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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
UNITED STATES DEPARTMENT OF ENERGY PROJECT MANAGEMENT CORPORATION TENESSEE VALLEY AUTHORITY	)	Docket No. 50-537
	)	
(Clinch River Breeder Reactor Plant)	)	

NRC STAFF TESTMONY OF PETER ERICKSON,
SEYMOUR BLOCK, AND RICHARD SMITH
ON CONTENTION 8 (DECOMMISSIONING)

Q.1. Mr. Block, by whom are you employed, and what is your position; and what is the nature of your work?

A.1. I am employed as a Senior Health Physicist, Division of Systems Integration, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission ("NRC").

Q.2. Have you prepared a statement of professional qualifications?

A.2. Yes, a copy of my professional qualifications statement is attached to this testimony.

Q.3. Mr. Erickson, by whom are you employed, and what is your position; and what is the nature of your work?

A.3. I am employed by the NRC as a Project Manager. My duties include the review and evaluation of licensee applications for decommissioning of reactor facilities. I also obtain and coordinate

reviews from other NRC branches when needed on decommissioning actions. I prepare safety evaluations, environmental assessments, license amendments and orders with respect to reactor decommissioning actions.

Q.4. Have you prepared a statement of professional qualifications?

A.4. Yes, a copy of my professional qualifications statement is attached to this testimony.

Q.5. What is the nature of the responsibilities you have regarding the Clinch River Breeder Reactor ("CRBR")?

A.5. I was responsible for the review of Section 5.9 of the Applicants' Environmental Report. I was also responsible for Sections 10.2.4 and 11.10.6 of the NRC Staff's 1982 Supplement to the Final Environmental Statement (FES) for CRBR ("FES Supplement")

Q.6. Mr. Smith, by whom are you employed, what is your position, and what is the nature of your work?

A.6. I am employed by the Battelle Memorial Institute at its Pacific Northwest Laboratory in Richland, Washington, as a Staff Engineer in the Energy Systems Department, and the Technical Leader for Decommissioning Evaluations. For the past six years we have been performing evaluations of conceptually decommissioning licensed nuclear reactors and non-reactor nuclear facilities for the Office of Nuclear Regulatory Research ("NRR") of the NRC. The Clinch River Breeder Reactor ("CRBR") Program Office of NRC has arranged

for my services to provide technical assistance in the area of reactor decommissioning.

Q.7. Have you prepared a statement of your professional qualifications?

A.7. Yes, a copy of my professional qualifications statement is attached to this testimony.

Q.8. Messrs. Block, Erickson, and Smith, what is the subject matter of your testimony?

Q.8. Our affidavit addresses Contention 8, which states:

> The unavoidable adverse environmental effects associated with the decommissioning of the CRBR have not been adequately analyzed, and the costs (both internalized economic costs and external social costs) associated with the decommissioned CRBR are not adequately assessed in the NEPA benefit-cost balancing of the CRBR.
>
> a) There is no analysis of decommissioning in the Applicants' Environmental Report;
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> b) Environmental Impact Statements (EIS) related to LWRs prepared by NRC have been inadequate due in part to recently discovered omissions (see below), and the FES for the CRBR is no different;
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> c) A recent report "Decommissioning Nuclear Reactors" by S. Harwood; May, K.; Resnikoff, M.; Schlenger, B; and Tames, P. (New York Public Interest Research Group (N.Y. PIRG), unpublished, January, 1976) indicated that (with the exception of the Elk River reactor) the isolation period following decommissioning of power reactors has been based on the time required for Co-60 to decay to safe levels. Harwood, et al. (p.2) believe the previous analyses are in error because they have underestimated the significance of radionuclide, Ni-59. The time period for Ni-59 to decay to safe levels is estimated by Harwood, et. al. (p.2) for LWR to be at least 1.5 million years. The economic and societal implications of this 1.5 million year decay period are at present unknown.

d) Petitioner believes the NRC must systematically analyze all neutron activation products that may be produced in the proposed CRBR to determine the potential isolation period, following decommissioning, and then provide a comprehensive analysis of the costs (both economic and societal) of decommissioning.

Q.9. Mr. Erickson, have you identified, analyzed, and evaluated the possible adverse environmental effects and socio-economic costs attributable to decommissioning of CRBR?

A.9. Yes. The Staff's discussion of decommissioning and possible adverse environmental effects and socio-economic costs are contained in Section 10.2.4 of the FES Supplement for CRBR.

Q.10. What are your conclusions regarding the decommissioning of CRBR?

A.10. As discussed in Section 10.2.4, the CRBR can be decommissioned with no significant adverse effect to the environment, or the health and safety of the public.

Q.11. Have you read, and are you familiar with the Applicants' Environmental Report ("ER"), with regard to Section 5.9, "Decommissioning and Dismantling," as contained in Amendment X to the ER, dated December 1981?

A.11. Yes, I have read Section 5.9 of the Applicants' ER, regarding decommissioning.

Q.12. Do you agree with the discussion of decommissioning in Section 5.9 of the CRBR?

A.12. Yes.

Q.13. Mr. Smith, what characteristics are relevant in assessing whether a radionuclide which is present in a nuclear power reactor are important in the decommissioning process?

A.13. The characteristics or properties of a radionuclide that determine whether that radionuclide is important to consider during decommissioning are those that contribute to delivering a radiation dose to decommissioining workers and to the public. Radionuclides that emit penetrating gamma rays are more important than radionuclides that emit essentially non-penetrating beta or alpha particles, since the penetrating gamma rays are more difficult to protect against. High energy gamma rays are more important than low energy gamma rays, due to the greater amount of ionization in the body from absorption of the higher energy gamma ray, and the associated higher radiation dose. The greater the level of radioactivity (disintegrations per second per unit volume) of a particular radionuclide, the greater the radiation dose rate will be.

Radionuclides with decay half-lives in range of years are more important than are radionuclides with decay half-lives of less than a year, since those radionuclides with short half-lives will decay to innocuous levels in much shorter times and hence will contribute much less radiation dose to workers during the several years required to decommission a reactor station than will the longer-lived radionuclides. Radionuclides having decay half-lives of thousands of years are no more important to the decommissioning of a reactor station than are radionuclides having decay

half-lives of a few years since neither will decay greatly during the periods of active decommissioning effort. The very long-lived radionuclides present more difficult problems in the area of permanent disposal, however.

Q.14. What are neutron activation products, and what are fission products?

A.14. Neutron activation products result when normally non-radioactive elements are bombarded with neutrons. Some of the neutrons are captured by the non-radioactive elements and form radioactive species. A common example in reactors is the production of radioactive cobalt-60, resulting from atoms of the stable element cobalt-59 capturing neutrons. Many of the metallic elements present in reactor structural materials will capture neutrons and result in radioactive species. Similarly, some of the elements present in concrete of the reactor shield will also capture neutrons and result in radioactive species.

Fission products, on the other hand, are the elements produced when a fissionable element such as uranium or plutonium captures a neutron and then breaks apart into several smaller elements (or nuclides), releasing additional neutrons and energy in the process. Many fission product nuclides are in excited energy states and emit neutrons, gamma rays, beta and/or alpha particles during their decay to a lower energy state. Some fission product nuclides are born in a stable energy state and thus are not radioactive.

Q.15. What radionuclides, which will be present at the end of the operating life of CRBR, will be most important in the decommissioning process, from the standpoint of minimizing radiation exposures to decommissioning workers and the public?

A.15. The various radionuclides expected to be present in significant quantities at CRBR at the time of decommissioning are listed in Table I, in order of probable contribution to worker radiation dose. The decay half-lives, the important decay modes, the range of energies associated with the decay process, and the likely locations within the plant where these radionuclides will be present are also presented in the Table I. Radionuclides having half-lives of less than 100 days are not considered to be serious contributors to the worker radiation dose since it is anticipated that they will have decayed by several half-lives before significant decommissioning activities are initiated. Since the only significant source of radiation dose to the public during decommissioning comes from radiation emitted while the radioactive materials are being transported from the reactor site to a radioactive waste disposal site, the same radionuclides that are important contributors to workers radiation dose are also important contributors to the very small public radiation dose resulting from decommissioning.

The principal contributors to external radiation dose are expected to be cobalt-60, sodium-22, cesium-137, and manganese-54 in the core structural materials and primary coolant system. Lesser contributions are expected from tantalum-182 and niobium-94.

Europium-152 and 154 are expected to be found in the concrete reactor shield. The remaining radionuclides listed in Table I are either pure beta particle emitters or produce inner brehmsstralung gamma spectra and are not expected to be significant contributors to the external radiation dose.

These conclusions are based on our previous analyses of activation products expected in light water reactors[1,2], on calculations performed by the Applicant[3], and on measurements made during the decommissioning of the Fermi 1 reactor[4] and the Hallam reactor[5].

Q.16. What radionuclides will be the most important contributors to surface contamination radiation exposures for the CRBR at the end of its projected operational life?

A.16. The radionuclides most likely to be important contributors to radiation doses resulting from surface contamination within the CRBR are those nuclides present in the largest quantities, i.e., cobalt-60, sodium-22, cesium-137, and manganese-54. However, experience during the decommissioning of Fermi 1[4] showed that radiation dose rates throughout the station were generally quite small, mostly less than 1 mR/hr (except in waste processing areas).

Q.17. What embedded radionuclides will be the most important contributors to radiation exposures for the CRBR at the end of its projected operational life?

A.17. The embedded radionuclides most likely to be important contributors to radiation doses are gamma emmitting activation products in the reactor vessel, the radial shield and the reactor concrete shield. Cobalt-60 and Niobium-94 will be present in the reactor vessel and radial shield, with cobalt-60 dominant for 70 to 100 years after shutdown. Beyond that time, Niobium-94 will be dominant. Cobalt-60, Europium 152 and Europium 154 will be present in the reactor concrete shield.

Q.18. Mr. Erickson, what are the Staff's guidelines for radiation exposures attributable to surface contamination and embedded radionuclides for unrestricted public access to decommissioned reactors?

A.18. Table 1 of Regulatory Guide 1.86 specifies the Staff's guidelines for surface contamination. In addition, licensees have been required to demonstrate by analysis that any residual imbedded activation/radioactivity in shielding structures, reactor components or soil had been reduced to levels acceptable for release to unrestricted access. In recent decommissioning actions, gamma radiation from reactor-generated radionuclides imbedded in reactor shielding structures, reactor components or soil has been considered acceptable to the NRC Staff if the potential exposure as measured 1 meter from any surface is 5 micro R/hr or less.

Q.19. Are these guidelines applicable to the CRBR?

A.19. Yes.

Q.20. Mr. Smith, will the presence, distribution, half-live, and energy level and types for the principal neutron activation products which will be present in the CRBR at the end of its projected 30 year operational life, preclude the decommissioning of CRBR in accordance with current NRC regulations and guidelines on decommissioning, and occupational and public radiation exposures?

A.20. The presence, distribution, half-lives, energy levels, and decay modes of the various neutron activation products expected to be present within the CRBR station at the end of its operational life will not preclude decommissioning the CRBR in accordance with the current NRC regulations and guidelines. Data from the decommissioning of the Fermi 1 and Hallam reactors indicate that the sodium-cooled reactors stations are generally quite clean and relatively uncontaminated. Once the primary system sodium was removed from the piping systems, the residual radioactivity within the stations was quite low, compared with the radioactivity levels normally encountered in LWR stations. The highly activated structures within the reactor vessel can be submerged under water once the primary system sodium has been removed, thus providing excellent shielding and visibility for disassembly operations. All of the operations necessary to accomplish decommissioning have been demonstrated in the laboratory and in the field. By performing the disassembly of the highly-activated core structures under water, the extenal radiation dose to workers is minimized and dispersion of cutting debris throughout the facility is eliminated. Under these conditions, the actual levels of radioactivity in the core

components are unimportant, since the water covering will provide shielding adequate to protect the workers from significant radiation exposure for any likely levels of radioactivity.

Q.21. Have you reviewed the report, "Decommissioning Nuclear Reactors," by Harwood, May, Resnikoff, Schlenger and Tames?

A.21. I have reviewed the reports, "The Costs of Turning It Off," and "Activation Products in a Nuclear Reactor," by Harwood, May, Resnikoff, Schlenger, and Tames, which I understand are more recent versions of the report, "Decommissioning Nuclear Reactors".

Q.22. Do you agree with the conclusions of the Harwood reports regarding the significance of nickel-59, from the standpoint of minimizing radiation exposures during and after decommissioning?

A.22. Analyses of activation products in LWRs[1,2] have shown that the radiation dose rate from nickel-59 is not a significant factor during decommissioning operations since other radionuclides (cobalt-60 during the first 100 years and niobium-94 after the first 100 years) will predominate. However, the long-lived radionuclides such as niobium-94 and nickel-59 do present a problem when considering where to place such materials in the radioactive waste disposal system. The radiation dose rates from these radionuclides are not large (100 mR/hr to a few R/hr) in comparison with the radiation dose rates from other sources such as cobalt-60, but their very long half-lives suggest that they should be isolated

from the biospheres in much the same manner as is planned for high level wastes and high-activity transuranic wastes.

Q.23. What is the radiation exposure attributable to nickel-59 at the CRBR at the end of its 30 year projected life?

A.23. Based on the level of activity calculated for nickel-59 by the Applicants[3], and an activity to dose conversion factor derived from our previous analysis of a PWR station[1], I conclude that the radiation dose rate from nickel-59 in the CRBR permanent steel components after 30 effective full power years will be in the range of 5 mR/hr.

In the PWR analysis, we calculated the spatial distribution of the activity of the various activation products throughout the structural members of the reactor, and from those distributions calculated the radiation dose rates at a distance of one centimeter above the surface of the activated material. These calculations are discussed in detail in Reference[1]. A factor for converting activity levels near the surface to radiation dose rate just about the surface is obtained by dividing the calculated dose rate by the calculated activity level. For nickel-59, this factor is about 9×10^{-5} R/hr/micro Ci/cm^3. This conversion factor includes the effects of self-shielding within the activated material, an important consideration when dealing with low energy decay events.

In the decay process for nickel-59, x-rays or Auger electrons are emitted during stabilization to the ground energy state. In the case of nickel-59, the energies are less than 8 keV, and approximately 33% of the emissions are x-rays and the rest are Auger electrons. These emissions do not contribute to the external radiation dose rate.

The contribution of the nickel-59 decay process to external dose rate comes from the EC-associated IB process. A continuous spectrum of gamma rays is emitted, with the maximum energy being 1.07 MeV. For computing the conversion factor given previously, the IB spectrum of nickel-59 decay is divided into seven energy ranges, with a specific yield fraction per decay event for each energy range, as follows:

0.01 to 0.07 MeV, 2.23×10^{-4}
0.07 to 0.12 MeV, 6.25×10^{-5}
0.12 to 0.21 MeV, 1.32×10^{-4}
0.21 to 0.4 MeV, 3.21×10^{-4}
0.4 to 0.6 MeV, 3.31×10^{-4}
0.6 to 0.9 MeV, 3.24×10^{-4}
0.9 to 1.2 MeV, 3.01×10^{-5}

As can be seen from the above listing, a brehmsstralung gamma is emitted in about 0.14% of the decay events.

Q.24. How does your figures for Nickel-59 radiation exposure compare with the Harwood calculated exposure? What is the reasons for the discrepancy?

A.24. In Section 4 of the Harwood report[6] it is suggested that the dose at a distance of one centimeter from a point source of nickel-59 would be 320 R/hr from the inner brehmsstralung gammas and 1.4×10^6 R/hr from the x-rays. It is not explicitly stated what their assumed source strength was. As a result it is very difficult to make any meaningful comparisons with our calculations. Several areas of discrepancy in their calculations have been noted, however.[7,8] For example, the report lumped the total reactor inventory of radionuclides into a point source. The lumping of the total reactor inventory of radionuclides into a point source results in a significant overestimate of the local dose rates. In addition, the self-shielding of the x-rays by the source material was neglected in the Harwood report. A crude calculation suggests that only about 0.3% of the nickel-59 x-rays will actually escape the source material. Another problem with the Harwood calculations is that the source data from the Piqua reactor which was used to justify the use of a point source model, was assumed in the report to be all cobalt-60. In actuality, about 90% of the dose was due to iron-55.

The differences between the Harwood results and our results are several orders of magnitude. However, these differences are not significant when dealing with decommissioning activities since, in the first 70 to 100 years after reactor shutdown, the cobalt-60 dose will be the most important contributor to radiation doses of decommissioning workers, by many orders of magnitude.

Q.25. Is nickel-59 a principal neutron activation product for the CRBR at the end of its operational life, from the standpoint of the Applicants' capability to decommission CRBR?

A.25. Based on our estimates of the dose rate to be expected from nickel-59 in CRBR during decommissioning, that particular radionuclide will not be a major contributor to the occupational radiation dose, and hence will not be a significant factor in determining the Applicant's ability to decommission CRBR. This conclusion is based on the expected radiation dose rates from cobalt-60 being many orders of magnitude greater than the nickel-59 dose rates. Operational procedures that permit decommissioning work to proceed in the presence of the cobalt-60 would easily permit the same work to proceed in the presence of the nickel-59.

Q.26. Have your reviewed the articles, "Trace Elements in Reactor Steels: Implications for Decommissioning," Stephens, et al., Nuclear Engineering Design (1978); "The Cost of Turning It Off," Harwood, et al., Environment 18 (Dec. 1976), pp. 17-26; and an article in Science, 215 (5 March 1982), pp. 1217-19?

A.26. Yes.

Q.27. Do you agree with the conclusions of those articles regarding the significance of nickel 59, or any other radionuclide, from the standpoint of minimizing radiation exposures during and after decommissioning?

A.27. I do not agree that nickel-59 is a significant factor in occupational radiation exposure to decommissioning workers, for the reasons stated in Answer 25. However, the concern about proper disposition of the very-long-lived radionuclides following decommissioning is a valid one.

Q.28. Mr. Erickson, what are the three alternative modes recognized as acceptable by the Staff for the decommissioning of a nuclear power reactor?

A.28. As discussed in Section 10.2.4.2 of the CRBR FES, the Staff recognizes three acceptable methods of decommissions: Mothballing/SAFSTOR, Entombment/ENTOMB and Dismantlement/DECON. More detailed information is available in Regulatory Guide 1.86 and NUREG/CR-0130.

Q.29. What are the environmental and socio-economic impacts which are associated with each of the three decommissioning alternatives?

A.29. Each decommissioning alternative has some environmental and socio-economic impacts. All three alternatives involve commitment of land at licensed low level waste burial grounds and potentially some space at deep geologic disposal facilities. SAFSTOR and ENTOMB would also commit some land at the reactor site for the period of safe storage or entombment. These two alternatives may, however, involve less waste disposal space because some of the radioactivity will decay in place to levels acceptable for release to unrestricted access. All three alternatives will involve

radiation exposure to workers who accomplish decommissioning and potential exposure to the public during shipment of radioactive waste. A more detailed discussion of environmental and socio-economic impacts is included in the FES Section 10.2.4.6.

Q.30. What direct economic costs would be incurred by the Applicants for each of the three alternative decommissioning modes? Please describe how you derived these cost estimates.

A.30. The cost of decommissioning the CRBRP is estimated to be no more than the estimated cost of decommissioning a 3500 MWt Pressurized Water Reactor. NUREG/CR-0130 indicates that cost may be up to $42.8 million in 1978 dollars. The cost of disposal of the sodium would be an additional cost for the CRBRP, however. Based on Fermi I sodium disposal costs, this would be about $1.25 million in 1978 dollars. Additional details on the costs of decommissioning are discussed in the FES Section 10.2.4.5.

Q.31. Mr. Smith, are you familiar with the decommissioning of the FERMI-1 reactor?

A.31. Yes, I have reviewed the documentation on the placement of the FERMI-1 reactor into safe storage, and supplemental information on radiation dose rates and accumulated dose to workers during the preparations for safe storage.

Q.32. Discuss the decommissioning of FERMI-1, with regard to radioactivity levels, and doses to workers during the decommissioning process.

A.32. The radiation dose rates within the plant were quite low, mostly less than 1 mR/hr. The dose for all workers, accumulated over a three-year period between November, 1972 and December, 1975, was 28 man-rem, and the annual dose to workers during the safe storage period has been in the range of 0.01 to 0.2 man-rem. These values can be compared with the values we estimated[1] for placing a PWR in safe storage (420 man-rem) and annual doses ranging from 10 to 0 man-rem. The conclusion drawn from this comparison is that a liquid-sodium-cooled reactor is generally much less radioactively contaminated than are present-generation LWRs and should represent a lesser source of radiation dose to decommissioning workers. The quantities of radioactive material containing long-lived activation products in an LMFBR may be rather similar to an LWR, and would have similar disposal requirements.

Q.33. Are you familiar with the decommissioning of other nuclear reactors?

A.33. I have reviewed the documentation on decommissioning of reactors in the U.S. and, to a more limited extent, in the rest of the world. Summaries of these activities have been included in several of our NRC-sponsored reports on reactor decommissioning.[1,2]

Q.34. Are you aware of any information, including the data generated by the decommissioning of FERMI-1 and the Hallam reactor, that would suggest that it would be impractical to decommission CRBR, either

from a radiological (exposures to workers and the public) or technological viewpoint?

A.34. No. There are no significant technical barriers to decommissioning nuclear reactors of all types, including the CRBR. Radiation exposures to workers can be controlled within allowable limits by appropriate planning and shielding. There is virtually no exposure to the public resulting from decommissioning operations, with the only significant potential for public exposure related to transport of radioactive wastes from the reactor site to the disposal site.

Q.35. Mr. Block, are you familiar with the decommissioning of the Hallam Nuclear Power Facility, the FERMI-1 Reactor, the Elk River Nuclear Power Reactor, the Pathfinder Reactor, and the Saxton Reactor?

A.35. Yes.

Q.36. Please discuss the decommissioning of Hallam Nuclear Power Facility, the FERMI-1 Reactor, the Elk River Nuclear Power Reactor, the Pathfinder Reactor, and the Saxton Reactor, with regard to occupational exposures to decommissioning workers.

A.36. The Hallam Nuclear Power Facility, a 254 megawatt thermal ("MWT") sodium-cooled reactor, was decommissioned by entombment/ENTOMB in 1968 and 1969. FERMI-1, a 200 MWT sodium-cooled fast breeder reactor was decommissioned by mothballing/SAFESTOR from 1973 to 1975. Elk River Nuclear Power Plant, which was operated by the United Power Association and owned by the AEC, was a 58 WMT boiling water reactor ("BWR"). Elk River was decommissioned during 1972

and 1973 by dismantlement/DECON. The Pathfinder Reactor, a 203 MWT BWR, was decommissioned by mothballing/SAFESTOR in 1968 through 1971. The Saxton Reactor, a 28 MWT pressurized water reactor ("PWR") was decommissioned by mothballing/SAFESTOR in 1972 and 1973. Occupational radiation exposures to decommissioning workers is shown on Table II. Table II shows the total person-rems, and annual average person rems for the five reactors.

Q.37. Are you aware of any information, including the data regarding the Hallam Nuclear Power Facility, the FERMI-1 Reactor, the Elk River Nuclear Power Plant, the Pathfinder Reactor and the Saxton Reactor, that would suggest that it would be impractical to decommission CRBR, in terms of radiological exposures to decommissioning workers?

A.37. No.

Q.38. Mr. Erickson, will the CRBR have to be isolated for 1.5 million years following any of three Staff-recognized decommissioning alternatives, before Staff guidelines regarding unrestricted public access are complied with?

A.38. No. The CRBR will not have to be isolated for 1.5 million years following any decommissioning alternative.

The NRC Staff position is that decommissioning is not complete until the residual activity is at levels acceptable for release to unrestricted access. This is accomplished through decontamination, removal of radioactive components, or radioactive decay. Certain

components such as the reactor vessel and reactor vessel internals would be activated with very long lived isotopes such as niobium-94. Those components would have to be removed at the end of a mothball/safe storage period or before entombing a reactor. Mothballing/safe storage is estimated to last no more than 100 years, and entombment no more than 150 years.

Q.39. In your professional judgement, can the CRBR be economically and safely decommissioned, with minimal and acceptable adverse socio-economic and environmental impacts?

A.39. Yes. My conclusions regarding this matter are discussed in greater detail in Section 10.2.4 of the FES Supplement for CRBR.

TABLE I. Radionuclides Expected to be Present Within the CRBR Station at the Time of Decommissioning

Radionuclide	Half-Life	Important Decay Mode	Energy Range (MeV)	Expected Locations
^{60}Co	5.27 yr.	gamma	1.17, 1.33	core structure; vessel
^{22}Na	2.6 yr.	gamma	0.5, 1.28	primary coolant
^{137}Cs	30 yr.	gamma	0.66	primary system cold trap
^{54}Mn	312 days	gamma	0.83	core structure, vessel
^{152}Eu	13.3 yr	gamma	0.12 - 1.4	concrete shield
^{182}Ta	115 days	gamma	0.07 - 1.6	core structure, vessel
^{154}Eu	8.2 yr.	gamma	0.12 - 1.28	concrete shield
^{94}Nb	20,000 yr.	gamma	0.7, 0.87	core structure, vessel
^{55}Fe	2.7 yr.	inner brehmsstrahlung gamma, x-rays	0.23 max	core structure, vessel
^{14}C	5730 yr.	beta	0.156 max	core structure, vessel, concrete
^{59}Ni	80,000 yr.	inner brehmsstrahlung gamma, x-rays	1.06 max	core structure, vessel
^{63}Ni	100 yr.	beta	0.067 max	core structure, vessel
^{90}Sr	29 yr.	beta	0.546 max	primary system cold trap

TABLE II. Comparison of Occupational Radiation Dose Experience from Decommissioning of Sodium-Cooled and Water-Cooled Reactors

Sodium-Cooled	MWT	Time Period for Decommissioning	Total Person Rems	Annual Average Person-Rems	Mode of Decommissioning
Hallam	256	1967 - 1969	11.29	3.8	ENTOMB
FERMI-1	200	1973 - 1975	28.21	9.4	SAFESTOR
Water-Cooled					
Elk River	58	1972 - 1973	76.28	38.0	DECON
Pathfinder	203	1968 - 1971	44.27	13.3	SAFESTOR
Saxton	28	1972 - 1973	66.29	33.0	SAFESTOR

References

1. Smith, R. I., G. J. Konzek, and W. E. Kennedy, Jr., Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station. NUREG/CR-0130, Vols. 1 and 2, Pacific Northwest Laboratory, Richland, Washington, June 1978.

2. Oak, H. D., G. M. Holter, W. E. Kennedy, Jr., and G. J. Konzek, Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station. NUREG/CR-0672, Vols. 1 and 2, Pacific Northwest Laboratory, Richland, Washington, June 1980.

3. Applicant's Updated Response #2 to Natural Resources Defense Counceil, Inc. and Sierra Club Interrogatories (Seventh, Ninth, Tenth, and Thirteenth Sets) Docket No. 50-537, dated 4/30/82.

4. Retirement of the Enrico Fermi Atomic Power Plant, NP-20047 and Supplement 1, Power Reactor Development Company, Newport, Michigan, March 1974 and October 1975.

5. Retirement of Hallam Nuclear Power Facility, AI-AEC-12709, Atomics International, Canoga Park, California, April 1964.

6. Harwood, Steve, et al, Activation Products in a Nuclear Reactor, New York Public Interest Research Group, Inc. Undated.

7. Letter, R. C. Liikala, Battelle-Northwest, to Peter Strom, U.S. NRC, Subject: Review of Report, "Activation Products in a Nuclear Reactor," put out by the New York Public Interest Research Group, Inc., dated April 27, 1976.

8. Letter, R. C. Liikala, Battelle-Northwest, to Peter Strom, U.S. NRC, same subject, dated May 19, 1976.

PETER B. ERICKSON

PROFESSIONAL QUALIFICATIONS

I am a Project Manager in the Standardization and Special Project Branch, Office of Nuclear Reactor Regulation, U. S. Nuclear Regulatory Commission. I am responsible for review and coordination of safety and environmental reviews of others on licensing actions for research and power reactors (1971 to present). Since 1973 most licensing actions involving decommissioning of reactors have been assigned to me.

I received a Bachelor of Science degree in Electrical Engineering from Montana State College in 1956. I also received a Master of Science degree in Systems Management from the University of Southern California in 1973.

I was a reactor operator at the MTR and ETR reactors, Idaho Nuclear Reactor Testing Station, Phillips Petroleum Company (1956-1958). From 1958 to 1963, I had the responsibility for design, evaluation and checkout of reactor control systems and hardware at the Los Alamos Scientific Laboratory. I had the responsibility at the Space Nuclear Systems Office for the evaluation, review and inspection of radiation, reactor and nuclear criticality safety programs of the Nuclear Rocket Development Station contractors (1963-1971).

At the ANS Topical Meeting of Spetember 16-20, Sun Valley, Idaho, I presented a paper entitled "U. S. Licensed Reactor Decommissioning Experience."

SEYMOUR BLOCK

PROFESSIONAL QUALIFICATIONS

RADIOLOGICAL ASSESSMENT BRANCH

DIVISION OF SYSTEMS INTEGRATION

I am employed as a member of the staff of the Radiological Assessment Branch, Division of Systems Integration, U.S. Nuclear Regulatory Commission, Washington, D.C. My duties include the determination and evaluation of the design and operation of operating nuclear power plants as well as review of Safety Analysis Reports of applicants for construction permits and operating licenses of nuclear power plants with respect to safety and environmental impact considerations including matters related to Health Physics Radiation Protection Programs.

I first became associated with the atomic energy program in 1944 when I was trained and educated as a Health Physicist at Clinton Laboratories in Oak Ridge, Tennessee, during the Manhattan Engineering Project. I later joined the Brookhaven National Laboratories as a Health Physicist responsible for radiological safety of Chemistry and Reactor operations. In 1953 I transferred to the University of California Radiation Laboratory and set up a small Health Physics program at the Livermore site. When the Livermore Hazards Control Department was formed in 1959, I was made Section Leader of the Special Projects Research and Development Group. For twelve years I engaged in Research and Development in Radiological Instrumentation and Applied Health Physics.

I am a Certified Health Physicist and former Treasurer of the Health Physics Society. I am Past President of the Northern California Chapter of the HPS and a former consultant to Physics International Corporation in San Leandro, California.

From 1938 - 1941 I attended City College in New York. I was inducted into the Army Air Force in 1942 and attended the University of Pennsylvania, Moore School of Electrical Engineering from 1943 - 1944.

I have published numerous articles in technical journals on instrumentation development and radiation dosimetry. I am a member of the Health Physics Society.

RICHARD I. SMITH
PROFESSIONAL QUALIFICATIONS

I am employed by the Battelle Memorial Institute at its Pacific Northwest Laboratory in Richland, Washington. Presently, I am a Staff Engineer and Technical Leader for Decommissioning in the Energy Systems Department at Battelle Northwest, and program manager for decommissioning studies. I was appointed to this position in August, 1978. My duties are to direct the activities of a group of scientists and engineers who are engaged in analyses of decommissioning of nuclear reactors and nuclear fuel cycle facilities, sponsored by the U.S. Nuclear Regulatory Commission. My position and duties prior to this appointment was Staff Engineer in the same organization and project manager and principal author for our study on the decommissioning of a large pressurized water reactor power station.

I received a B.S. in Physics from Washington State University in 1955, and an M.S. in Applied Physics from UCLA in 1957. I have been licensed as a professional engineer, specializing in Nuclear Engineering, in the State of Washington since 1972 and in the State of California since 1975.

I have been employed at Richland, Washington, since 1957, initially with the General Electric Company and since 1965 with Battelle-Northwest. My technical efforts have been primarily in the area of experimental reactor neutronics, and I have held various positions including that of senior physicist at the Plutonium Recycle Test Reactor, and section manager for several R&D sections conducting experimental programs in reactor facilities. I developed systems and techniques for gamma scanning irradiated reactor fuels in the reactor fuel pool to study power distributions and fuel densification effects. I also handled the administrative and technical direction of programs conducted in our licensed critical facility. Since early in 1976, I have been engaged in studies of decommissioning of nuclear facilities for the NRC.

I have authored or coauthored several articles published in Nuclear Science and Engineering, and in Nuclear Technology. I have presented papers at six national meetings of the American Nuclear Society, and have authored and coauthored more than 50 formal and/or informal reports of research sponsored by the USAEC, ERDA, NRC, EPRI, and other organizations. During 1978, I presented an invited paper titled "Cost and Occupational Radiation Exposure Estimates for Decommissioning Nuclear Power Reactors" at the 1978 Annual Meeting of the American Nuclear Society, made presentations on our decommissioning studies before the Waste Management subcommittee of the Advisory Committee on Reactor Safeguards and at a series of NRC-sponsored workshops with state officials, and was selected by the U.S. Government to participate in an international symposium on decommissioning of nuclear facilities held in Vienna, sponsored by the International Atomic Energy Agency (IAEA), where I presented a paper titled "Analyses of the

Decommissioning of a Pressurized Water Reactor and a Fuel Reprocessing Plant."

In 1979, I authored an Addendum to our study on decommissioning of a pressurized water reactor, was a member of the Technical program committee and chaired on session at the ANS Topical Meeting on Decontamination and Decommissioning of Nuclear Facilities in Sun Valley, Idaho, and made presentations and participated in the second series of NRC-State Workships on Decommissioning.

I have made invited presentations on decommissioning of power reactors at the 1980 Annual Meeting of the Washington Public Power Supply System and at a workshop on decommissioning sponsored by the Redwood Alliance, in Arcata, California. More recently, I led a study of decommissioning alternatives for the TMI-2 reactor for the Programmatic EIS on decontamination and disposal at TMI-2.

The staff presently under my direction has completed ten major reports on conceptual decommissionings of reactors and fuel cycle and non-fuel-cycle facilities, including a PWR, a BWR, research and test reactors, multiple reactor stations, several fuel fabrication plants, a fuel reprocessing plant, a UF_6 plant, non-fuel cycle facilities, and a low level waste burial ground. Studies on decommissioning independent spent fuel storage installations and on cleanup and decommissioning at nuclear facilities that have experienced accidents are in progress.