 to 1.6 because of the factors discussed *supra*. The overestimate is likely to be greater because a substantial amount of tritium may be found in the fuel cladding. The krypton release of 400,000 ci is also an overestimate by a factor of 1.2 to 1.7 because of the factors discussed *supra*, and the staff may also have used a high value for the yield of krypton-85. Whether the carbon-14 release is an overestimate is uncertain because the amount of nitrogen in the reactor fuel is variable.[12/]

12/ The carbon-14 in the fuel is produced by neutron reaction with nitrogen-14 impurity in the fuel.

The value of 24 ci/RRY in Table S-3 is what one might realistically expect to be released from fuel that contains nitrogen impurity well into the medium to high range of values. We find that the use of the 24 ci emission value is reasonable.

e. Releases of other Radionuclides

The releases of other radionuclides depend on the effectiveness of the systems designed to contain them. The effluent control measures proposed for the staff's model facility have not been operated in the combinations proposed and some have been tested only in the laboratory. The staff has examined each control system in detail and has calculated the releases on the basis of what it concludes is the lower range of performance of each of the systems. The designers of Barnwell and the NFRRC expect the systems to be one to two orders of magnitude more effective than has been assumed by the staff. However, the Sierra Club, among others, contends that the control measures have not been developed and demonstrated sufficiently to support the use of decontamination factors for the model facility that greatly exceed those demonstrated in the NFS facility.

The staff has used a decontamination[13/] factor of 40 for iodine in the reprocessing facility. This results in a release of 0.03 ci/RRY of iodine-129 and 0.83 ci/RRY of iodine-131. This decontamination factor was arrived at on the basis that 90 percent of the iodine would be released into the off-gas from the dissolver and 10 percent would remain in solution with the fuel and other fission products. The off-gas stream would be scrubbed with a mercuric nitrate-nitric acid solution and passed through silver zeolite sorbers with an overall decontamination factor of 10^3 or more. The iodine in the solution would eventually enter the vaporizer where mercuric nitrate would be added to obtain a decontamination factor of 4 and an overall iodine decontamination factor of 40.

We find that the staff has considerably overestimated the likely release of iodine from the reprocessing facility. Laboratory studies have shown that 99 percent or more of the iodine can be volatilized into the dissolver off-gas stream. Methods are also available for substantially reducing the release of iodine from the liquid waste stream.

13/ Decontamination factor as used here is the ratio of the number of curies of a radionuclide entering the plant in the fuel to the number of curies released in the effluents.

Iodine-131 has an 8-day half life, and based on a realistic appraisal of reprocessing prospects, will have decayed away before reprocessing is likely to begin. The iodine-129 removed in reprocessing would be packaged and shipped to a disposal facility. For the purposes of Table S-3, whether the iodine-129 is released in reprocessing is of no consequence. The staff has assumed that all the iodine-129, 1.3 ci/RRY, would be released from spent fuel and escape to the environment if spent fuel were disposed of as waste in a repository. The value for total release has been included in Table S-3.

The staff has used a decontamination factor of 1×10^8 for ruthenium-106, 5×10^8 for non-volatile fission products such as strontium-90 and cesium-137, 2×10^8 for plutonium and 5×10^8 for other TRU nuclides in estimating the release from the reprocessing facility. The lower decontamination factors for ruthenium and plutonium reflect the greater volatility of ruthenium under some conditions and the greater amount of processing of the plutonium. These decontamination factors compare with a decontamination factor of about 10^5 measured for ruthenium, strontium and cesium at NFS.

On the basis of the record before us we are persuaded that faulty design and possibly faulty operation of the acid concentrators and waste evaporators at NFS were largely responsible for the low decontamination factors experienced there. We find the evidence convincing that the decontamination factors assumed by the staff for its model can be achieved and probably surpassed by use of well engineered evaporator systems and the air filtration systems that are now in use.[14/] The Sierra Club expressed concern that ruthenium and technetium would be volatilized and released in the process of solidifying the high level wastes. We believe that the results of the Waste Solidification Engineering Program (WSEP) provide sufficient evidence that the waste solidification process will not cause the ruthenium-106 releases to exceed those estimated by the staff.[15/] Although no measurements of decontamination factors for technetium were made during the tests, chemical considerations support a conclusion that technetium would be contained at least equally well. We find that the staff

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14/ This evidence while not found in the conclusional statements in NUREG-0116 and the GESMO report, NUREG-0002, is obtained from technical reports referenced in these documents.

15/ See our Summary Report, p. 58.

has overestimated the amounts of ruthenium, non-volatile fission products and TRU nuclides that are likely to be released during normal operation of a model reprocessing facility.

A substantial fraction of the technetium will accompany the uranium through the Purex process. Some of the participants in this proceeding questioned whether the technetium could be separated well enough from the uranium, during the fluorination, for the uranium hexafluoride to meet the specifications for feed for the enrichment plant, and whether the technetium would be released to the environment from the fluorination process. We find that this record[16/] indicates that the uranium hexafluoride can be decontaminated sufficiently and the technetium can be contained and packaged for disposal as a waste.

Except for the releases discussed above, all the radioactivity that enters the reprocessing facility decays or is packaged as solid waste for shipment to a disposal facility. The magnitude of further releases depends on how well the radioactivity is contained during the subsequent interim storage, shipment and handling, and how well it is confined by the media in which it is finally buried.

16/ See Summary Report, pp. 59-60, particularly notes 136, 139, 141, 143 and 144.

f. Occupational Exposure

The staff has estimated that the occupational exposure to workers in the reprocessing facility would be 1250 person-rem per year or 22 person-rem/RRY. This exposure was calculated on the basis of the number of people in various work zones and design values for the radiation levels in those zones. The estimate is for normal operation, including minor incidents, but does not include exposures incurred in recovering from major accidents or unexpected equipment failures.

The Sierra Club contends that the staff's estimate is much too low.[17/] This contention is based on comparison with occupational exposures experienced at NFS and consideration of the much larger amount of more highly irradiated fuel that would be reprocessed in the model facility. However, the testimony of the Sierra Club indicates that operation of the NFS was mostly abnormal and the need to reduce occupational exposures was one of the reasons for shutting down the plant for modifications. In a similar vein Dr. Walton A. Rodger,[18/] a witness for BG&E,

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17/ See our Summary Report, pp. 64-66.

18/ Dr. Rodger had several years personal experience with operation of NFS.

in answer to Board questions stated that approximately 40% of the total occupational exposure at NFS came from problems with the cranes, shears, saw and the whole process mechanical end (Tr. 863). He also noted that in 1968 and 1969 when the plant was operating reasonably well and had its largest throughput (150 and 136 tonnes for 1968 and 1969, respectively), total occupational exposure (permanent plus temporary workers) was about 900 man-rem. However, in 1970 and 1971 when major maintenance work was being performed throughput dropped to 37 tonnes (1970) and 69 tonnes (1971), but exposures rose to 1531 and 2366 man-rem respectively (Tr. 867 and 870). Dr. Rodgers expressed confidence that lessons learned from NFS would produce exposures at the Barnwell and NFRRC facilities within the staff's estimate.

Future facilities will be designed and operated to comply with the Commission's ALARA requirements. However, the staff's values are based on calculations, are unsupported by reference to experience in any of the U. S. Government plants and appear to allow no margin for major maintenance. T[illegible], we cannot find the exposure values to be conser-[illegible]e for a model facility that reprocesses fuel cooled for only 160 days.[19] But, on the evidence presented on the designs of Barnwell and the proposed NFRRC as compared with

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19/ Note, however, our recommendation, pp. 65-66, *infra*, concerning the staff model which uses the 160-day decay time before reprocessing.

NFS and realistic decay times, there is reasonable assurance that the staff's estimate of occupational exposures is realistic.

B. Interim Storage

Present concepts of facilities for disposing of HLW and spent fuel, that is treated as waste, are based on the assumption that the radioactivity will have decayed for ten years or more before those wastes are placed in a geologic repository. The decay eases the problems of cooling and handling the waste, and increases the amount that can be stored per unit area of repository. Other TRU wastes, including plutonium, could be disposed of shortly after they are generated. When repositories for permanent disposal will be available is uncertain, so the staff has considered the impacts of longer interim storage in deriving the values for Table S-3.

1. Wastes from Fuel Reprocessing

The canisters of solidified HLW are to be stored in a water basin at the reprocessing facility for five years or more until the radioactivity has decayed for ten years after removal from the reactor. The staff assumed that the waste might then have to be shipped to a Retrievable Surface Storage Facility (RSSF) where it would be stored for up to twenty years until a geologic repository becomes available for permanent disposal. The sealed storage cask concept was specified for storing the canisters of HLW at the RSSF on the recommendation of a committee of the National Academy of Sciences. (NUREG-0116, Section 4.2.5, Refs. 1 and 4).

The packaged TRU wastes were assumed to be stored at the reprocessing facility for 15 to 20 years before being shipped to a geologic repository. The drums of cladding hulls and hardware, which generate appreciable heat, would be stored in the fuel storage basin. Other packaged, solidified waste would be stored in an earth-covered concrete vault.

The containers of plutonium oxide would be stored at the reprocessing facility for up to five years. Then, if a permanent repository were not available, they would be shipped to a facility with a capacity specified to be sufficient for storage for twenty years. For interim storage, each container of plutonium oxide would be placed in a pressure vessel that would be inserted in a stainless steel lined hole in a thick concrete slab. Air would be circulated through the holes to remove the heat from decay of the radioactivity.

Water basins are used for storing highly radioactive materials throughout the nuclear industry. The other facilities for interim storage of wastes from fuel reprocessing have been studied in conceptual designs. None of the facilities presents problems so difficult or unique as to raise serious questions of practicality. The staff assumed that some radioactivity would be released from containers that were contaminated or were damaged or failed during shipment, handling and storage. The facilities would be equipped with air filtration systems and equipment for processing liquid waste. The staff estimated that the amount of radioactivity released during normal operation of the interim storage facilities would be small in comparison with the amount released during reprocessing.

Although questions were raised, no participant took serious issue with the staff's choice of facilities for interim storage or the assessment of the impacts of normal operation. We find that the staff choice of facilities is reasonable. Because of the uncertainties as to when permanent repositories for waste will be available and when or whether reprocessing facilities will operate, it is necessary to include interim storage, beyond that at the reprocessing facility, in the staff model. The assumption that such storage would be for about twenty years seems to be as reasonable for the purposes of Table S-3 as any other that might be made at the present time. We consider the staff's assessments of the impacts and releases from normal operations to be reasonable. Although the impacts from interim storage of plutonium were not fully analyzed the staff's judgment that they would not significantly increase the values in Table S-3 seems reasonable.

2. Spent Fuel

Although some capacity for storage of spent fuel is provided at the nuclear power plant, additional capacity will be required if spent fuel is disposed of as waste. The staff assumes that the spent fuel will be stored in water basins for ten years and then placed in canisters and shipped to a Federal repository for storage.

Water basins are in use for storing fuel elements at the nuclear power plants and the technology is well established. A small fraction of the spent fuel is expected to leak radioactive materials into the pool water. About one percent of the krypton-85 in the fuel would be released to the atmosphere. The radioactive materials in the pool water would be removed, packaged and shipped to a burial facility. We find that the staff has chosen a reasonable facility for interim storage of spent fuel and has made a reasonable analysis of the environmental impacts. Some participants in this proceeding indicated that the fuel would have to be stored longer before repositories could be brought into operation, and that deterioration of the cladding for longer storage in water could lead to greater releases and impacts. The evidence indicates that deterioration of the cladding is unlikely to be serious during storage times of the order of twenty years. Also, increases in the values for releases of volatile nuclides during interim storage would be compensated by decreases in the values for releases from the geologic repository.[20/] We find that the assumption of longer interim storage of spent fuel would have little or no effect on the values in Table S-3. This Board, however, is greatly concerned that consideration of the environmental impact of temporary storage

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20/ For purposes of its cost analysis, the staff assumed that the spent fuel would be stored in water basins at the reactor facilities for ten years. It would then be packaged and transported to an RSSF where it would be stored for twenty years. Storage in a pool would serve equally well.

of spent fuel has not, to this date, resulted in any positive action to build off-site interim storage facilities for the rapidly mounting volume of spent fuel. The record here indicates that within five years the lack of such storage space will have serious environmental and economic impacts on the country.

C. Disposal of Radioactive Waste in a Geologic Repository

The staff has assumed that the HLW, TRU waste, and plutonium from reprocessing of the spent fuel will be disposed of by burial in a geologic repository in bedded salt. This mode of disposal has been under study since 1957 when it was recommended as a promising method by a committee of the National Academy of Sciences-National Research Council. Experience was gained in the handling of radioactive waste in a salt mine in Project Salt Vault. A large program has been in progress for several years on design studies for a repository and on the thermal, chemical, mechanical, radiation and safety problems that can be foreseen. Field investigations have been undertaken to determine promising locations for repositories.

We see no reason to doubt that the model repository could be constructed and operated to bury the wastes as proposed. The testimony in the record, including statements by the U. S. Geological Survey, supports the conclusion that sites can be found which satisfy the criteria being developed by the Department of Energy and the NRC. A substantial number of investigations would have to be made at the site before beginning construction, as the mine was being opened, and, possibly, during the first years of operation in order firmly to establish site suitability.

1. Releases of Radioactive Material before the Mine is Closed.

In its analysis of the environmental impacts of normal operation, the staff assumed that some radioactive material would be released during the handling and emplacement of the wastes. Radioactive particles would be removed from the ventilating air by HEPA filters and the radioactive gases would be discharged to the atmosphere. The amount of radioactivity released would be very small except in the case of disposal of spent fuel. The staff assumed that all the tritium, krypton-85, carbon-14 and iodine-129 would be released from the spent fuel.[21] This assumption was made on the grounds that the fuel canister and cladding would be corroded by the salt and those nuclides or their volatile compounds would be released by the fuel. The staff assumed that after the repository was backfilled with salt and the shafts were filled and sealed no radioactive materials would be released.

2. Integrity of the Sealed Mine

The major concern with regard to the integrity of the repository is whether water might enter, dissolve the radioactive materials, and transport them to the biosphere. The staff's position is 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 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

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21/ In calculating the release the staff assumed that the radioactivity had decayed for only five years after discharge of the fuel from the reactor.

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 could reach the biosphere.

a. Effects of Heat

Concern was also expressed on this record that the presence of the repository might create conditions that would give access to water from aquifers in strata above and below the bedded salt. One matter that has been of particular concern is the effect of the temperature rise produced by heat released by decay of the radionuclides. It has been suggested that excessive temperatures in the region surrounding the waste would result in migration of brine to the waste. Furthermore, chemical reactions might occur that would make the waste more easily transportable. In addition, the heating of the earth in the vicinity of the repository would cause some expansion of the salt and rock, and thus uplift the surface. As the radioactivity continued to decay, and the heat dissipated, the surface would subside. These events might produce fractures that would give water access to the salt.

Measures can be taken to reduce the temperature gradients in the vicinity of the waste canisters, so that the maximum temperature and the severity of the effects of heating in a given repository are governed by the specific heat rate in kilowatts per acre. Heat rates of 150 kw/acre and a maximum temperature of 250°C in the salt are among the emplacement criteria that have often been mentioned. For a given repository the maximum temperature and the heat effects would be reduced by reducing the emplacement density and, thereby, the heat rate.

Insofar as the staff's impact analysis and the values in Table S-3 are concerned, reducing the emplacement density and heat rate would increase the land committed, the energy consumed and the heat released by the facility operations. During this proceeding the staff proposed to change Table S-3 on the basis that spent fuel, or HLW, TRU waste and plutonium combined, would be emplaced such that the heat rate would be 24 kw/acre or less for the model situation that was calculated. With these conditions the average temperature rise in the salt at the waste disposal level would be less than 30°C. The surface would be raised less than 0.8 meters in 1000 years and would subside over tens of thousands of years. The calculations were only illustrative of what one might expect in a model situation.

Much more elaborate analysis would have to be made for specific repository sites. However, the calculations indicate that measures can be taken to satisfy the concerns about temperature effects.

b. Mine Shaft Sealing

Another major concern is with the mine shafts and bore holes that pass through aquifers and into or near the repository. Unless the holes are sealed when the repository is closed they would provide pathways for water to reach the waste. Development work is in progress that the staff believes will provide reliable seals. It is expected that, over the long term, the salt would flow and maintain the seals in the zone within the salt bed. Whether failure of a seal would lead to release of radioactivity depends on many circumstances. The waste would be buried deep within the salt bed. Information in the record indicates that large flows of water over salt beds dissolve the salt away at rates of the order of five or six feet per 1000 years. Or, if all the water flowing through the aquifers above a potential repository site in New Mexico were diverted to flow through the salt, it would take 50,000 years to dissolve the salt associated with one year's waste.22/

22/ Summary Report, pp. 87, 88.

We find that the staff has described a reasonable facility for the deep burial of the HLW, TRU waste, plutonium and spent fuel. The values for the environmental impacts, as modified during the proceeding, are based on substantial information, are reasonable for most impacts and highly conservative with regard to releases of radioactivity from spent fuel. We find a high degree of assurance that the radioactivity will be confined to the vicinity of the repository for hundreds of thousands of years after the repository has been closed and sealed. According to the record, geological, hydrological and other studies will be carried out, before the repository is built and during its operation, to provide assurance that the criteria necessary for the long term operation of the repository will be met. The areas will be posted with permanent markers to deter intrusion by man.

c. Catastrophic Events

We find substantial reason to accept the staff's assumption that the waste will remain undisturbed for millions of years, although this cannot be proven. Several studies have been made of the possible consequences of events that might cause radioactivity to be released. If a very large meteor were to strike the earth above the repository it could penetrate to the waste. Some of the radioactivity would be dispersed into the atmosphere. Most of the radioactivity would be deposited over an area within several miles of the repository. The local consequences would be severe but worldwide consequences would not. The probability of such an event occurring would be extremely low and the risk is small. (NUREG-0116, Section 4.4.2, Ref. 1).

Earthquakes or other events might open paths for water to reach the waste. Again, depending on the circumstances, local consequences could be severe. But the probability of an event occurring or of the conditions being the most unfavorable are generally judged to be low and the risks small. (Ibid.)

After a few hundred years, the radioactive nuclides in the waste will have decayed sufficiently that the carbon-14, iodine-129, technetium-99, and plutonium and other TRU nuclides in the waste are the principal hazards. For purposes of Table S-3 the staff has assumed that the carbon-14 and iodine-129 are released, but that the other nuclides decay before they can reach the biosphere. The studies on the retention of plutonium by soils (including the experience at the OKLO site) indicate that the staff's assumption of no release to the biosphere is reasonable for the purposes of Table S-3.

We find that the staff has described a reasonable model facility for the geologic disposal of radioactive waste and has made reasonable estimates of the environmental impacts of normal operation of the facility.

D. Shallow Burial of Low Level Waste

The staff has assumed that the low level radioactive wastes that contain less than 10 nci/g of TRU nuclides will be disposed of by shallow burial in licensed facilities located on state or federal land. This method has been used for many years. As a result of experience at existing burial facilities, some of which has not been satisfactory, the staff has developed criteria for future burial facilities. Its analysis of environmental impacts is based on a model facility that satisfies those criteria. The present burial facilities at Barnwell, South Carolina and Beatty, Nevada satisfy most or all the criteria. It is generally agreed that many locations that satisfy the criteria can be found.

The staff's analysis assumes small releases while the burial facility is operating and no release to the biosphere after the facility has been closed. Monitoring of the environs, maintenance of the cover over the burial area, and restricted usage of the site may be required for several hundred years after the facility has been closed in order to prevent releases.

We find that the siting and operation of future facilities for shallow burial of low level waste can be expected to be improved over those of the past. The information available indicates that the staff may have underestimated the amount of waste that must be disposed of, particularly the amount from decommissioning of facilities by immediate decontamination and dismantlement.[23/] However, increasing the permanently committed land to compensate would increase the total permanent commitment in Table S-3 by only a few percent. We find the staff's estimates of the other impacts from normal operation to be reasonable. They are generally

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23/ According to the Battelle studies (NUREG-0395 or NUREG/CR-130) the burial volume from decommissioning a large PWR would be about 18,000m^3 or 450 to 600m^3/RRY as compared with the staff's value of 360m^3/RRY for the decommissioning of all the fuel cycle facilities.

so small that they could be in error by factors of 2 or 3 without much effect on the overall values in Table S-3.

The validity of the staff's assumption with regard to the long term release of radionuclides is much less certain. The nuclides of most concern here are nickel-59 and niobium-94 (from reactor components and corrosion products), iodine-129, technetium-99, and the TRU nuclides. Because of the good sorptive properties of many soils, it is reasonable to expect that the TRU nuclides, nickel and niobium, unless complexed by reaction with constitutents of the waste, would remain in the burial area. Over the very long term iodine and technetium could migrate with the ground water.

Likely modes of transfer of the radioactivity into the biosphere are intrusion by man, erosion, and dissolution over very long times. These are being considered in developing the limits on amounts and concentrations of the various radionuclides that will be permitted in waste disposed of by shallow burial in the future. The objective is to set limits such that individuals making unrestricted use of the disposal area and subjected to exposure by the other processes at times after the strontium-90 and cesium-137 have decayed would not receive excessive doses of radiation.

We find that the staff assumption of no release underestimates the amount of radioactivity that is likely to be released to the biosphere from shallow burial facilities over the long term. We consider the matter further in our recommendations.

E. Accidents and Sabotage

In arriving at values for impacts of fuel reprocessing and waste disposal, the staff considered the impacts that might result from accidents in each of the model facilities and processes. The accidents are described briefly in NUREG-0116 and the GESMO report NUREG-0002 and in more detail in the safety analysis reports for the Barnwell and NFRRC facilities and in other principal references. They include minor accidents that would release no radioactivity, but emphasize events that have the potential for releasing large amounts. These include explosions and fires in process equipment and cells, rupture of waste canisters during handling, and events as locally catastrophic as the impact of a large meteor on a waste repository. For the purposes of the accident analyses, the HLW was assumed to be packaged as the calcined material and the plutonium as a fine powder, both readily dispersible forms, so that the calculated releases would tend to be conservative.

As a result of its analyses, the staff concluded that the impacts from accidents would be only a few percent of the impacts from normal operation and did not include them in the values in Table S-3. Although the amount of radioactivity released in a major accident could be greater than that released during a considerable period of normal operation, the frequency of such accidents and the net impact were judged to be relatively small. During the licensing process, each facility for reprocessing and waste disposal is subjected to an extensive safety analysis. A wide range of potential accidents is analyzed. Measures are taken in the design and operating procedures to reduce the probability of any accidents and to provide assurance that the probability of having an accident involving a large release of radioactivity is very low. We find that the staff's conclusion is reasonable.

After considering the impacts of sabotage, the staff concluded that, overall, those impacts would be small in comparison with the impacts of normal operation and need not be explicitly included in Table S-3. This conclusion was based on the fact that acts of sabotage tend to resemble accidents. Measures provided to mitigate the effects of accidents should also mitigate the effects of sabotage.

Moreover, the Commission now requires that substantial measures be taken to protect nuclear facilities from sabotage including measures to protect against groups of highly motivated, well trained saboteurs. We find the staff's conclusion reasonable.

F. Socioeconomic Effects

The staff considers the socioeconomic effects associated with the construction and operation of a reprocessing plant or a waste disposal facility to be essentially the same as those from the construction and operation of a reactor. These effects include the noise and dust of construction activities; disruptions or dislocations of residences and businesses; impacts on public services such as education, utilities, road systems, recreation and public health and safety; increased local expenditures for services and materials; social stresses; and such items as increased revenues and business in jurisdictions where such facilities are located.

Witnesses for the States of Ohio and Wisconsin asserted that the staff's consideration of socioeconomic effects of the fuel cycle was cursory. This claim was made on the basis of their theory that the psychological stress and economic benefits from fuel cycle facilities would be different than those from a reactor because

(1) The security at the fuel cycle plants would be greater and more obvious than at reactors, and

(2) The benefits of the reactor would be more obvious as a source of electricity to the local residents than would the remote benefits from the fuel cycle facilities.

The witnesses also stated that, because public perception of the risks and benefits of reprocessing and waste management, including its international implications, may decide where and under what constraints fuel cycle facilities can be sited, it must be assessed in evaluating socioeconomic impacts.

NRDC witness, Dr. Todd R. LaPorte considered the staff's analysis to be inadequate because it was not supported by a thorough systems analysis of the nuclear fuel cycle industry as it is projected to expand to the year 2000 and beyond. Such an analysis would have to address local, national and international aspects of technical, political and social problems.

Drs. LaPorte and Deese[24/] were concerned that the staff's methodology of relating the socioeconomic impacts to one reactor year did not give a true picture of the scale of operations and the impact on local residents (particularly with regard to transportation to and from the plant) at any particular fuel cycle facility. This lack of information, according to these witnesses, leaves the public uncertain as to the true socioeconomic impacts of any given facility.

Baltimore Gas and Electric, et al. and TVA strongly supported the staff. BG&E pointed out that under the new regulations security is essentially the same at the reactor as it will be at the fuel cycle plants. TVA gave examples of the efforts it, as a federal resource agency, has made to ameliorate adverse socioeconomic impacts by grants and assistance to local communities.

The Board finds that the staff's appraisal of socio-economic effects was adequate with the possible exception of the local effects of transportation. The local impacts depend on the site and size of plant and are difficult to generalize. These will, however, be examined in detail in

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24/ Dr. LaPorte was a witness for NRDC and Dr. Deese for the States of Wisconsin and Ohio.

the studies made for licensing each actual reprocessing or waste disposal facility.

We concur in the staff's conclusion that the magnitude of the socioeconomic impacts will be similar to those associated with a nuclear power plant, which is a project of similar magnitude. Since each reprocessing and waste disposal facility would serve many power plants, the fraction that appears in the value in Table S-3 for a single plant is small and is not intended to reflect the total industry impact. Although a thorough systems analysis of an expanding nuclear power industry could provide a somewhat better understanding of the potential socioeconomic impacts and of ways to reduce adverse impacts, we do not believe that the lack of such a detailed analysis invalidates the staff's conclusions.

G. Decommissioning

In its initial testimony (NUREG-0116) the staff discussed the environmental impacts of decommissioning of fuel cycle facilities. It was noted that several options were available (e.g., mothballing (or layaway), protective storage, entombment or decontamination). The staff chose to consider decontamination shortly after decommissioning because this option would have the greatest environmental and economic impact due to handling and disposing of large amounts of radioactive material and would provide the most conservative values of impacts for use in Table S-3.

While the parties were in disagreement on whether the staff assumption of immediate decontamination is reasonable, the principal issue that developed was the economic cost of decommissioning the nuclear power plant.

The Board finds the staff's evaluation of the impacts of decommissioning the nuclear facilities to be reasonable in most respects. As noted in section D, supra, more recent studies have indicated that the volume of radioactive waste generated in decommissioning a nuclear power plant is likely to be larger than the amount used by the staff. Also, no studies have been made of the decommissioning of enrichment plants so wastes from that operation are not included. On the other hand, the Board considers the assumption of immediate decontamination to be unrealistic and to result in an overestimate of the likely impacts. The Board's findings with regard to the costs of decommissioning a nuclear power plant are discussed in section H, infra.

H. Economic Feasibility

The subject was included in this proceeding by our order of December 23, 1977, following requests made by the states of New York, Ohio and Wisconsin. The capital and operating costs of the reprocessing and waste disposal facilities are in part determined by the measures taken to confine the radioactivity. Statements in the decision of the Court of Appeals led us to decide that testimony should be received on whether building and operating the model facilities chosen by the staff, to limit the impacts to the values in Table S-3, would be prohibitively expensive.

As a result of our order the staff submitted supplemental testimony[25/] on the costs of fuel reprocessing and waste management. This testimony relied heavily on the estimates of such costs prepared for the GESMO proceeding.[26/] Supplemental information was used to update the GESMO estimates and to provide estimates of costs of facilities that had not been included in GESMO. The data included estimates of facility costs for reprocessing, low and high level waste

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25/ Staff Testimony on Economic Data to Support the Feasibility of the S-3 model (dated February 3, 1978).

26/ Generic Environmental Statement on the use of recycle Plutonium in Mixed Oxide fuels in light water cooled reactors. NUREG-0002, August 1976.

disposal, spent fuel disposal and transportation. The accuracies of the components of the capital cost were estimated to be in the range of ±20 to ±50 percent.

During the hearings, we made a special effort to assure that the costs of all facilities had been included and properly distributed to individual reactors.[27/] At our request, the staff revised and supplemented their testimony to specifically indicate the methods used to distribute the reprocessing and waste management costs.

The staff arrived at an overall capital cost of $71 million per reference reactor for the reprocessing and waste disposal facilities for the uranium-only recycle option and $76 million for the spent fuel disposal option. These costs are less than 10 percent of the capital cost of a reference reactor.[28/] They include a few facilities, such as krypton-85 removal and storage, that were not included in the staff models.

27/ This requires careful consideration since not all components have the same relative capacity or life expectancy. While a reprocessing plant might have a life expectancy of 30 years and serve some 50 reactors, some facilities may have shorter life expectancy or lower capacity and must therefore be duplicated.

28/ A reference reactor is said to cost about $1 billion but this can vary considerably depending on where it is constructed and what facilities are included in the cost.

The staff estimated that the discounted cost of managing the waste would be \$4.9 million per RRY or 0.6 mills/kW-hr for the uranium recycle option and \$3.1 million or 0.4 mills/kW-hr for the spent fuel disposal option. In its cost calculations the staff used a discount rate of 10 percent as recommended by the Office of Management and Budget.

The staff did not include the cost of reprocessing fuel in the model facility in its estimates, but, based on the GESMO analysis the cost would be \$260 to \$360/kg uranium.[29/] This would amount to \$9 to \$13 million/year or 1.3 to 1.8 mills/kW-hr[30/] and would be reduced by the value of the uranium recovered.[31/]

29/ Page 35 of Attachment 2 of the staff's supplemental testimony indicates that the cost of reprocessing fuel in a 1500 MT/yr plant that cost \$500 million and \$100 million per year to operate would range from \$145/kg uranium for a 9 percent/year return on investment to \$190/kg for a return of 14 percent. The reprocessing cost for the same range of return would be \$260 to \$360/kg in a 2000 MT/yr model facility costing \$1.6 billion and \$150 million/yr to operate.

30/ The reprocessing cost to the reactor is independent of whether one assumes a capacity factor of 0.8 and 35 MT/RRY reprocessed or 0.7 and 30 MT/RRY reprocessed.

31/ A value of \$120 to \$170/lb for the recovered uranium would be required to compensate for the entire reprocessing cost.

The State of New York (New York) provided an analysis of the economics of some phases of waste management and reprocessing and contended that the staff has failed to demonstrate the economic feasibility. As we read the record this contention is based primarily on disagreement with the staff's discounting of waste management costs, disagreement with the magnitude of the staff's estimate of the cost of decommissioning a nuclear power plant, the belief that the reprocessing cost will be much higher than \$350/kg, and the definition of economic feasibility. Except as will be discussed below, we find no differences between the staff's estimates of costs and those put forward by New York that would markedly affect the economic feasibility.

New York contends

> that not only is the 10% discount rate economically unrealistic, but that the use of any discounting mechanism in connection with nuclear waste management is irresponsible as a matter of public policy. 32/

New York considers 0 to 2 percent to be a more realistic return on investment when inflation is taken into account. 33/

32/ Final Statement of the State of New York, p. 12.

33/ *Id.*, pp. 14-15.

Based on the staff's cost estimates, the waste management costs for the uranium recycle option would be 1.6 and 2.3 mills/kW-hr for discount rates of 2 and 0 percent, respectively. For the spent fuel discard cycle the corresponding costs would be 1 and 1.4 mills/kW-hr.[34/] New York also contends that the staff had used excessively long times for storage of the various wastes in discounting the costs. This is a matter of judgment, but if the times are too long the staff's estimates include more facilities than would be needed for shorter storage periods.

The staff's estimate of the cost of waste management includes $30 million for the decommissioning of the model reactor facility. This estimate was based on a detailed study of the decommissioning of a nuclear power plant that was prepared for the Atomic Industrial Forum. The magnitude of the estimate was corroborated by the results of an even more detailed study by the Battelle Pacific Northwest Laboratories.[35/]

34/ Id., based on values in Table 1.

35/ The results of the Battelle study were published as NUREG-CR-0130, Technical Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station. The cost of immediate decontamination and dismantlement was estimated to be $42.1 million.

New York's witness, Mr. Skinner, estimated that the uninflated decommissioning cost would be about 25 percent of the original facility cost or $300 million for a $1.2 billion nuclear power plant and that this cost would greatly increase the cost of the back end of the fuel cycle.[36/] His estimate was not based on a detailed analysis of the decontamination, dismantling and disposal operations but on a study of the percent-of-original facility cost of decommissioning the Elk River Reactor and the Sodium Reactor Experiment. Mr. Skinner made a critical review of the AIF and Battelle studies in which he discussed what he believed to be gross deficiencies in the cost estimates.

Based on the record before us we find that the AIF and Battelle estimates, grounded on detailed studies of plants, more nearly represent the costs of decommissioning than do Mr. Skinner's estimates. We recognize the substantial uncertainties that could exist in the estimates, but

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36/ We note here, as we failed to do in the Summary of the Record in our Report to the Commission, that Dr. Bupp, in supplementary testimony on behalf of the States of Wisconsin and Ohio, stated that "* * * decontamination and decommissioning costs in the range of Skinner's estimates could have a significant and perhaps decisive impact on the economics of nuclear power. * * * For such an addition implies incremental electricity costs in the range of tens of mills per kilowatt-hour; not mills per kilowatt hour." (P. 2). Dr. Bupp did not comment on the accuracy of the estimates.

are unable to find errors of a factor of 8 to 10 that would be required to raise the AIF and Battelle costs to those of Mr. Skinner.[37/] Furthermore, we believe that the cost of decommissioning the nuclear power plant is misplaced when it is included in the cost of the back end of the fuel cycle. Decommissioning is considered in the licensing of each nuclear power facility. The cost is specific to each plant and depends on the method chosen. Controversies regarding the decommissioning costs should be resolved in individual reactor licensing proceedings.

New York estimated that the cost of reprocessing would be in the range of \$350 to \$900/kg of uranium.[38/] The \$350/kg was obtained for conditions similar to those assumed by the staff. The \$900/kg was calculated on the assumption that the facility would operate at only half the design rate (0.4 capacity factor) and on a rate of return well above the range considered reasonable by the staff. We have found (p. 15, *supra*) that a capacity factor of 0.7 is reasonable for the model facility.

37/ Although Mr. Skinner was critical of cost estimates, Attachment 3 to his Responses to Hearing Board Oral Questions showed that the estimated cost of decommissioning the Elk River Reactor was \$5.1 million as compared with an actual cost of \$5.7 million.

38/ New York's costs were based on analyses made by Dr. Barry J. Smernoff.

We also find that the rates of return used by the staff are reasonable and that a reprocessing cost at the lower end of New York's range is a reasonable assumption for the purpose of assessing the economic feasibility.

From the discussion above we have capital costs for reprocessing and waste management of 10 percent or less of the cost of a nuclear power plant. We also have a cost for waste management of 0.4 to 1.4 mills/kW-hr for the spent fuel discard option and a combined cost for reprocessing and waste management of 1.9 to 3.9[39/] mills/kW-hr minus the value of the uranium recovered for the uranium recycle option. These ranges of values depend entirely on the discount rate and rate of return on investment used in the calculations.

New York's position, as we understand it, is that the staff has not considered all the financial factors and their uncertainties and has not proved that the facilities can be financed or that the costs will not be much greater than presented here. Moreover, New York claims, the economic feasibility of building new nuclear power plants is so marginal that:

39/ The number is not the sum of 1.8 and 2.3 mills/kW-hr because about 10 percent of the undiscounted waste management cost was also included in the reprocessing cost.

> * * * a purportedly small increment of 3% to 10% tends to push weak nuclear economics into "unambiguous non-feasibility."40/

Whether costs of this magnitude are sufficient to make nuclear power economically unfeasible in some or all locations will depend on the cost of power from other sources and will be determined in the marketplace. Our requirements for a showing of economic feasibility are less than those of New York. We do not consider costs of the order of 10 percent of the total power cost to be prohibitive.41/ More importantly, the costs are not so large as to provide a major incentive for reducing them at the expense of increasing the radioactive effluents above the values included by the staff in Table S-3. The staff's estimates indicate that the undiscounted cost of disposal of spent fuel as a waste would add less than 5 percent to a 30 mill/kW-hr cost of power. Presumably, the value of

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40/ Final Statement of the State of New York, p. 39.

41/ In his supplementary testimony Dr. Bupp stated, "The economics of nuclear power has become a swamp in which it is possible to 'prove' anything one wishes by judicious choice of assumptions. * * * His (Mr. Skinner's) estimates of fuel transportation and storage costs (not including decommissioning costs) are higher than many earlier estimates. But, even if Skinner is correct, these costs do not in my opinion decisively alter the economics of nuclear power relative to realistic near-term alternatives. The prospect of additional potential costs on the order of several mills per kilowatt-hour which Skinner's estimates imply has limited practical meaning in the present circumstances." (P. 1).

the materi[illegible]ecovered or other incentives would have to reduce the costs to this level or below in order for the uranium recycle option to be chosen. Accordingly, we find the model facilities described by the staff to be economically feasible.

I. Transportation

No serious issue was raised in the proceeding concerning transportation. The Board finds the staff's analysis of the environmental impacts of transportation to be reasonable. However, this assumes that the indicated shortage of shipping casks will be overcome in timely fashion.

III. Board Recommendations

As is evident in the findings we have made in section II, we believe that this proceeding has provided the additional record required by United States Court of Appeals for the District of Columbia. However, as the result of this supplemental record we believe that changes should be made in Table S-3 beyond those proposed by the staff in its concluding statement for this proceeding.42/

In making our recommendations we have taken into consideration the recent Commission announcement of its intent to update the supporting documents for the S-3 rule.43/ As a result we are recommending certain modifications in the presently published S-3 Table before adoption as a final rule, while suggesting further changes be made during the updating action.

42/ Staff Concluding Statement, May 18, 1978. Revised Table S-3 is included as Appendix A of the staff document and is included with this report as Attachment 1.

43/ NRC action -- advance notice of intent to update WASH-1248 (supporting document for Table S-3), 10 CFR 51, 20. 43 Fed. Reg. 39801.

A. Summary of Recommendations

1. Table S-3 as modified and recommended by the staff should be adopted as the final rule in this proceeding.

2. Table S-3 should be accompanied by a brief explanatory narrative.

3. For updating the rule:

a. The staff should base its analysis on models that are consistent and realistic in terms of the conditions of today and the foreseeable future.

b. The staff's estimates of environmental impacts should be conservative but not so conservative that the values produced are impossible for a realistic model.

c. Technetium releases and their impact should be considered by the staff.

d. The environmental dose commitments should be determined for 100 years.

e. Socioeconomic impacts should be included in the rule but economics need not be included.

f. Information should be included in the narrative so that the impacts of one year's operation can be converted to approximate cumulative impacts.

B. Adoption of Final Rule in this Proceeding

We believe that Table S-3 as modified and recommended by the staff in Appendix A of the Staff Concluding Statement (Attachment A to this report) satisfies the requirements of the Court and should be adopted as the final rule in this proceeding. Overall, the values for resources used and effluents released in fuel reprocessing and waste disposal that were incorporated in the Table are conservative. The major controversy in this proceeding was concerned with the amounts of radioactive materials released and the magnitudes of the environmental dose commitments and health effects resulting from those releases. The record would support the adoption of other values for some of the releases. The effect would be to reduce the total number of curies released and some of the calculated impacts. Because of uncertainties in the values for some of the releases and in the calculation of the impacts, we consider it appropriate, at this time, to adopt the values proposed by the staff.

By amendment to the rules on April 14, 1978 (43 F.R. 15613) population doses and health effects were removed from Table S-3 and made subject to litigation in individual reactor licensing proceedings. Although the record in this proceeding contains much testimony on the calculation of dose commitments and health effects, it does not provide a sufficient basis for placing values for those impacts in Table S-3 and removing them from further litigation.

C. Need for Explanatory Narrative

In its present format Table S-3 presents a column of numbers that represent such items as land committed, water used, and effluents released. In a second column an idea of the magnitude of the impact of some of these items is given by comparison with power plants. For some effluents only the major source is given, or the concentration of pollutant is said to be insignificant. Titles of the three supporting documents are given in a footnote.

Table S-3 is intended for use in arriving at an overall cost/benefit balance in the licensing of nuclear power plants. If all the impacts of the fuel cycle could be expressed in the Table in terms of familiar impacts of the operation of a power plant or other common facility, other explanation might not be necessary. However, the radiological impacts and some others cannot be described in this manner. We conclude, therefore, that Table S-3 should be supplemented by a brief explanatory narrative.

The staff has taken a first step toward such a narrative in its draft of Appendix A to Section 5.7 of the Environmental Standard Review Plan (Attachment B to this report). We believe the narrative should contain a brief description of the fuel cycle with references to specific sections of reports where more detailed information can be obtained. The numbers in Table S-3 should be related to the major sources in the narrative and the impacts should be explained.

Environmental dose commitments resulting from the radiological releases should be discussed in the narrative. Health effects could be included or dealt with in the discussion of the health effects of reactor operation. Socio-economic impacts should be discussed but economics need not be included.

The bases, including major assumptions, that have been used to evaluate the impacts should be made clear. References to specific sections of supporting documents should be provided. Hopefully, the narrative could be adopted as part of the rule in a future proceeding and remove the fuel cycle impacts from litigation in reactor licensing proceedings.

D. Recommendations for Updating the Rule

1. The Models Should be Realistic

For the purpose of evaluating the environmental impacts the staff should describe model fuel cycles and facilities that are realistic and consistent throughout. The performance of the model facilities should be evaluated conservatively, but the model should not be made unrealistic in order to force the analysis to be conservative. Until a firm decision is made with regard to reprocessing, fuel cycles that involve reprocessing and those that involve disposal of spent fuel as waste are realistic options.

The assumption that reprocessing will begin within 160 days after the fuel has been discharged from the reactor is unrealistic for any model that involves the reprocessing of fuel from LWR's. Even if the Barnwell reprocessing facility were activated immediately and the full requirement of reprocessing plants were built as rapidly as is likely to be possible, it appears that the backlog of spent fuel would not be worked down to a five-year cooling period for at least 20 years. To assume only 160 days cooling for the sole reason of deriving a larger value for the possible amount of radioactivity in the effluents released from the reprocessing plant, only serves to detract from the credibility of the staff's analysis. For similar reasons, the need for realism extends to assumptions regarding the facilities and the time for interim storage of spent fuel.

2. The Analyses Should Be More Realistic

The staff should make conservative estimates of the amounts of radioactivity in the effluents from the model facilities, but the amounts should not exceed what is possible or reasonable for a realistic model. Because of the time factors discussed above, iodine-131 would decay away before reprocessing and the amounts of ruthenium-106, tritium and krypton-85 would be reduced by decay. The record shows that means are available to extract krypton and to reduce the iodine releases well below the values assumed by the staff.

For spent fuel disposal the assumption that all the tritium, krypton-85, iodine-129 and carbon-14 will escape from fuel that has decayed for only a few years needs to be reexamined. The facts presented in this proceeding indicate that such rapid release is unlikely. The EPA has promulgated regulations that require the release of iodine-129, krypton-85 and TRU nuclides from the fuel cycle be kept far below the amounts now in Table S-3.

We recommend that the staff use more realistic appraisals of the information that is available when estimating the amounts of radioactivity likely to be released in plant effluents. Such appraisals can be expected to result in lower values for some entries in Table S-3. Where major uncertainties exist, they should be noted and their implications should be discussed.

The need for realism also extends to the analysis of releases from waste disposal facilities. There should now be, or soon will be, enough information available on sites which appear to satisfy the criteria for disposal of low level or high level wastes to enable the staff to make realistic estimates of the releases over the short and long term. We do not see that such analyses need prejudge the licensability of a site.

3. Technetium-99

Technetium-99 is considered to be one of the least hazardous of the fission products and has been mostly ignored in the impact analyses. The assumption that all the iodine-129 is released tends to compensate for the neglect of technetium, but an assumption of releases within the EPA limits would not. Based on the record in this proceeding, one would have to assume that technetium in the uranium sent to an enrichment facility will enter the biosphere in effluents from the plant and from waste disposed of by shallow burial. It might enter from other sources, also. Estimates of technetium-99 releases to the environment and the resulting impacts should be included in the staff's analyses.

4. Inclusion of Man-Rem data in S-3 Table.

Whatever values are finally chosen for the radioactive emissions to be used in Table S-3 if they are stated only in curies, they will remain essentially meaningless to all but the experts insofar as a measurement of environmental impact is concerned.

At present the environmental impacts of <u>reactor</u> effluents of radioactive nuclides carried through the various pathways to man are expressed first in curies emitted then in man-rems as a measure of their impact. To make the added impact of radioactive effluents from the fuel-cycle meaningful they too should be expressed in terms of man-rem as part of the S-3 rule.

It is our recommendation that man-rem impacts should be presented in the narrative of the S-3 rule in terms of the

100-year[44] environmental dose commitment and a long term environmental dose commitment. In each case the dose commitments should be compared with the potential doses from natural background radiation. Since such comparative data can be expressed for any arbitrary population, we suggest the use of the presently estimated population of the United States in the year 2000.[45]

If desired, the estimated man-rem dose commitments may be utilized to estimate potential health effects in Table S-3 or dose commitments can be added to those of specific reactors and the total potential health effects calculated. The staff should choose the method most convenient to them for use in their environmental statements.

44/ This time period has been suggested by the Environmental Protection Agency (EPA).

45/ As the Court of Appeals for the Ninth Circuit has observed, an environmental impact statement "need not discuss remote and conjectural consequences." Sierra Club v. Hodel, 544 F.2d 1036, 1039 (see also Swain v. Brinegar, 542 F.2d 364, 368 (7th Cir. 1976) and Trout Unlimited v. Morton, 509 F.2d 1276, 1283 (9th Cir. 1974)). The estimates of man-rem dosage from wastes material alone beyond 100 years become increasingly speculative. We feel that choosing an arbitrary population, with the natural background as a basis of comparison, gives some meaning to the significance of long range fuel cycle impacts for any specific time period.

5. Socioeconomics and Economics

The socioeconomic impacts of construction and operation of the power plant are among the impacts considered in the environmental statement for the licensing of each nuclear power plant. The fuel cycle rule should reflect consideration of an equal range of impacts and should, therefore, include socioeconomic effects. On the other hand, the fuel cycle costs are examined as part of the total power costs in the reactor licensing proceeding and need not be included in the fuel cycle rule.

6. Cumulative Impacts

Table S-3 and the narrative would report the environmental impacts normalized to operation of one reactor for one year. The Court, among others, has commented that it is misleading to focus solely on incremental impact.[46/] Some of the numerical values can be multiplied by an assumed lifetime for the reactor to obtain an idea of the total impact of the power plant and then by a number of reactors to approximate the impact of an industry. Other impacts cannot be scaled in this way. The narrative should contain information that would enable the reader to convert the normalized numbers into approximate values of cumulative impact.

46/ NRDC v. NRC, supra, n. 3, 547 F.2d at 639, fn. 12.

IV. Additional Board (ments

A. The Staff is presently in the process of establishing new criteria for design and suitability of locations for low level waste disposal facilities. These criteria include the technical requirements for design, type of soil, hydrology, etc. The record of the proceeding indicates that the technical requirements and the operational requirements will be thoroughly examined before any new facility is licensed to operate. The same can be said for new reprocessing facilities. They will have to be designed and constructed to high standards and it will have to be concluded that the releases will be as low as reasonably achievable (ALARA) before a f ility will be licensed to operate.

The cord indicates that the one commercial reprocessing facility and some of the low level waste disposal facilities were designed and licensed on the basis that the releases would be less (much less in some instances) than were experienced. Although some problems were caused by faulty design and inexperience many of the difficulties were due to poor management and inadequate quality assurance. In some cases the problems were compounded by lack of cooperation or coordination between the NRC, or its predecessor, and the states.

The values in Table S-3 are based on the assumption that the releases of most of the radioactive nuclides and the occupational exposures will be ALARA. We believe that a major responsibility of the staff will be to ensure that the management and quality assurance practices at the facilities are adequate to ensure that the releases do not exceed the design criteria.

B. Because the availability of the facilities assumed in the staff models is an essential ingredient to the realism of the models, we repeat here our statement at pages 31-32, supra:

> This Board, however, is greatly concerned that consideration of the environmental impact of temporary storage of spent fuel has not, to this date, resulted in any positive action to build off-site interim storage facilities for the rapidly mounting volume of spent fuel. The record here indicates that within five years a lack of such storage space will have serious environmental and economic impacts on the country.

We stress that the failure of the staff to adequately address the environmental impacts of the lack of temporary storage is not so serious as to warrant invalidation of Table S-3. However, we believe that the Commission should direct the staff to promptly undertake an assessment of these environmental impacts and consider the results in the process of updating Table S-3. Should the staff's assessment of such impacts reveal them to be greater than presently foreseen, the Commission will then be in position to take appropriate action.

V. Conclusion

In view of the foregoing discussion this Hearing Board recommends that the modifications described in section III.B. (pp. 62-63), supra, be made in the presently published Table S-3 before the Commission adopts it as a final rule. We further recommend that the Commission supplement the final S-3 rule with an accompanying narrative such as suggested in section III.C. (pp. 63-64), supra. Finally, we recommend that the changes in Table S-3 outlined in section III.D. (pp. 65-70), supra, be made during the updating process.

FUEL CYCLE RULEMAKING
HEARING BOARD

Michael L. Glaser

John H. Buck

R. Beecher Briggs

October 26, 1978

Attachments - 2

ATTACHMENT A

TABLE S-3

Summary of environmental considerations for uranium fuel cycle[1]

(Normalized to model LWR annual fuel requirement [WASH-1248] or reference reactor year [NUREG-0116])

ENVIRONMENTAL CONSIDERATIONS	Total	Maximum effect per annual fuel requirement or reference reactor year of model 1,000 MWe LWR
Natural Resource Use:		
Land (acres):		
Temporarily committed[2]	[94] 100	
Undisturbed area	[73] 79	
Disturbed area	22	Equivalent to 110 MWe coal-fired powerplant
Permanently committed	[7.1] 13	
Overburden moved (millions of MT)	2.8	Equivalent to 95 MWe coal-fired powerplant.
Water (millions of gallons):		
Discharged to air	[159] 160	= 2 percent of model 1,000 MWe LWR with cooling tower.
Discharged to water bodies	11,090	
Discharged to ground	[124] 127	
Total	[11,373] 11,377	< 4 percent of model 1,000 MWe LWR with once-through cooling.
Fossil fuel:		
Electrical energy (thousands of MW-hour)	[321] 323	< 5 percent of model 1,000 MWe LWR output.
Equivalent coal (thousands of MT)	[117] 118	Equivalent to the consumption of a 45 MWe coal-fired powerplant.
Natural gas (millions of scf)	[124] 135	< 0.4 percent of model 1,000 MWe energy output.
EFFLUENTS - CHEMICAL (MT):		
Gases (including entrainment):[3]		
SO_x	4,400	
NO_x^4	1,190	Equivalent to emissions from 45 MWe coal-fired plant for a year.
Hydrocarbons	14	
CO	29.6	
Particulates	1,154	

TABLE S-3 (Continued)

ENVIRONMENTAL CONSIDERATIONS	Total	Maximum effect per annual fuel requirement or reference reactor year of model 1,000 MWe LWR
EFFLUENTS - CHEMICAL (MT) (cont'd):		
Other gases:		
F^-	.67	Principally from UF_6 production, enrichment, and reprocessing. Concentration within range of state standards - below level that has effects on human health.
HCl	.014	
Liquids:		
$SO_4^=$	9.9	From enrichment, fuel fabrication, and reprocessing steps. Components that constitute a potential for adverse environmental effect are present in dilute concentrations and receive additional dilution by receiving bodies of water to levels below permissible standards. The constituents that require dilution and the flow of dilution water are: NH_3 - 600 cfs. NO_3 - 20 cfs. Fluoride - 70 cfs.
NO_3^-	25.8	
Fluoride	12.9	
Ca^{++}	5.4	
Cl^-	8.5	
Na^+	12.1	
NH_3	10.0	
Fe	.4	
Tailings solutions (thousands of MT)	240	From mills only - no significant effluents to environment.
Solids	91,000	Principally from mills - no significant effluents to environment.
EFFLUENTS - RADIOLOGICAL (curies):		
Gases (including entrainment):		
Rn-222	——	Presently under reconsideration by the Commission.
Ra-226	.02	
Th-230	.02	
Uranium	.034	

TABLE S-3 (Continued)

ENVIRONMENTAL CONSIDERATIONS	Total	Maximum effect per annual fuel requirement or reference reactor year of model 1,000 MWe LWR
EFFLUENTS - RADIOLOGICAL (curies) (cont'd.)		
Tritium (thousands)	18.1	
C-14	24	
Kr-85 (thousands)	400	
Ru-106	.14	Principally from fuel reprocessing plants.
I-129	1.3	
I-131	.83	
Fission products and transuranics	[~~0.023~~] .203	
Liquids:		
Uranium and daughters	2.1	Principally from milling - included in tailings liquor and returned to ground-no effluents; therefore, no effect on environment.
Ra-226	.0034	From UF_6 production.
Th-230	.0015	
Th-234	.01	From fuel fabrication plants - concentration 10 percent of 10 CFR 20 for total processing 26 annual fuel requirements for model LWR.
Fission and activation products	5.9×10^{-6}	
Solids (buried on site):		
Other than high level (shallow)	11,300	9,100 Ci comes from low level reactor wastes and 1,500 Ci comes from reactor decontamination and decommissioning - buried at land burial facilities. 600 Ci comes from mills - included in tailings returned to ground ~ 60 Ci comes from conversion and spent fuel storage. No significant effluent to the environment.
TRU and HLW (deep)	1.1×10^{7}	Buried at Federal Repository.
Effluents - thermal (billions of British thermal units)	[~~2,462~~] 4,063	< 5 percent of model 1,000 MWe LWR.
Transportation (person-rem):		
Exposure of workers and general public	2.5	
Occupational exposure (person-rem)	22.6	From reprocessing and waste management.

[1] In some cases where no entry appears it is clear from the background documents that the matter was addressed and that, in effect, the Table should be read as if a specific zero entry had been made. However, there are other areas that are not addressed at all in the Table. Table S-3 does not include health effects from the effluents described in the Table, or estimates of releases of Radon-222 from the uranium fuel cycle. These issues which are not addressed at all by the Table may be the subject of litigation in the individual licensing procedures.

Data supporting this table are given in the "Environmental Survey of the Uranium Fuel Cycle," WASH-1248, April 1974; the "Environmental Survey of the Reprocessing and Waste Management Portion of the LWR Fuel Cycle," NUREG-0116 (Supp. 1 to WASH-1248); and the "Discussion of Comments Regarding the Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle," NUREG-0216 (Supp. 2 to WASH-1248). The contributions from reprocessing, waste management and transportation of wastes are maximized for either of the two fuel cycles (uranium only and no recycle). The contribution from transportation excludes transportation of cold fuel to a reactor and of irradiated fuel and radioactive wastes from a reactor which are considered in Table S-4 of § 51.20(g). The contributions from the other steps of the fuel cycle are given in columns A-E of Table S-3A of WASH-1248.

[2] The contributions to temporarily committed land from reprocessing are not prorated over 30 years, since the complete temporary impact accrues regardless of whether the plant services one reactor for one year or 57 reactors for 30 years.

[3] Estimated effluents based upon combustion of equivalent coal for power generation.

[4] 1.2 percent from natural gas use and process.

ATTACHMENT B

The staff's analysis and conclusions are as follows:

A. Land Use

The total annual land requirement for the fuel cycle supporting a model 1000 MWe LWR is about 41 hectares (101 acres). Approximately 3 hectares (7 acres) per year are permanently committed land, and 38 hectares (94 acres) per year are temporarily committed. (A "temporary" land commitment is a commitment for the life of the specific fuel-cycle plant, e.g., mill, enrichment plant, or succeeding plants. On abandonment or decommissioning, such land can be used for any purpose. "Permanent" commitments represent land that may not be released for use after plant shutdown and/or decommissioning.) Of the 38 hectares per year of temporarily committed land, 29 hectares are undisturbed and 9 hectares are disturbed. Considering common classes of land use in the U.S.,* fuel-cycle land-use requirements to support the model 1000 MWe LWR do not represent a significant impact.

B. Water Use

The principal water-use requirement for the fuel cycle supporting a model 1000 MWe LWR is that required to remove waste heat from the power stations

*A coal-fired power plant of 1000 MWe capacity using strip-mined coal requires the disturbance of about 81 hectares (200 acres) per year for fuel alone.

supplying electrical energy to the enrichment step of this cycle. Of the total annual requirement of 43×10^6 m^3 ($11{,}373 \times 10^6$ gal), about 42×10^6 m^3 are required for this purpose, assuming that these plants use once-through cooling. Other water uses involve the discharge to air (e.g., evaporation losses in process cooling) of about 0.6×10^6 m^3 per year and water discharged to ground (e.g., mine drainage) of about 0.5×10^6 m^3 per year.

On a thermal effluent basis, annual discharges from the nuclear fuel cycle are about 4% of the model 1000 MWE LWR using once-through cooling. The consumptive water use of 0.6×10^6 m^3 per year is about 2% of the model 1000 MWe LWR using cooling towers. The maximum consumptive water use (assuming that all plants supplying electrical energy to the nuclear fuel cycle used cooling towers) would be about 6% of the model 1000 MWe LWR using cooling towers. Under this condition, thermal effluents would be negligible. The staff finds that these combinations of thermal loadings and water consumption are acceptable relative to the water use and thermal discharges of the proposed project.

C. Fossil Fuel Consumption

Electrical energy and process heat are required during various phases of the fuel-cycle process. The electrical energy is usually produced by the combustion of fossil fuel at conventional power plants. Electrical energy associated with the fuel cycle represents about 5% of the annual electrical power production of the model 1000 MWe LWR. Process heat is primarily generated by the combustion of natural gas. This gas consumption, if used to generate electricity, would be less than 0.3% of the electrical output from the model plant. The staff finds that the direct and indirect consumption of electrical energy for fuel-cycle operations are small and acceptable relative to the net power production of the proposed project.

D. Chemical Effluents

The quantities of chemical, gaseous, and particulate effluents with fuel-cycle processes are given in Table S-3. The principal species are SO_x, NO_x, and particulates. Based on data in a Council on Environmental Quality report,* the staff finds that these emissions constitute an extremely small additional atmospheric loading in comparison with these emissions from the stationary fuel-combustion and transportation sectors in the U.S., i.e., about 0.02% of the annual national releases for each of these species. The staff believes such small increases in releases of these pollutants are acceptable.

Liquid chemical effluents produced in fuel-cycle processes are related to fuel-enrichment, -fabrication, and -reprocessing operations and may be released to receiving waters. These effluents are usually present in dilute concentrations such that only small amounts of dilution water are required to reach levels of concentration that are within established standards. Table S-3 specifies the flow of dilution water required for specific constituents. Additionally, all liquid discharges into the navigable waters of the United States from plants associated with the fuel-cycle operations will be subject to requirements and limitations set forth in an NPDES permit issued by an appropriate state or Federal regulatory agency.

Tailings solutions and solids are generated during the milling process. These solutions and solids are not released in quantities sufficient to have a significant impact on the environment.

E. Radioactive Effluents

Radioactive effluents estimated to be released to the environment from reprocessing and waste management activities and certain other phases of the fuel-cycle process are set forth in Table S-3. Using these data, the staff has calculated the 100-year involuntary environmental dose commitment** to the U.S. population. These calculations estimate that the overall involuntary total body gaseous dose commitment to the U.S. population from the fuel cycle

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*The Seventh Annual Report of the Council on Environmental Quality, September 1976. Figures 11-27 and 11-28, pp. 238-239.

**The environmental dose commitment (EDC) is the integrated population dose for 100 years, i.e., it represents the sum of the annual population doses for a total of 100 years. The population dose varies with time, and it is not practical to calculate this dose for every year.

(excluding reactor releases and the dose commitment due to radon-222) would be approximately 400 man-rem per year of operation of the model 1000 MWe LWR. Based on Table S-3 values, the additional involuntary total body dose commitment to the U.S. population from radioactive liquid effluents due to all fuel-cycle operations other than reactor operation would be approximately 100 man-rem per year of operation. Thus, the estimated involuntary 100-year environmental dose commitment to the U.S. population from radioactive gaseous and liquid releases due to these portions of the fuel cycle is approximately 500 man-rem (whole body) per year of operation of the model 1000 MWe LWR.

At this time Table S-3 does not address the radiological impacts associated with radon-222 releases. Principal radon releases occur during mining and milling operations and as emissions from mill tailings. The staff has determined that releases from these operations for each year of operation of the model 1000 MWe LWR are as follows:

Mining:	4060 Ci	(Ref. 5)
Milling and Tailings: (during active milling)	780 Ci	(Ref. 6)
Inactive Tailings: (prior to stabilization)	350 Ci	(Ref. 6)
Stabilized Tailings: (several hundred years)	1 to 10 Ci/yr	(Ref. 6)
Stabilized Tailings: (after several hundred years)	110 Ci/yr	(Ref. 6)

The staff has calculated population dose commitments for these sources of radon-222 using the RABGAD computer code described in NUREG-0002, Section IV.J of Appendix A (Ref. 4). The results of these calculations for mining and milling activities prior to tailings stabilization are as follows:

Radon 222 Releases		Estimated 100-Year Environmental Dose Commitment (man-rem) per Year of Operation of the Model 1000 MWe LWR		
		Total Body	Bone	Lung (bronchial epithelium)
Mining	4100 Ci	110	2800	2300
Milling and active tailings	1100 Ci	29	750	620
Total		140	3600	2900

When ac[illegible]the 500 man-rem total body dose commitment for the balance of the fuel [illegible] overall estimated total body involuntary 100-year environmental dose [illegible]itment to the U.S. population from the fuel cycle for the model 1000 MWe LWR is approximately 640 man-rem. Over this period of time, this dose is equivalent to 0.00002% of the natural background dose of about 3,000,000,000 man-rem to the U.S. population.*

The staff has also considered health effects associated with the releases of radon-222, considering both the short-term effects of mining, milling and active tailings, and the long-term effects from stabilized tailings. Dose to the bronchial epithelium was used as the standard of comparison. As noted, this dose for mining, milling, and active tailings is approximately 2900 man-rem per year of operation of the model 1000 MWe LWR. For long term radon releases from stabilized tailings, the staff has assumed that these tailings would emit, per year of operation of the model 1000 MWe LWR, 1 Ci/yr for 100 years, 10 Ci/yr for the next 400 years, and 100 Ci/yr for periods beyond 500 years. With these assumptions, the cumulative radon-222 release from stabilized tailings piles per year of operation of the model 1000 MWe LWR will be 100 Ci in 100 years and 53,800 Ci in 1000 years (Ref. 7). The bronchial epithelium dose commitments for these two periods are 56 and 30,000 man-rem, respectively.

Using a risk estimator of 22.2 cancer deaths per million man-rem lung exposure, the estimated risk of lung cancer mortality due to mining, milling, and active tailings emissions of radon-222 would be 0.065 cancer fatalities per year of operation of the model 1000 MWe LWR. When the risk due to radon-222 emissions from stabilized tailings over a 100-year release period is added, the estimated risk of lung cancer mortality over a 100-year period is estimated to be 0.066 cancer fatalities per year of operation of the model 1000 MWe LWR and, similarly, a risk of 0.74 cancer fatalities over a 1000-year release period. When all other risks of cancer mortalities (e.g., bone cancer) are considered, the overall risks of cancer fatalities per year of operation of the model 1000 MWe LWR are as follows:

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*Based on an annual average natural background individual dose commitment of 100 mrem and a stabilized U.S. population of 300 million.

0.11 fatalities for a 100-year period
0.19 fatalities for a 500-year period
1.2 fatalities for a 1000-year period.

To illustrate: A single model 1000 MWe LWR operating at an 80% capacity factor for 30 years would be predicted to induce 3.3 cancer fatalities in 100 years, 5.7 in 500 years, and 36 in 1000 years as a result of releases of radon-222.

These doses and predicted health effects have been compared with those that can be expected from natural-background emissions of radon-222. Using data from the National Council on Radiation Protection (NCRP, Ref. 8), the average radon-222 concentration in air in the contiguous United States is about 150 pCi/m^3, which the NCRP estimates will result in an annual dose to the bronchial epithelium of 450 mrem. For a stabilized U.S. population of 300 million, this represents a total dose commitment of 135 million man-rem per year. Using the same risk estimator of 22.2 lung cancer fatalities per million man-rem used to predict cancer fatalities for the model 1000 MWe LWR, estimated lung cancer fatalities alone from background radon-222 in the air can be calculated to be 3000 per year. Against this background, the staff concludes that both the dose commitments and health effects of the uranium fuel cycle are insignificant when compared to dose commitments and health effects to the U.S. population resulting from natural background radiation sources.

F. Radioactive Wastes

The quantities of buried radioactive waste material (low-level, high-level, and transuranic wastes) are specified in Table S-3. For low-level waste disposal at land burial facilities, the Commission notes in Table S-3 that there will be no significant radioactive releases to the environment. For high-level and transuranic wastes, the Commission notes that these are to be buried at a Federal Repository, and that no release to the environment is associated with such disposal. NUREG-0116 (Ref. 2), which provides background and context for the high-level and transuranic Table S-3 values established by the Commission, indicates that these high-level and transuranic wastes will be buried and will not be released to the biosphere. No radiological environmental impact is anticipated from such disposal.

G. Occupational Dose

The annual occupational dose attributable to all phases of the fuel cycle for the model 1000 MWe LWR is about 200 man-rem. The staff concludes that this occupational dose will not have a significant environmental impact.

H. Transportation

The transportation dose to workers and the public is specified in Table S-3. This dose is small and is not considered significant in comparison to the natural background dose.

I. Fuel Cycle

The staff's analysis of the uranium fuel cycle did not depend on the selected fuel cycle (no recycle or uranium-only recycle) since the data provided in Table S-3 include maximum recycle option impact for each element of the fuel cycle. Thus, the staff's conclusions as to acceptability of the environmental impacts of the fuel cycle are not affected by the specific fuel cycle selected.

VI. REFERENCES

1. U.S. Atomic Energy Commission, Environmental Survey of the Uranium Fuel Cycle, WASH-1248, April 1974.

2. U.S. Nuclear Regulatory Commission, Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle, NUREG-0116 (Supplement 1 to WASH-1248), October 1976.

3. U.S. Nuclear Regulatory Commission, Public Comments and Task Force Responses Regarding the Environmental Survey of the Reprocessing and Waste Management

Portions of the LWR Fuel Cycle, NUREG-0216 (Supplement 2 to WASH-1248), March 1977.

4. U.S. Nuclear Regulatory Commission, Final Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light-Water-Cooled Reactors Cooled Reactors, NUREG-0002, August 1976.

5. U.S. Nuclear Regulatory Commission, In the Matter of Duke Power Company (Perkins Nuclear Station), Docket No. 50-488, Testimony of R. Wilde, filed April 17, 1978.

6. U.S. Nuclear Regulatory Commission, In the Matter of Duke Power Company (Perkins Nuclear Station), Docket No. 50-488, Testimony of P. Magno, filed April 17, 1978.

7. U.S. Nuclear Regulatory Commission, In the Matter of Duke Power Company (Perkins Nuclear Station), Docket No. 50-488, Testimony of R. Gotchy, filed April 17, 1978.

8. National Council on Radiation Protection and Measurements, Publication 45, (1975).