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Mr. Robert M. Bernero
Office of Standards Development
U.S. Nuclear Regulatory Commission
Washington, D.C. 20535

(64)

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Dear Mr. Bernero:

Attached are the comments of the staff of the California Energy Commission in response to the NRC's recently proposed rulemaking to amend its present decommissioning regulations (FR 43 10370-10371, March 13, 1978; FR Doc. 78-6461).

The California Energy Commission fully supports the holding of such a rule-making proceeding. Our staff have devoted considerable attention to the subject of decommissioning as evidenced by a recent report included as Appendix A of these comments.

The specific questions on which NRC has requested comment are, for the most part, very timely and appropriate. The questions listed in the March 13, 1978, announcement, however, are not complete and, moreover, in some cases there are fundamental issues which need to be resolved before specific answers to certain of the questions posed can be answered.

One basic question which appears to have gone unasked is, "What should be the definition of decommissioning?" Presently, NRC's Regulatory Guide 1.86 gives four alternative and substantially dissimilar actions which presumably would all be equally acceptable to the NRC. In addition, many variations of these options have been considered or discussed by others. Questions such as #5 in your March 13, 1978, announcement focus on the period of delay between reactor shutdown and complete dismantling. This delay period is the distinguishing feature of one decommissioning option suggested by an Atomic Industrial Forum study. It has, however, never been clearly stated, though perhaps implicitly assumed, that a reactor will at some point in time require dismantling. Will all reactors or even some reactors under certain specified conditions require dismantling to remove all structures or at least those still substantially radioactive? If dismantling is the eventual or terminal action, this should be explicitly stated since it is fundamental to other considerations such as procedures, cost and financing.

A second issue, the resolution of which seems fundamental before any discussion of the requiring of any particular funding mechanism can be profitable, is the clearly expressed intention as to who should pay the costs of

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decommissioning and who should not. There have been many potential funding schemes and mechanisms proposed for paying the costs of decommissioning and these mechanisms can be differentiated and an option selected to a large extent on the basis of the decision as to who should pay, who should not, and to what degree do we want to ensure that those who should pay will pay.

In addition to the fundamental questions of what should constitute decommissioning and who should pay for it, there are several other more specific yet still important questions which were not raised in the NRC announcement of March 13, 1978. Two topics not covered by your March 13 questions, but which should be part of any rulemaking discussions, are the experience with and ability to decommissioning present facilities and cost estimates for performing this work.

1. <u>Experience and Ability to Decommission</u>

   Our staff research indicates that discussion is needed as to the true extent of our actual experience in decommissioning as well as our ability to handle future facilities which may be of a larger size or otherwise structurally different from those facilities with which we have had some previous experience? Particular questions which might be posed include:

   What is the extent of our experience with the <u>complete dismantling</u> of reactors not merely with their mothballing or entombment? Is much, if not virtually all, of our reactor decommissioning experience with the less extensive options of mothballing and entombment which involve largely surface decontamination rather than the more costly and massive efforts required to dismantle, remove and dispose of a pressure vessel or containment structure?

   Is it clear that the techniques used previously on small experimental facilities are in all instances applicable to today's facilities? (e.g., While the novel technique of plasma arc cutting was used to remove the relatively thin pressure vessel of the Elk River reactor, is this technique directly applicable to the much thicker pressure vessels of large power reactors of current design?) Should special efforts be made to gather additional experience relevant to the dismantling of large facilities especially their highly radioactive portions?

   Some criticisms of past cost estimates have centered on the costs for demolition and removal of the containment structures. Since containment structures for today's large reactors are much more massive and constructed to different standards than earlier containments, should the effort required for their removal be carefully assessed and verified so that the cost of this removal, which may be a major factor in determining total reactor decommissioning cost, can likewise be verified?

2. <u>Cost Estimates</u>

   Questions as to the form of any financing requirement and even as to the necessity for having a financing requirement often hinge upon estimates of the cost involved in decommissioning. (The greater the potential cost, the greater the potential financial liability of the public and the greater

the need to ensure that the costs will be paid by the responsible party.) The limits of our previous decommissioning experience and the accuracy of extrapolating past costs to cost estimates for future decommissioning activities are frequently raised issues.

Specific questions for comment might include:

To what extent do recent cost estimates for decommissioning facilities reflect actual costs incurred in the past?

For each class of facilities, to what extent can we extrapolate from past costs for facilities of that class to derive estimates for future costs of facilities which may be of a different size or of a different design or structure from those we have actually had experience with?

A number of estimates as to the cost of decommissioning a large light water reactor are now available and the estimates range considerably (see Chapter 4 of Appendix A). Do these discrepancies suggest lack of knowledge, differences of opinion as to what constitutes acceptable decommissioning, or simply erroneous estimates? In particular, are there certain key assumptions as to the cost of pressure vessel removal or containment demolition which are the source of much of this disagreement and, if so, what could be done to resolve these apparent inconsistencies?

These general comments above are supplemented in our attached specific comments and our more lengthy discussion of the issues in Appendix A.

Another suggestion we would make regarding any proposed rulemaking proceeding would be the coordination of such a proceeding with the Battelle report on PWR decommissioning (NUREG-0395) which we understand is expected out in draft form shortly. Given that the interest of the California Energy Commission and presumably those of similar agencies in other states center largely on reactors among the fuel cycle facilities, it would therefore be extremely valuable if the draft report NUREG-0395 were expeditiously made available to all interested participants and discussion of the findings of this report were permitted to be an integral part of any rulemaking proceeding on decommissioning reactors.

In closing, I'd like to thank you for extension of the comment period by a few days to enable us to submit these comments in time for your consideration. We trust that our comments will be of some value.

Sincerely,

Emilio E. Varanini III

EMILIO E. VARANINI, III
Commissioner

Attachment

SPECIFIC COMMENTS ON THE DECOMMISSIONING QUESTIONS POSED BY THE NRC IN THEIR MARCH 13, 1978 FEDERAL REGISTER ANNOUNCEMENT

Question #1

Is it desirable to develop more definitive decommissioning criteria for production and utilization facility licensees and byproduct, source, and special nuclear material licensees? If so, should the criteria be in the form of: (1) potential exposures to individuals; (2) numerical contamination limits; (3) other? (specify).

Comment

The distinction between decommissioning criteria in Question #1 and the decommissioning plans of Question #2 is unclear. We will assume that "criteria" refers to regulations and guidelines that are of a generic nature. Criteria, therefore, would not be specific for a single facility design or site but would form limits and boundaries and present conditions with which a site- or facility-specific, detailed, decommissioning plan must conform to be acceptable.

Using this definition, there does appear to be a need for additional and more definitive criteria. Additionally, existing criteria might be re-examined for their direct applicability to decommissioning, especially in cases where such criteria were not developed specifically for the decommissioning of facilities but where they may have been developed for routine facility operation and have now been extended to decommissioning activities as well. An example of such "extended" criteria might be sections of 10 CFR 20.

A particular criterion which presently seems to be lacking and which will be mentioned again in response to Question #4 would be a standard for acceptable contamination levels for radioactivity which is not surface deposited but is deposited initially in depth in non-radioactive material. Table I of the U.S. NRC's Reg. Guide 1.86 gives contamination levels only for surface contamination, yet for reactor or accelerator decommissioning, substantial amounts of the contaminating radioactivity may be the result of induced radiation and therefore be deposited over some depth in the contaminated materials. Where the induced radioisotopes are long-lived and the non-radioactive material surrounding them might be providing some level of shielding or isolation of these radioisotopes from the environment, the consequence of these radioisotopes at some point in the future not being so shielded or isolated needs to be considered and assessed. A simple surface count of radioactive decay such as would be performed to satisfy Table I seems inadequate to assess the long term hazards of such materials with induced long-lived radioisotopes.

Similarly, for porous material such as the contaminated rock from the reactor site in Antarctica or concrete that has had radioactive liquids spilled on it, the measurement of radiation at the surface may not adequately determine the hazard posed by the contaminating isotopes if the shielding and isolation provided by the porous material was not present.

The second half of Question #1 requests opinions as to the form such criteria should take. This may be a premature question to ask before first determining fully what kinds of criteria are needed. Without more specific information as to the particular criteria or standards in question, it is difficult to determine their form. However, it should be noted that standards expressed in terms of numerical contamination limits as measured in a well-defined manner and for specific isotopes or classes of isotopes would have obvious advantages from a monitoring or enforcement standpoint. The residual radiation levels at decontaminated facilities could be directly measured with available instruments and compliance could be determined with a minimum of work by the enforcing party. On the other hand, asking an agreement state, for instance, to determine, as an alternative, if a certain portion of a decontaminated facility will result in less than a prescribed exposure to the surrounding population may be very difficult, especially for smaller states which lack the staff capabilities of the NRC.

In developing numerical contamination limits, effort should be made, however, to assess the maximum population exposures expected for a specified level of contamination. That is, the public should be assured that although a criteria may specify a numerical value for measured radioactivity, that this numerical value is founded on the maximum radiation exposure that could result from this level and that such an exposure would not be unduly hazardous.

Question #2

Should detailed decommissioning plans be required prior to the issuance of licenses?

Comment

The question of whether or not detailed decommissioning plans should be required prior to issuing licenses is perhaps somewhat premature. A more basic license requirement and one which would be a necessary prerequisite to detailed plans would be the requirement that there exists at least one set of procedures that could be used to decommission the facility in question and which have been demonstrated or validated.

In discussions as to the merit of attempting to regulate facility decommissioning at this relatively early stage in the development of the nuclear industry, it is often pointed out that our experience with decommissioning techniques and procedures has just begun since most facilities built have not yet been decommissioned and that one may reasonably expect advances in this area in the interval before most present facilities will require decommissioning. These postulated advances are expected to result in simplified procedures, reduced cost and reduced occupational radiation exposure. If "detailed plans" are meant to infer facility site and design specific procedures, then it may well be that such non-generic detailed procedures might not in all cases be justified before operating licenses are granted. The requiring of such detailed plans may depend on the type of facility in question (power reactor vs. small radioisotope handler) and the relative radiation hazard posed by the facility. They may also depend on the amount of past experience that exists for decommissioning or decontaminating the type of facility in question. In the instance where a facility is very

similar to previously decommissioned facilities, there is an increased likelihood that there exists at least one procedure that could be employed for decommissioning and, therefore, increased confidence that decommissioning can be readily carried out. It is possible that for the larger and more potentially hazardous facilities (e.g., power reactors), that plans may be required at the start of operation which would be based on currently demonstrated technology and which could be periodically updated to reflect technological advances.

It is important to note the distinction between the suggested requirement that at least one, probably generic, approach for decommissioning each type of facility exist before operation is permitted and the requirement of detailed, perhaps facility specific, plans. The former requirement provides a minimum level of assurance to the public that, regardless of cost, some means exists to adequately deal with the problem of terminating any type of facility allowed to operate. This minimal guarantee is in contrast to a detailed plan which might well become obsolete during the operating life of the facility and which, depending on other factors such as previous experience and relative hazard, may or may not be desirable prior to operation.

Efforts should be made to ensure that the questions of financial responsibility and minimal generic approaches for each facility type have been dealt with before proceeding to the question of detailed plans. It is not clear that we have adequate funding assurances or minimal generic decommissioning procedures for all present facilities. The AIF study for reactors may be one example of a generic plan for one type of facility (power reactors). Perhaps attention should be focused on procedural outlines such as that proposed in the AIF report and a careful determination made as to the completeness of the AIF procedures (or anyone else's suggested procedures) and the demonstrated ability to perform all phases of such procedures on facilities of the size and type presently being constructed. Perhaps what is needed is a coordinated, thorough program by the NRC to demonstrate the availability of all procedures necessary for facility dismantling to the extent necessary to achieve unrestricted site use, especially the demonstration that remote cutting techniques and containment demolition techniques previously used on small reactors can be readily scaled up to today's more massive designs.

Question #3

Should funding or other surety arrangements be required before the issuance of licenses for all cases? If not, which cases?

Comment

The facilities which the NRC licenses directly or through agreement states form long continua based on several parameters such as the amount of radioactivity present at decommissioning, the specific isotopes present, the physical nature of the contamination (surface deposited vs. depth or induced radiation), and facility size. These differences arise because the licensed facilities range from educational, medical and research users of small amounts of radioisotopes in sealed sources to large reactors and reprocessing plants. Further, these differences between facilities generally translate into differences in the hazard posed to public health by a terminated facility and the cost to remove that hazard by decommissioning.

Requiring the establishment of funding arrangements, even bonding, is probably not necessary before licenses are issued to all facilities. The handlers of small amounts of radioisotopes, especially where these isotopes may be short-lived, not readily transported by the environment, and used as sealed radiation sources would presumably sit at the lower end of the hazard and cost continua and may not require financial arrangements as a licensing precondition.

State-licensed users, handlers and packagers of radioactive materials whose facilities pose a potentially greater hazard for health and have higher potential decontamination costs may well be expected to provide some sort of financial assurance to the licensing authority such as the posting of a bond to cover decontamination costs. The National Conference of Radiation Control Program Directors have made excellent suggestions as to the form a state authority might take to require bonds of state licensed facilities. These suggestions could be adopted by the NRC for use with these small state licensable facilities in states which are not agreement states. Furthermore, the NRC could require of agreement states that such bonding authority be obtained from state government by the appropriate state licensing authority for states desiring the "agreement state" designation.

The larger fuel cycle facilities such as reactors, reprocessing plants, and fuel fabrication facilities generally form the higher end of the hazard and cost continua. Hard estimates are needed to establish the hazards and decommissioning costs for such facilities. These values may be forthcoming from the series of decommissioning studies presently underway at Battelle for NRC. It appears that the hazards and costs are greatest for large reactors, reprocessing plants, and for facilities with similar radioactive inventories. For such facilities, some funding mechanism should be required as a licensing condition. Chapter 22 of Appendix A presents a more lengthy discussion of the reasons why such a funding requirement is needed and a discussion of the advantages and disadvantages of some of the commonly mentioned forms such a required funding mechanism might take.

Appendix A basically argues that the NRC should seriously consider requiring establishment of some funding mechanism which will ensure that the money necessary to cover the costs of decommissioning will be available when needed and will be accumulated by a licensee over the operating life of the facility in an equitable manner from that segment of the population directly benefiting from the facility's existence. If the funding mechanism chosen were of a type that only accumulates the full amount of money needed at the time of anticipated plant shutdown, a bond could be required in addition. In the event that premature decommissioning is required, this bond would provide the difference between the costs and the amount of funds collected at shutdown if the latter were insufficient. Additionally, if the funding mechanism were of a type that does not actually retain the funds collected for decommissioning exclusively for this purpose, but rather depends on future revenue to pay the expenses when incurred (e.g., depreciation-type mechanism), it is possible that unanticipated, insufficient future revenues may be inadequate to meet the expenses of decommissioning. To guard against any financial liability to the public, an additional bond could also be required which would guarantee the availability of funds at the time of decommissioning equal to those collected over time for this purpose.

In summary, facilities vary with respect to the need for required funding arrangements and can be categorized into groups of facilities which pose differing degrees of hazard and have differing costs. Facilities which pose the greatest hazards owing to the amount of radioactive contamination, longevity of the hazard, or which involve large decommissioning costs or requirements for perpetual care are the most important candidates for some form of required financial arrangements.

Question #4

What are acceptable criteria for residual levels of radioactivity on materials which can be released for unrestricted use?

Comment

Since material containing radioactivity at levels less than the standard for residual contamination will presumably be released for uses which may include close contact with humans and the environment in general, it is important that such standards be derived only after careful consideration as to the maximum possible exposure that could result. While we cannot at this time suggest specific numeric values for such standards, we can suggest a number of factors which need to be considered in the derivation of any residual contamination standard.

Such standards should reflect consideration as to the type of radiation (alpha, beta, gamma) released by the contaminating radionuclides since this will in turn help define if the potential hazard is greater from external or internal exposure. The specific isotopes contaminating the material are also important since long half-lived isotopes may continue to pose a hazard for thousands of years resulting in a significant cumulative exposure. Additionally, the cumulative exposure could be increased if the isotopes and/or the particular chemical form they are released in resulted in their being particularly active and therefore readily taken up by humans, resulting in internal exposure or perhaps affecting a series of organisms as they cycle through the environment.

Also important can be the physical nature of the contamination and the chemical nature of the contaminated non-radioactive material. If fission products or induced radioisotopes are deposited beneath the surface of the contaminated material and thereby shielded by or bound to the substate material, their hazard could be increased over time if they were to be leached from the material or the material were to otherwise fail to shield or contain them relative to their period for radioactive decay. As a result, a surface level standard for an in-depth deposited, long-lived, biologically active radioisotope might underassess the hazard its unrestricted release might pose if the nuclide were to be freed from the non-radioactive material and enter the environment.

Present NRC criteria for residual levels of radioactivity in materials for unrestricted use appear to rest largely in Table I of NRC's Reg. Guide 1.86. Table I needs to be examined for its adequacy in terms of fully incorporating the above mentioned factors. While in part its standards are in terms of specific nuclides and radiation types, the extent to which it fully considers the lifetime of all contaminating isotopes likely to be encountered

and their biological activity is unclear. It does, for instance, single out certain long-lived biologically active beta emitting isotopes but fails to specifically mention others such as C-14 and H-3. It is not clear to what extent the Table I category of "Beta-gamma emitters" adequately encompasses the risk of such non-specified nuclides.

A more important deficiency of Table I is that it is only for surface contamination and the extent to which it could be used to adequately assess the hazard of radionuclides not deposited on the surface of materials deserves serious consideration. Specific standards should be developed for nuclides deposited in depth as a result of induction by particle bombardment or absorption of contaminated liquids by porous material.

Question #5

Proposals have been made to maintain reactors, which have been shutdown, in protective storage for lengthy periods of time to allow for radioactive decay prior to dismantlement. From the standpoint of determining the impact to future generations, what is an acceptable length of time, if any, after facility operation ceases before the facility should be decommissioned?

Comment

The decision as to how long to delay reactor dismantling depends on a number of factors. The desirability of possibly delaying reactor dismantling for long periods of time in order to permit the level of radioactive contamination to subside due to decay has been most prominantly championed by the Atomic Industrial Forum study on reactor decommissioning alternatives. The basic premise of delayed dismantling is that a delay period will result in lower occupational radiation exposure when dismantling is finally performed and that lower radiation fields inside the reactor will also permit less expensive, easier and quicker ways to perform the decontamination and dismantling work.

These postulated benefits must be weighed against the likelihood that the funds to pay dismantling costs will be available after a 100 year or greater delay, that the work will eventually take place, that the security costs to guard the facility during the delay are not prohibitive, that inflation in costs during the delay does not pose a problem, and lastly that the reduction in radiation field strength will be large enough that dismantling can eventually be accomplished by methods sufficiently easier and cheaper than immediate dismantling to justify the delay.

At the present time, it does not appear that we have the answers to all of these negative factors affecting the desirability of delayed dismantling, and NRC should seriously look at the assumptions made by the AIF study regarding the cost benefits and at the impact which delayed dismantling would have on the question of providing an assurance of equitable funding for decommissioning.

Radiation field decrease. Recent work by Resnikoff and the New York Public Interest Research Group on the levels of Nickel-59 in reactor steel and by Stevens and Pohl on the Niobium-94 in pressure vessel steel indicate that

the decrease in radiation in the "hottest" portion of the reactor, the pressure vessel, may not be as large as the AIF study had assumed. If trace amounts of the long-lived activation products Ni-59 and Nb-94 keep radiation fields high, what does this do to any anticipated cost savings in pressure vessel dismantling or reductions in occupational exposure anticipated by proponents of delayed dismantling?

Funding. The desirability of delayed dismantling may also be greatly impacted by the basic policy decisions made regarding the financial assurance that decommissioning will take place and be paid for by the appropriate parties. If no funding mechanism is required of reactor operators, as is presently the case, the concern that an operator may fail to fully decommission a reactor at termination of operation with no liability to government are compounded by the addition of a 100+ year delay. If a funding mechanism such as depreciation were to be employed by a utility to collect the costs of dismantling from rate payers during plant operation, the question arises as to how the sum of money collected at the time of plant shutdown would be adequate for dismantling costs that will be actually paid only after another 100+ years of inflation (see Chapter 4, Appendix A).

In summary, the purported advantages of delayed dismantling need to be re-examined and seemingly external factors such as the funding requirement imposed may also play a role in determining the advisability of delayed dismantling.

Question #6

Should decommissioning criteria extend to buildings, structures, and components which have not been contaminated with radioactive materials?

Comment

From a radiation health standpoint, decommissioning non-contaminated portions of a facility is unnecessary to protect public health. Whatever requirements might be made of a licensee to dismantle or otherwise decommission any non-contaminated portions would presumably be made on the basis of environmental, economic or aesthetic considerations. At any rate, for facilities such as reactors, it would appear that the cost of removing non-contaminated structures such as a guard building, offices and transmission facilities would be relatively minor compared to the costs associated with decommissioning contaminated structures.

APPENDIX A

Appendix A consists of a section (Part V) of a report recently drafted by the California Energy Commission staff for a State of California Task Force on Nuclear Energy and Radioactive Materials. Among the charges to this task force was one requiring an evaluation of the present technologies and procedures available for decommissioning the range of state and federally licensed nuclear facilities in California with an assessment of the costs, financial liability and methods necessary to ensure that the work will be performed.

Since the decommissioning topics covered in Chapters 19 to 23 of this task force report appear to be highly relevant to the NRC's deliberations regarding the need for improved regulation of decommissioning, these chapters are being provided as Appendix A of our comments. In this manner, reference can be made in our shorter specific comments on the NRC March 13 announcement to sections of these chapters which can provide greater elucidation of particular concerns of the CERCDC.

The recommendations made in the text of this appendix are, of course, only draft recommendations of the California Task Force to the State of California. Many are applicable only to the State of California but many should also be relevant to the NRC.

PART V:

DECOMMISSIONING AND DECONTAMINATION

OF RADIOACTIVE FACILITIES

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Decommissioning and Decontamination
of Radioactive Facilities

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CHAPTER 19: BACKGROUND*

In the near future an increasing number of facilities in California that use, handle or produce radioactive materials will reach the end of their useful lives. These contaminated facilities cover a broad scale in terms of size, form, and purpose and include nuclear reactors, accelerators, packagers and producers of radioisotopes, medical, industrial and research users of radioisotopes, waste handlers, and miscellaneous facilities that concentrate or augment natural radioactivity, such as uranium mines and mills.

These facilities will require some form of decontamination and/or decommissioning in order to protect the health of the people of California from the hazards of any radioactive contamination that may remain. Part V evaluates the present status of the technologies available to perform this radiological clean-up, the present federal and state regulatory positions, and the methods of ensuring that such work, when necessary, will be performed without becoming a financial liability or health hazard to the people of California.

Accelerators

Induced radioactive contamination (explained in Chapter 20 below) in accelerator structures, biological shielding, and beam dumps make retired accelerators a potential health hazard. Additionally, where accelerators are used for target activation, facility contamination from radiochemical manipulations must also be considered.

Induced radioactivity from operation of accelerators is first an operational radiation protection problem, most frequently solved by delay in re-entry to the accelerator cell. This allows short-lived induced radionuclides to decay away, thus reducing exposure of operating staff. Site restoration following shutdown of an accelerator facility requires that all significant surface contamination and induced radioactive material in the facility be removed.

Among the facilities operating under State jurisdiction that might be expected to produce significant amounts of induced contamination are the Crocker Nuclear Laboratory and Cyclotron at the University of California at Davis, Cyclotron Corporation in Berkeley, Medi-Physics, Inc. in Emeryville (which uses a cyclotron to produce radiopharmaceuticals), and Varian Associates and Stanford University, which have high-energy linear electron accelerators in Palo Alto.

Medical therapy accelerators are not presently a serious problem because, for clinical reasons, scrupulous attention must be given to the avoidance of production of neutrons (high energy nutrons are a major source of induced radiation).

Deuterium:tritium generators have not, in the State's experience, been a significant problem from the point of view of site restoration. Removal of the tritium-contaminated vacuum system and checks to confirm the absence of significant tritium or induced contamination on surfaces have been sufficient.

Department of Energy Prime Contractors

A number of laboratories under prime contract to the Department of Energy use substantial quantities of radioactive material for nuclear weapons research and production and physics and biomedical research. These prime contractors include the Lawrence Livermore Laboratory, Lawrence Berkeley Laboratory, Stanford Linear Accelerator Center, Atomics International in Canoga Park, and General Atomic in San Diego.

DECOMMISSIONING AND DECONTAMINATION REQUIREMENTS FOR STATE-LICENSED FACILITIES

State-licensed users of radioactive material must restore facilities and equipment before their release for uncontrolled use. This restoration involves removal of any significant radioactive contamination to prevent exposure of workers or the public in subsequent unrestricted use of facilities and equipment. The user's restoration of contaminated facilities is confirmed by a survey conducted by a State regulatory health physicist before release. Restoration of equipment is reviewed by a regulatory health physicist on a spot-check basis during routine compliance inspections before and after release.

Restoration of facilities and equipment where radioactive materials have been used can be a problem depending on (1) the type of material and physical form,

(2) how it was used, and (3) the half-life of the material. Radioactive material in the form of surface contamination can often be cleaned at fairly low cost by scrubbing and washing with acids and water.

The potential for radioactive contamination is significant if unsealed radioactive materials are used for manufacturing or research and development. On the other hand, potential for contamination is quite small if the user was working only with sealed sources or with radioactive materials with short half-lives, as is the case for most medical uses.

The need for decontamination as part of facility restoration is usually a consequence of activities where contamination surveys and decontamination have been a normal part of the facility's radiation safety program. In many cases, decontamination will amount to little more than a thorough scrubbing of exposed surfaces.

Notable exceptions can follow accidental spills or normal operations involving highly contaminated situations under engineered controls or protective clothing requirement, where decontamination effects can be time-consuming and expensive.

A special situation arises in the case of licensees involved in collection of packaged radioactive waste for transfer to licensed land burial sites outside California. Such waste is moved to central collection points for accumulation before transfer to the site, generally Beatty, Nevada. It is conceivable that a financially pressed collector of packaged waste might find himself unable to discharge his obligation to deliver the waste for burial, thus presenting a liability to the State.

PROCESS AUGMENTATION OF NATURAL RADIOACTIVITY

Uranium Milling. While uranium milling requires a specific radioactive material license from the NRC, and would require environmental review under the California Environmental Quality Act (CEQA), no significant uranium milling has yet been undertaken in California. In the early 1950s, a few hundred tons of uranium-bearing rock was processed through a prototype mill in the northwestern Mojave Desert in Kern County.[5] Nonetheless, because of the rising price of uranium, energy companies are interested in California's low-grade and marginal uranium deposits. If commitment to nuclear power continues, California may eventually have significant uranium milling associated with mining activities in the State.*

Phosphate Fertilizer Production. Production of phosphate fertilizer results in enhancement of the activity of uranium and daughter products contained in phosphate rock, which are separated and concentrated by the production processes. This problem is currently under review by the Environmental Protection Agency.[6]

Radioactive Byproducts from Non-Nuclear Energy Facilities. Non-nuclear production of energy produces radioactive byproducts in concentrations and amounts with potential for occupational and environmental health impact.

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*According to Nucleonics Week (March 2, 1978, p. 6), there will be mining operations near Bakersfield in the fall of 1978.

Significant concentrations of long-lived radon daughters have been identified in cooling tower sludge from The Geysers geothermal area in Sonoma County.[7] There is some reason to believe that these concentrations are not unique to The Geysers but are common to all cooling towers as a result of the removal of natural radioactivity from the air by the scrubbing action of the cooling water on the huge volumes of air passing through. Cooling tower sludge from the Geysers is currently going to a dump site for hazardous materials (Class I) because of its noxious chemical constituents. The appropriateness of this disposal is currently under study by the Department of Health, Pacific Gas & Electric, and Lawrence Livermore Laboratory. Furthermore, coal-fired plants are known to concentrate uranium, radium, and daughter products, which occur as trace elements in fly ash and bottom ash. Finally, at liquifed natural gas (LNG) facilities, radon's long-lived daughter products, Pb-210, Bi-210, and Po-210, accumulate as condensates in amounts which require employee radiation-protection when modifying or dismantling such facilities.

<u>Potential Thorium Mining and Milling</u>. Lastly, increasing discussion has recently centered on the development of a nuclear fuel cycle based on thorium-232, as a substitute for uranium-235. Such a thorium cycle might have advantages of being resistant to proliferation and in conserving uranium. Should there be such a switch in nuclear fuels, California has large deposits of thorium in an unusual and desirable form. The potential exists, therefore, for a large California thorium mining and milling industry, which would have decommissioning problems very similar to uranium mining and milling.

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4. Nuclear Regulatory Commission Show Cause Order, October 24, 1977.

5. John S. Rapp, Uranium in California (California Division of Mines and Geology, 1975).

6. W.D. Rowe, "Radiation Protection Standards and Waste Management," in Proceedings of the International Symposium on the Management of Wastes from the LWR Fuel Cycle, CONF-76-0701, sponsored by the Energy Research and Development Administration, Denver, Colo., July 1976.

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CHAPTER 20: HEALTH HAZARDS

DRAFT

HEALTH HAZARDS IF FACILITIES ARE NOT DECONTAMINATED OR DECOMMISSIONED

The hazards of not decontaminating or decommissioning facilities using, handling, or producing radioactive materials are in some cases extremely high.

Facilities that produce, use, or handle radioactive materials can become contaminated by the radioactive materials when small amounts are deposited on facility or equipment surfaces. In facilities where radioisotopes are packaged or processed radioisotopes inevitably come in contact with equipment handling the isotopes. Contamination may also result from failures to contain the radioisotopes, such as accidental spills and leaking seals on containment equipment.

Contamination may also occur at accelerators, nuclear reactors, and other facilities where high-energy particles are produced. In this case, the high-energy particles (e.g., neutrons) may strike atoms in the surrounding equipment or structures and cause non-radioactive atoms to change into radioactive isotopes of different elements; this is termed induced radiation.

The danger to health from deposited or induced contamination can vary tremendously. Because all radioisotopes decay with time, radioactive material becomes less radioactive over time. When decaying, different radioisotopes produce types of radiation that differ in their energy and danger to living organisms. Consequently, the hazard of contamination can vary from a low level of danger that will, however, continue for thousands of years, to a high

degree of danger that might subside in weeks, days, or even minutes. The degree of hazard and the procedures to mitigate this hazard will depend on the nature of the radioisotopes involved, the radiation they produce and their longevity. However, rough perspective may be given on the relative hazards of different facilities.

Reactors

The components and parts of a large commercial reactor might be contaminated at shutdown with as much as 15 million curies of radioactivity (i.e., exclusive of its highly radioactive fuel). Because much of this radioactivity is from very short-lived isotopes, the level begins to drop immediately after reactor shutdown. There are, however, substantial amounts of dangerous isotopes with medium to long half-lives that would persist as induced and deposited contamination for at least a few years. This contamination would pose a possible hazard if no action were taken and any one were to be exposed directly to the heavily contaminated portions of the reactor.

Among the deposited contaminants, which would be contained principally within the primary cooling system, would also be a number of intermediate to very long-lived fission products and activation products such as H-3, Cs-137, Sr-90, Pu-239, I-129. Induced radiation in the reactor materials themselves would consist of Co-60, Fe-55, and smaller amounts of long-lived isotopes such as Ni-59, Nb-94, and C-14. Reactors, then, contain large amounts of radioactivity and certain long-lived radionuclides will continue to pose a hazard to health for thousands of years if reactors are not properly disposed of after their useful life has ended.

State-Licensed Facilities

The danger from State-licensed facilities varies widely. Those facilities handling sealed sources of radiation pose little hazard unless the containment of a source failed. Facilities using or handling short-lived isotopes, such as certain medical and research users, also pose little danger if sufficient time has elapsed for any radioactive contamination to decay away. Facilities handling, using, or producing long-lived isotopes such as plutonium or other transuranic elements may pose a much greater hazard. State-licensed facilities would not be expected to handle the extremely large quantities of radioactive material that a reactor would, and would not, therefore, be expected to have a level of contamination approximating that of a commercial reactor. Nonetheless, they can pose a significant hazard because, in most cases, the basic structure of these facilities was not designed to contain these materials to the same extent as reactors. Small amounts of dangerous long-lived isotopes in State-licensed facilities would conceivably be a readier source of exposure to the public over time than might larger amounts contained in a reactor.

Non-State-Licensed Facilities and Sources

Non-State-licensed process-augmentation facilities and sources of radioactivity, such as uranium mines, mills, phosphate plants, and geothermal cooling towers, produce very low levels of radiation, but could remain hazardous for extremely long periods of time. Generally speaking, the naturally occurring radioisotopes that these facilities expose and concentrate are very long-lived, but these sources do not have high levels of radioactivity and the radiation they produce is very diffuse. Uranium mines

and mills throughout the U. S. may be responsible for roughly half of the total radiation dose produced by the uranium fuel cycle.[1] These non-State-licensed sources may, therefore, be important to control but, because of their low-level long-term nature, control does not need to take place immediately after use has ended.

HEALTH HAZARDS CREATED BY DECONTAMINATION AND DECOMMISSIONING

While doing nothing to a shutdown contaminated facility may prove unacceptable from a health standpoint, the decontamination and dismantling of a facility may also create some health hazards to the public and workers. These hazards need to be identified and dealt with in the specific decontamination and decommissioning procedures employed.

Decontamination

The kinds of hazards created during decontamination might include workers' ingestion of or contact with contaminated particulates released into the air during the decontamination process. The workers will also receive an external dose of radiation from their proximity to contaminated surfaces and solutions. The public might similarly share some risk from airborne particulates or radioactive liquid spills entering the water system as a result of decontamination efforts.

Dismantling

Dismantling may involve the cutting of steel or other materials and the demolition of concrete structures. Workers might be exposed to vaporized

materials from cutting torches or fine airborne particulates of concrete or steel from cutting or demolition. Deposited on the skin, ingested, or inhaled, these materials could be a hazard. The external radiation dose from components such as a reactor pressure vessel with high levels of induced activity will also contribute substantially to the worker exposure. Public risk would be primarily from airborne particulates created by the dismantling processes.

Long-Term Hazards

Included in the rationale for decontaminating and decommissioning is the belief that decontamination solutions and radioactive dismantling materials disposed of in a licensed waste disposal facility will pose less of a hazard to public health than simply leaving them in an abandoned facility. It has been suggested that this may not be a valid assumption in all instances. Given present federal waste disposal policies and the present situation with regard to operating burial grounds (see Part III, Chapter 10), one could argue that leaving certain isotopes protected within a mothballed or entombed* reactor might afford more isolation from the environment than dumping them at a low-level waste burial site.[2]

Given the problem that has been encountered with radionuclide migration at the Maxey Flats burial site in Kentucky,[3] it might be that for certain

*Mothballing and entombment are modes of decommissioning and will be described in detail in Chapter 21. Mothballing means placing a nearly intact facility in protective storage, while entombment means sealing the facility within concrete or similar material.

intermediate half-lived isotopes such as Cs-137 or Sr-90, retention within an entombed reactor would afford better isolation. This, however, would require that the environmental barrier presented by the entombment process be maintained for several hundred years in order for radioactive decay to sufficiently reduce the hazard of these isotopes. Although leaving short half-lived waste within an entombed reactor may possibily be safer than burying them at a low-level waste facility, the question still remains with regard to long-lived radioisotopes.

Long-lived isotopes such as C-14 and I-129, are presently treated as low-level waste and are disposed of by shallow burial. While the hazard posed by these isotopes will continue for thousands of years, reactor structures were not designed to endure for that length of time, so it is unrealistic to expect that alternatives such as mothballing or entombment will enable a reactor structure to isolate these materials for the period of time necessary. By the same token, there may be good reason to question whether shallow burial of these isotopes at low-level waste facilities will ultimately provide any better environmental isolation. Finding a satisfactory means of disposing of long-lived nuclides seems to require a third alternative to shallow burial or mothballing and entombment, and it seems clear that this class of radioactive waste alone is sufficient to rule out the option of leaving all decommissioning waste permanently within the reactor. Alternative disposal methods need to be employed for at least long-lived radioactive waste.

STANDARDS AND REGULATION

State and Federal Standards

Regulatory requirements for decontamination of facilities and equipment are specified in the California Radiation Control Regulations.[4]

The primary radiation protection standards are the maximum permitted doses to the whole body and various critical organs for radiation workers, the public living in the vicinity of facilities and the population at large. In the United States these standards are set by the Environmental Protection Agency, based on recommendations made by the National Council on Radiation Protection and Measurements, the International Commission on Radiological Protection, and other advisory bodies (see Part IV, Chapter 14 for details on standard setting).

Secondary standards limit concentrations of radioactive material in various media such that the primary standard will not be exceeded even after a lifetime of exposure. The primary and secondary standards represent a consensus at the international and national levels and are adopted more or less verbatim by the NRC and California.

Third-order standards are adopted by regulatory agencies and users to meet operational requirements for providing assurance that the primary and secondary standards will not be exceeded. An example of a third order standard is maximum permitted levels of radioactive contamination on surfaces of facilities and equipment for uncontrolled release.[5] California's standards for

uncontrolled release are similar to the NRC's with a few changes that account for the toxicity of some tritium and carbon compounds and that establish a quality assurance procedure for the contamination surveys conducted by regulatory health physicists to confirm facility decontamination.

The State and federal regulations for decontamination provide standards for the amount of decontamination that must be achieved for surface-contaminated materials only.[6] This is a serious inadequacy since decommissioning and decontamination will quite likely involve materials where the contamination is deep in such porous materials as concrete and rock that have absorbed radioactive solutions, or in such structural materials as steel and concrete where radioactivity has been induced by particle bombardment.

Surface contamination standards are inadequate for evaluting radiologically safe levels of contamination for such bulk or induced radiation materials. These present surface standards do not address the ability of radioisotopes contained in depth with non-radioactive materials to leach or migrate from these materials. If such migration occurs, the hazards posed by the radioisotopes will continue over a long period of time. A piece of rock containing short-lived isotopes, and which will contain these isotopes long enough to permit their radiological decay, may have its health hazard adequately assessed by measuring the radiation levels at its surface. The same rock containing leachable, mobile, long-lived radioisotopes may pose a greater total health hazard than would be predicted by only a reading of radiation at the rock surface since the radioisotopes inside the rock would be inadequately measured at the surface yet would be released over time to affect public

health. Specific standards for bulk material and induced radiation need to be developed to permit decommissioning to be efficiently and effectively carried out.

Enforcement

The enforcement of what present state and federal standards do apply to decontamination is assured by radiological survey at the site conducted by regulatory authorities. According to the General Accounting Office (GAO) report on decommissioning,[7] federal enforcement by the NRC has been less than vigorous. While the NRC may survey a site upon which decontamination has been performed to verify the reported residual radiation levels, the GAO cited an NRC official as saying that the NRC only surveys less than 1 percent of the decontaminated sites.

In California, radiation surveys are conducted by State health physicists whenever a California licensee is relocating his operations or terminating his license to assure adequacy of the licensee's removal of radioactive material and decontamination efforts. These contamination surveys are made before release of the facility for uncontrolled use in all cases where any substantial quantity of long-lived unsealed radioactive material was used and in many cases where only sealed sources were utilized to assure removal of these sealed sources. This is done even though it is understood that where sealed sources are concerned, the possibility of surface contamination is remote.

Occupational Dose

The possibility exists that workers may receive more than the maximum permissible dose as a consequence of working for more than one employer. The NRC has recently announced its intention to hold rulemaking procedures to improve the present procedures for monitoring the doses that radiation workers receive.[8]

Some checks in the present system should be recognized, however. There is the fact that accounting for radiation exposure is by calendar quarter. Hence, there must be a high frequency of job changes with durations of less than one quarter if this is to present a serious problem for an individual. Additionally, this is an area where self-interest should operate. Ideally, the employee should understand the concept of maximum permissible dose and obtain from his employer a statement of his exposure history. Next, the recruiting employer should normally contact the previous employer and request the exposure history. Finally, personnel monitoring records are reviewed during compliance inspections. A comprehensive exposure history is required if exposure is in the range of 1.25 to 3 rem per quarter and will frequently be at issue in instances of exposure of less than 1.25 rem per quarter.

PROBLEM AREAS AND RECOMMENDATIONS

1. Bulk Material Contamination Standards

A fundamental issue that remain to be resolved is the maximum permissible limits for radioactive contamination of bulk material together with

consideration of the models upon which these limits can be based and the protocols for conducting contamination surveys before unconditional release.

The Environmental Protection Agency has indicated that development of these standards is its responsibility but that guidance will not be available prior to 1984.[9] The U.S.S.R. has apparently adopted standards in this area at 10 times of the maximum permissible concentration for water to individual members of the public.[10]

RECOMMENDATION V-1:

BULK MATERIAL CONTAMINATION STANDARDS ARE NEEDED

Maximum permissible limits for radioactive contamination of bulk material together with consideration of the models upon which these limits can be based are needed.

2. Reporting of Occupational Radiation Exposure

Present regulations and procedures covering the reporting of occupational radiation exposures may be inadequate and further tightening may be necessary to guard against workers exceeding their allowable radiation doses by working for multiple employers.

RECOMMENDATION V-2:

STATE SHOULD SUPPORT IMPROVED OCCUPATIONAL

EXPOSURE REPORTING PROCEDURES

The State should express support of improved Nuclear Regulatory Commission

REFERENCES

Chapter 20: Health Hazards

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3. Preliminary Data on the Occurrence of Transuranium Nuclides in the Environment at the Radioactive Waste Burial Site at Maxey Flats, Kentucky, EPA-520/3-75-021 (Environmental Protection Agency, Office of Radiation Programs, February 1976).

4. California Administrative Code, Title 17, Sec. 30298.

5. Nuclear Regulatory Commission, Regulatory Guide 1.86 (June 1974). (See Appendix B of this report.)

6. Ibid., Table I.

7. Cleaning Up the Remains of Nuclear Facilities: A Multibillion Dollar Problem, EMD-77-46 (U.S. General Accounting Office, June 1977).

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9. Testimony of David Henkins, Assistant Administrator for Air and Waste Management, Environmental Protection Agency, before the Senate Subcommittee on Nuclear Regulation, March 1978.

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CHAPTER 21: DEFINITION, REGULATION, PROCEDURES, AND EXPERIENCE

DRAFT

DEFINITION OF DECOMMISSIONING AND DECONTAMINATION

Federal Definition

While no formal definition of decontamination apparently exists, the term is relatively unambiguous. Decontamination simply refers to the process of removing radioactive material that has been deposited or induced on or into materials originally non-radioactive in the course of handling or producing radioisotopes.

The definition of decommissioning is not so straightforward. Federal regulations provide that the holder of an NRC license to operate a reactor may terminate the operating license if the dismantlement and disposal of the facility is carried out in a manner which "will not be inimical to the common defense and security or to the health and safety of the public."[1] To facilitate this safe disposal the NRC published Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors" that specified four options for reactor retirement[2] (quoted verbatim):

1. Mothballing. Mothballing of a nuclear reactor facility consists of putting the facility in a state of protective storage. In general, the facility may be left intact except that all fuel assemblies and the radioactive fluids and waste should be removed from the site. Adequate radiation monitoring, environmental surveillance, and appropriate security procedures should be established under a

possession-only license as opposed to an operating license to ensure that the health and safety of the public are not endangered.

2. In-Place Entombment. In-place entombment consists of sealing all the remaining highly radioactive or contaminated components (e.g., the pressure vessel and reactor internals) within a structure integral with the biological shield. All fuel assemblies, radioactive fluids and wastes, and certain selected components are shipped offsite beforehand. The structure should provide integrity over the period of time in which significant quantities of radioactivity [greater than those specified in Regulatory Guide 1.86] remain with the material in the entombment. An appropriate and continuing surveillance program should be established under possession-only license.

3. Removal of Radioactive Components and Dismantling. All fuel assemblies, radioactive fluids and waste, and other materials having activities above accepted unrestricted activity levels should be removed from the site. The facility owner may then have unrestricted use of the site with no requirement for a license. If the facility owner so desires, the remainder of the reactor facility may be dismantled and all vestiges removed and disposed of.

4. Conversion to a New Nuclear System or a Fossil Fuel System. This alternative, which applies only to nuclear power plants, utilizes the existing turbine system with a new steam supply system. The original nuclear steam-supply should be separated from the electric generating system and disposed of in accordance with one of the previous three retirement alternatives.

The NRC makes no distinctions between the desirability or suitability of these four options. Judging from past reactor decommissioning experiences, the NRC finds mothballing or entombment to be entirely satisfactory options for terminating a reactor operating license. Mothballing and entombment permit unlimited amounts of induced radiation and surface contamination to remain on the site. The conversion option also permits the turbine system and any radioactive contamination contained within it to remain. The mothballing and entombment options do not provide for permanent removal of the dangers of radiation from the site since they provide only for "security procedures" or "sealing" of radioactive components to remove the immediate public danger from contact with the remaining radioactivity.

It is difficult to conceive of any option other than "removal of radioactive components and dismantling" that constitutes complete and final protection of the public health and safety. The reason is that some radioisotopes that contaminate a reactor or other facility will remain radioactive for thousands of years. To rely upon "security procedures," such as alarms and guards or even sealing the facility structures with concrete or steel, seems patently inadequate to ensure safety for thousands of years. At best, entombment or mothballing might serve as only short-term, interim measures after reactor shutdown to be followed after a brief period by complete dismantlement and removal.

State Definition

While the State of California has no specific definition of what constitutes decommissioning, the State does have some health standards (adopted from

federal standards) for acceptable levels of radiation for unrestricted use of decontaminated equipment, facilities, or land (see Chapter 20).

Adequacy of Definitions

The federal definition of decommissioning appears to give too much latitude to possessors of reactor operating licenses in equating temporary methods of protecting public health and safety, such as mothballing and entombment, with the only method that permanently protects the public, the complete dismantlement and removal of the radioactive portions of the facility coupled with the safe and permanent disposal of the waste generated. California does not now have a definition of decommissioning but apparently does have the authority to adopt one.[3]

A better definition would resemble the following: any facility licensed by the State or any facility that could eventually pose a hazard to public health should, upon the end of its useful life, be decontaminated in such a manner that all radiation is removed to a level permitting unrestricted use by the public, and where such surface decontamination is not possible that radioactive portions should be completely removed and disposed of at appropriate and approved disposal facilities. (Note: This is incorporated in Recommendation V-3 below.)

This report uses this definition of decommissioning; the terms "mothballing" and "entombment" are used to denote any partial decommissioning.

STANDARDS AND REGULATIONS

Federal Regulations

The present federal regulations pertinent to decommissioning and decontamination are summarized in the following list of Code of Federal Regulations (CFR) part and section numbers and regulation titles:

- o 10 CFR Part 50 - Licensing of Production and Utilization Facilities
  - Sec. 50.51 - Duration of License, Renewal
  - Sec. 50.59 - Changes, Tests, and Experiments
  - Sec. 50.90 - Application for Amendment of License or Construction Permit
  - Sec. 50.82 - Applications for Termination of Licenses
  - Sec. 50.33 - Contents of Applications
- o 10 CFR Part 20 - Standards for Protection Against Radiation
- o 10 CFR Part 51 - Licensing and Regulatory Policy and Procedures for Environmental Protection
- o 10 CFR Part 30 - Licensing of Byproduct Material

Most of these regulations were written for operating reactors but have been interpreted to apply to decommissioning as well. One regulation specifically written for decommissioning is NRC's Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors," published June 1974 and reprinted in Appendix B of this report. While no hard and fast specifications are laid out in this regulation for the procedures to be followed in decommissioning, it does make suggestions that can be used to form the following likely scenario.

Upon beginning to decommission a reactor, a licensee would probably first apply for a "possession-only" license following the procedures specified in 10 CFR 50.90. A possession-only license does not permit the licensee to operate the facility but does permit the possession of all types of radioactive materials. This step would enable the operator to reduce the amount of insurance and indemnification that must be carried. If the licensee intended to only perform minimum decontamination, such as in mothballing, these operations might be performed within the latitude of the existing technical specifications. At most, such operations might require approvals for changes in the technical specification of the license as specified in 10 CFR 50.59. If major structural changes were planned, as would be the case for entombment or complete decommissioning, a dismantlement plan must be submitted to the NRC under 10 CFR 50.82 detailing the actions to be taken.

Having obtained approval of this "plan," the operator could begin decommissioning, and as different classes of radioactive materials are removed the possession license would be modified and the insurance requirements would be reduced. Federal regulations (10 CFR 70) also cover the removal of all special nuclear materials from the site which for reactors would be all reactor fuel; source material is covered by 10 CFR 40, and byproduct material by 10 CFR 30. The radioactive contamination remaining in a reactor after removal of the fuel is expected to be from material covered by the byproduct license, and in cases of mothballing or entombment where sufficient decontamination has taken place, the special nuclear materials possession-only license may be reduced to a byproduct material possession license. This is important in that California and other agreement states are permitted to license byproduct possession, and a facility that is decontaminated sufficiently to

obtain a reduction from a special nuclear materials license to a byproduct material license could become the responsibility of the state even though the facility is still far from radiologically "clean."

If all radioactive contamination or radioactive materials are removed so that levels of radiation are below the NRC's acceptable surface contamination levels (See Table I, Appendix B), then the NRC may terminate all licenses on a facility and release the facility for unrestricted use. The State Department of Health argues that states have the right to set standards for residual levels of radioactive contamination more stringent than the NRC's. In this case, a state might find itself responsible for a facility that the NRC had determined was clean enough for unrestricted use but which was not radiologically clean by a state's definition. Present California standards for acceptable surface contamination levels are the same as those of the NRC except that, for tritium and carbon-14 not present in molecules that are DNA precursors, the California standard is more lenient than the federal standard.

State Regulations

State regulations applicable to decontamination and decommissioning consist largely of standards for ambient radioisotope concentrations in air and water and some surface radiation-level standards and dose standards, all of which are adopted from federal standards. These health-related standards are discussed in more detail in Chapter 20 above.

There appears to be little State regulation of the procedures involved in decontamination and decommissioning. The California Radiation Control

Regulations specify that a user is responsible for decontamination of a State-licensed facility upon termination or transfer of the license.[4] Guidelines have been prepared by the Radiologic Health Section of the Department of Health specifying conditions and procedures to be employed prior to the release of equipment or facilities for unrestricted use. These guidelines are virtually a repeat of the NRC's.[5] They are general in nature and in no way specify the procedures to be employed in decontaminating any class of State-licensed facilities.

PROCEDURES INVOLVED IN DECOMMISSIONING AND DECONTAMINATION

To provide a fuller understanding of what constitutes decontamination and decommissioning, this section briefly describes the procedures commonly employed.

Procedures for Reactors

As defined earlier, decontamination generally involves the removal of radioactive material deposited on the surfaces of nonradioactive objects. Decontamination of individual components is a frequent step in the process of decommissioning an entire facility. Decommissioning is, therefore, a more complete process to remove all radioactive hazards posed by a nuclear facility as a result of its operation and may involve complete dismantling and removal of material contaminated by surface deposited radioisotopes or by the formation of induced radiation in the material as a result of bombardment by high-energy particles. While a facility might be decontaminated to decrease the levels of radiation produced by contaminants and returned to operation,

decommissioning denotes a terminal action: there is little or no intention ever to return to operation a decommissioned facility.

What decontamination and decommissioning actually involve can best be appreciated by considering their application to a nuclear reactor.

Sequence of Major Tasks. The general series of events that would take place in the decommissioning of a power reactor, gleaned from a recent study of San Onofre 1 prepared by the NUS Corporation, are as follows.[6] (Reference to the schematic diagram of a pressurized water reactor in Figure V-1 may prove useful.)

1. Decommissioning Plan and Procedures. Detailed plans of the activites necessary to decontaminate the reactor, to dismantle the reactor core and external structures, and to dispose of the wastes are prepared. In the case of commercial and test reactors licensed by the Nuclear Regulatory Commission, this information is submitted for approval to the NRC in a "decommissioning plan," in accordance with 10 CFR 50.82.

2. Primary System Decommissioning. The reactor is shut down and the fuel is removed and shipped off-site. The primary cooling system, the cooling loop that circulates the water in the reactor core, is decontaminated. One way to accomplish this is by circulating solutions to dissolve the radioactive material that has deposited on the inside surface of the primary system piping.

3. Reactor Vessel Disposal. High-temperature, remotely manipulated plasma torches are installed inside the 9-inch-thick steel reactor vessel. Because this vessel contained the core of the reactor, the levels of radiation within are so high that even years after reactor shutdown these levels will probably be too high to permit direct contact by dismantlement workers. This necessitates the use of remote-controlled torches operated under a pool of water for radiation shielding. These torches first remove the reactor pressure vessel internals and then dismantle the vessel itself. The cut pieces would be loaded into specially shielded casks and shipped to appropriate burial facilities.

4. Steam Generator and Primary System Disposal. The steam generators and the primary cooling systems are cut up and removed from within the containment structure and the inside of the structure is decontaminated in preparation for the next step.

5. Containment Structure and Containment Structure Piping Removal. Any remaining contaminated tanks and piping within the structure are removed and all contaminated concrete and reinforcing bar in the walls of the containment are removed either by (a) the use of such conventional demolition tools as jackhammers or, perhaps, (b) the controlled use of explosives with procedures to control the scatter of radioactive dust. Remaining non-radioactive portions of the containment structure are removed down to below ground level and disposed of.

6. Secondary Plant and Auxilaries Removal. The steam turbines and all cooling system components in auxiliary buildings outside the containment

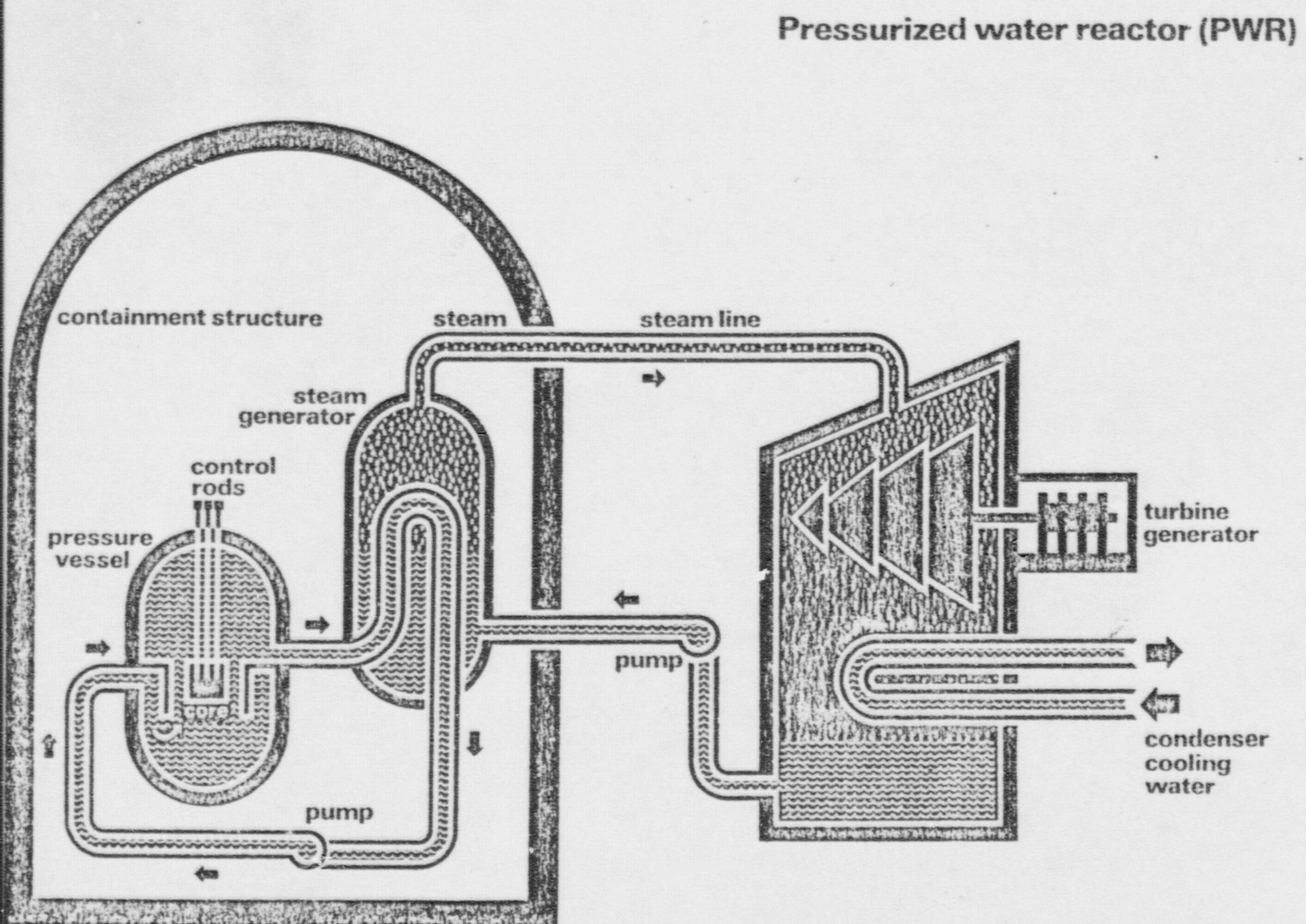

Figure V-1

From the Atomic Industrial Forum.

structure are removed and the buildings demolished. These materials may require some decontamination and certain pumps, motors, and electrical equipment may be salvageable.

7. Fuel Pool and Contaminated System Removal. The pool that housed spent reactor fuel as an interim storage measure is drained, decontaminated, and completely dismantled and removed.

8. Radwaste Facility Removal. Having processed all of the decontamination liquids and other radioactive wastes generated during decommissioning, the radwaste facility can now, in turn, be decontaminated, removed, and disposed of.

9. Civil Structures and Site Refurbishment. If desired, any remaining non-contaminated structures, such as office buildings, paving, railroad tracks, transformers, fencing, and conduits, are now removed.

10. License Changes and Surveys. Final radiation surveys are taken, a final report is prepared, and termination of all NRC licenses is requested.

This sequence of major tasks is not inflexible. At many points in the decommissioning process, decontamination of equipment or structures is called for. In the case of reactors, decontamination would be similar to that which might be required of State-licensed non-reactor facilities.

Timetable. The question of when the optimal dismantling of highly contaminated portions of the reactor should occur is not fully resolved, but the two primary options would seem to be to dismantle either immediately after shut-

The series of activities described above could take a minimum of six to seven years for completion. With a short timetable decommissioning would entail the rapid completion of all 10 steps with, at most, a short (three- to four-year) wait after shutdown to allow for the decay of short-lived radioisotopes.

However, the Atomic Industrial Forum study of decommissioning has advanced an alternative procedure:[7] shortly after shutdown work begins on preliminary decontamination and dismantling of certain components with low radiation levels, but the removal of the highly radioactive pressure vessel and the surrounding containment structure might be delayed for approximately 100 years, under the presumption that this would be sufficient time for their high radiation fields to decay to levels permitting less complicated and expensive dismantling techniques to be employed. Because of the significant radiation remaining during the hundred-year delay, some level of security and maintenance would have to be sustained over that period. The technical basis for the selection of a one-century delay was at least partly theoretical, and two recent reports have provided arguments that, if correct, would diminish the utility of such a delayed dismantling.[8]

RECOMMENTATION V-3:

STATE DEFINITION OF DECOMMISSIONING SHOULD COVER

DECONTAMINATION OR DISMANTLEMENT

<u>The State should adopt a definition of reactor decommissioning that incorporates the complete decontamination and/or dismantlement of any radioactive portions of the facility and the safe, permanent disposal of all radioactive wastes produced.</u>

State enforcement of reactor decommissioning by such a definition would provide a much more complete and safe disposition of California reactors than would the use of the present federal definition. The federal definition would permit incomplete partial decontamination and dismantling to fulfill the total obligation of reactor operators to decommission these facilities, even though substantial amounts of dangerous radioactive materials remaining at the site would pose a health hazard to future generations of Californians.

The NRC has, it should be noted, recently requested public comment on possible amendment of its decommissioning regulations, specifically on the desirability of developing more definitive criteria for decommissioning.[9]

Procedures for Facilities Other than Reactors

For all facilities, reactors and non-reactors, removing the hazards of radiation can be broadly split into those instances where the contaminants are surface-deposited and those where radioactive contamination has penetrated materials or is distributed in depth as a result of being induced from bombardment of high-energy particles.

Contamination Control. All decontamination should always minimize exposure to the decontamination workers and to the general public. For extremely radioactive environments this may involve the use of remote-control equipment or shielding by lead or water. In extreme cases workers may wear completely enclosed air suits to protect them from airborne radioactive particles; where this danger is less they might wear ordinary work clothes or as little as a dust filter over their faces.

Non-Porous Surfaces. When radioactive material has coated the surface of equipment or buildings, a variety of procedures may be employed for its removal, depending on the chemical nature of the contaminant and the object to which it is adhering, the tenacity with which it is adhering, and the necessity to leave the contaminated object undamaged by the decontamination procedures. In a research lab that handles solutions of radioisotopes, decontamination may consist of washing or scrubbing the contaminated surfaces with ordinary cleanser. For reactors, reprocessing plants or other facilities processing radioisotopes, strong chemical agents at high temperatures might be pumped through the systems to be decontaminated. Sandblasting or applying and removing special paints can also be used to remove surface contamination.

Contamination of Porous Surfaces, Contamination in Bulk, Induced Contamination. In situations where the radioactive contaminants are not simply distributed on the surface of an object, more destructive means may have to be employed to remove the hazardous material. In cases where radioactive solutions are allowed to contact porous material (such as rock or concrete) and the radioisotopes penetrate the material and chemically bind inside, the material may be removed by jackhammering, explosives, or grit blasting designed to remove the porous material containing the contaminating radioisotopes. For metals with induced radiation or where surface treatment methods prove ineffective, torches or saws can be used to dismantle the contaminated material as long as special care is taken to avoid melting the materials or creating contaminated particulates. Like reactors, accelerators might need to be decontaminated with these techniques.

Volume Reduction. In order to ease the shipment and burial of decontaminated materials and decontaminating solutions and equipment, the volume is reduced

whenever possible and the radioactivity is fixed in some solid, non-soluble form. This may involve mechanical compaction or further cutting, the incineration of contaminated combustibles, and the evaporation of contaminated liquids or otherwise fixing these liquids in a solid such as concrete or asphalt.

Problem Areas and Recommendation

1. Present Facilities Not Designed for Easy Decontamination or Decommissioning. While it may appear that procedures are available to handle most decontamination requirements, much additional research and development is necessary. As presently practiced, decontamination can be very expensive and time-consuming and exposes workers to more radiation than necessary. Experts on decommissioning and decontamination have stated that a number of areas need attention.[10] They point to the fact that presently built facilities were not designed to be easily decontaminated. Many previously constructed facilities handling radioactive materials were designed to provide protection from and containment of the radioactive materials they contained. Little consideration, however, was given to features of their construction that might facilitate routine or terminal decontamination and dismantlement. Plumbing that carries contaminated fluids may contain bends or other features that tend to trap radioactive solids contained in the fluid, making decontamination much more difficult and expensive.

For other handlers or processors of radioactive materials, the consequences of inappropriate design may not be so substantial. Still, there might be effective measures that these licensees might employ and that a State agency might encourage or require.

Several studies[11] have indicated that much could be accomplished in rethinking the design of new facilities to better accommodate the eventualities of decontamination and decommissioning. An NRC contractor, Battelle Pacific Northwest Laboratories, will be examining this issue of better design for fuel cycle facilities, reactors, reprocessing plants, etc.* State and federal agencies should be encouraged to continue and to expand efforts along these lines and to look at State-licensed facilities as well.

The California Energy Commission may be able to play a role in setting standards for power reactors that require such planning. Substantial savings in the cost of D&D, decreased loss of productivity from decontamination, extended facility lifetimes, and decreased occupational and public radiation exposure could be the resulting benefits.

RECOMMENDATION V-4:

DESIGN OF FUTURE FACILITIES SHOULD

FACILITATE EVENTUAL DECOMMISSIONING

The State and federal authorities should develop a program of research and regulation to determine and require design features for future facilities handling radioactive materials that would facilitate the decontamination and/or decommissioning of these facilities.

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*Battelle is conducting studies for the NRC to provide information for developing criteria and guidelines for decommissioning reactors and other NRC-licensed fuel cycle facilities. An evaluation of the technology, costs, and environmental impact will be made. The report on decommissioning pressurized water reactors is scheduled for release in May 1978.

2. Inadequacy of Decontamination Techniques. Along with redesign of facilities, the experts have called for further development of almost all present decontamination techniques, including:

- simpler techniques for decontaminating metals
- techniques for removing thin layers of porous materials
- improved explosive techniques for removal of large masses of material
- more development of special remotely operated cutting tools and remote viewing equipment
- more efficient and economic ways of handling large volumes of low-level waste
- better methods of packaging waste to ensure its isolation from the environment
- improved equipment for measuring alpha and beta-gamma exposures in the field

3. Inadequacy of Decommissioning Procedures. The procedures involved in decommissioning either are not known or, in many cases, have not been adequately refined or proved. While a few studies have attempted to specify exactly how a large commercial reactor should be decommissioned,[12] these procedures have never been actually used for a large reactor. Furthermore,

the adequacy of these proposed procedures as a basis for accurately estimating costs awaits confirmation. Estimating the time, labor and cost of decontaminating and decommissioning radioactive facilities is presently very difficult.

Federal and state authorities have at best only vague and very general requirements for the decontamination and decommissioning work that must be performed at a facility. More specific standards need to be developed to give guidance regarding the amount of decontamination and dismantling that must take place, the timeframe during which this work must be accomplished, and the specific procedures that will enable this work to be carried out on schedule and with acceptable risk to public and worker health.

RECOMMENDATION V-5:

U.S. SHOULD DEVELOP DETAILED DECONTAMINATION AND DECOMMISSIONING PROCEDURES

The State should encourage the NRC to continue the work it has begun with Battelle Pacific Northwest Laboratory to develop detailed procedures for the decontamination and decommissioning of radioactively contaminated facilities, especially reactors.

EXPERIENCE IN DECOMMISSIONING REACTORS

As preliminary steps to developing improved decontamination and decommissioning procedures, it may be necessary to gain more experience with the possible decontamination and decommissioning procedures that might be employed and to determine permissible radiation exposure levels and contamination

levels which are adequate to protect public and occupational health. It is evident that the inadequacies in our present knowledge and capability to decontaminate and decommission radioactive facilities stem largely from our lack of experience in performing these tasks.

Several prominent authors on decommissioning have made emphatic claims regarding the large amount of reactor decommissioning experience the U.S. presently possesses. Statements such as this one are common: "The decommissioning of power reactors is not novel. In the United States alone over sixty-five experimental and demonstration reactors have been either entombed or dismantled."[13]

Lists such as those presented in Figure V-2 have been compiled to show the depth of our experience. Closer examination of such tables and statements reveals a more realistic picture of our actual decommissioning experience.

Of the reactors listed in Figure V-2, only one has actually been completely decommissioned, i.e., completely decontaminated or dismantled. Under the present loose definition of the NRC's Regulatory Guide 1.86, minor decontamination and security measures are equated with total dismantlement. Under the definitions used in this report (see beginning of this chapter) the only decommissioned reactor on this list would be the Elk River Reactor.

The Elk River Reactor at Elk River, Minnesota, was a small (53 MW thermal, or approximately 18 MW electric) boiling water reactor. As a result of the construction agreement between ERDA and the operating utility, the reactor was dismantled between 1972 and 1974 after its useful life ended. It is the

Figure V-2

TABLE SR-4. EXPERIMENTAL AND DEMONSTRATION REACTOR DECOMMISSIONING HISTORY[a]

Reactor Facility and Location	Reactor Type	Reactor Thermal Rating, MW	Type of Decommissioning	Status of License	Monitoring System	Protective Storage Measures
CVTR Parr, SC	Pressure tube heavy water	65	Mothballing	Byproduct per 10 CFR 30	Periodic surveillance	Welded closure, locked doors, security fence
Pathfinder Sioux Falls, SD	BWR nuclear superheat	190	Mothballing with steam plant conversion	Byproduct to state[b]	Continuous security force[c]	Welded closure, security fence
FERMI 1 Monroe Co., Mich.	Sodium cooled fast	200	Mothballing	Possession only[d]	Continuous security force[c]	Locked doors, security fence
Peach Bottom 1 York Co., Penn.	Gas cooled graphite moderated	115	Mothballing	Possession only	Continuous security force[c]	Not yet established
VEWR Alameda Co., CA	BWR	50	Mothballing with steam plant conversion	Possession only	Continuous security force[c]	Locked doors, security fence
NASA Plumbrook Sandusky, Ohio	Light water	0.1	Mothballing	Possession only	Continuous security force[c]	Locked doors, security fence
GE EVESR Alameda Co., CA	BWR with nuclear superheat	17	Mothballing	Possession only	Continuous security force[c]	Locked doors, security fence
Saxton, PA	PWR	23.5	Mothballing	Possession only	Intrusion alarms	Welded closure, locked doors, security fence
SEFOR Strickler, Arkansas	Sodium cooled, fast	20	Mothballing	Byproduct to state	Intrusion alarms	Welded closure, locked doors, security fence
Westinghouse Test Reactor Waltz Mill, PA	Tank	60	Mothballed	Possession only	Continuous security force[c]	Locked doors, security fence
B & W Lynchburg, VA	Pool	6	Partial dismantling	Byproduct per 10 CFR 30	Not required	Not required
Hallam Hallam, Neb.	Sodium cooled graphite moderated	256	Entombing	Operating authorization terminated	Not required	Welded closure, concrete cover, weatherproofed
Piqua Piqua, Ohio	Organic cooled and moderated	45.5	Entombing	Operating authorization terminated	Not required	Welded closure, concrete cover, waterproofed
BONUS Ricon, Puerto Rico	BWR with nuclear superheat	50	Entombing	Operating authorization terminated	Not required	Welded closure, concrete cover, locked doors, security fence
Elk River Elk River, Minn.	BWR	58.2	Dismantling & partial conversion	Operating authorization terminated	Not required	Not required

[a] Reference: "Decommissioning and Decontamination of Licensed Reactor Facilities and Demonstration Nuclear Power Plants", by P.B. Erickson and G. Lear, U.S. NRC, presented at conference on Decontamination and Decommissioning in Idaho Falls, Idaho, August 19-21, 1975.

[b] A byproduct license may be issued by agreement state per 10 CFR 150.

[c] The use of a continuous security force was not required by the NRC because continuous manned security was provided for other on-site activities that were unrelated to the decommissioned reactor. If such a security force was not present, the NRC may have stipulated manned security or other additional access control measures.

[d] A possession only license permits possession of a reactor facility but not its operation.

From "An Engineering Evaluation of Nuclear Power Reactor Decommissioning Alternatives," Atomic Industrial Forum, National Environmental Studies Project.

decommissioning of this reactor that forms a large part of our decommissioning experience, especially in the use of remotely controlled cutting equipment to remove highly radioactive pressure vessels and in the use of explosives to demolish concrete containment structures.

One other reactor, the Sodium Reactor Experiment (SRE) operated by Atomics International for the Department of Energy at Santa Susana, California, is being decommissioned and all radioactive portions of the reactor will be dismantled and removed. SRE is a small experimental reactor of a design unlike any present commercial reactors. SRE may provide useful knowledge in remote dismantling using the plasma torch and other techniques of decontamination and removal, but experience in the complete process of decommissioning a large pressurized water reactor (PWR) will still not be obtained.

Experiences such as these with small reactors of experimental design constitute the whole of our reactor decommissioning experience, given the definition of the term that this report has adopted.

Problem Areas and Recommendations

Little actual experience exists in the complete dismantling of even small experimental reactors and experience with large pressurized water reactors is completely nonexistent. Past reactor decommissioning experience has been on facilities that were much smaller than today's new reactors and on reactors often having design features much different from today's commercial plants thereby making extrapolations of decommissioning procedures, labor, and costs very difficult.

While there are no reactors of the 1,000 MWe size in need of immediate decommissioning, the NRC could encourage the immediate dismantlement of a smaller commercial reactor should a final decision be made to permanently shut down such a reactor. Possible candidates for such shut down at this time include the Humboldt Bay, Indian Point I, and Dresden I reactors. Since most of the actual dismantlement experience accumulated thus far is from the small Elk River Reactor and the small Sodium Reactor Experiment, dismantling any larger, commercial, non-experimental reactor will provide valuable additional experience on which to base better estimates of costs and detailed regulations or guidelines regarding acceptable decommissioning procedures. While experience relevant to portions of the decommissioning process, such as pressure vessel removal or cooling system decontamination, may be gained from this limited past experience in mothballing, entombing, and decommissioning small experimental reactors, a comprehensive and thorough experience would provide a solid basis for assuring that decommissioning today's large reactors is a readily achievable task. Furthermore, it would greatly enhance our ability to accurately predict the present and future costs of decommissioning.

RECOMMENDATION V-6:

U.S. SHOULD HAVE A PROGRAM TO ACCUMULATE

REAL DECOMMISSIONING EXPERIENCE

The State should urge the U.S. Nuclear Regulatory Commission to embark on a decommissioning research program designed to accumulate actual decommissioning experience on the dismantlement of reactors of a size and design more similar to those being constructed today.

REFERENCES

Chapter 21: Definition, Regulation, Procedures, and Experience

1. Code of Federal Regulations, Vol. 10, Sec. 50.82 (cited as 10 CFR 50.82).

2. Nuclear Regulatory Commission, Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors" (June 1974). Reprinted in Appendix B of this report.

3. Dixie Lee Ray, Governor of Washington, v. Atlantic Richfield Co. and Seatrain Lines, Inc. (1978) _____U.S.________; 46 U.S. Law Week, March 7, 1978, at 4205; and Goldstein v. California, 412 U.S. 546, 554-555 (1973)

4. California Administration Code, Title 17, Sec. 30298.

5. Regulatory Guide 1.86, Sec. C.4. (See Appendix B of this report.)

6. R. Jon Stouky and E. J. Ricer, San Onofre Nuclear Generating Station Decommissioning Alternatives, Report 1851, for Southern California Edison (NUS Corporation, February 1977).

7. William J. Manion and Thomas S. LaGuardia, An Engineering Evaluation of Nuclear Power Reactor Decommissioning Alternatives, AIF/NESP-009SR (Atomic Industrial Forum, National Environmental Studies Project, November 1976).

8. Steven Harwood et al., Activation Products in a Nuclear Reactor (Buffalo: New York Public Interest Research Group); and John H. Stephens, Jr., and Robert O.Pohl, "Trace Elements in Reactor Steels: Implications for Decommissioning," submitted to the Journal of Nuclear Engineering and Design, 1977.

9. Federal Register 43:49 (March 13, 1978).

10. R. M. Harmon et al., "Decommissioning Nuclear Facilities," in Proceedings of the International Symposium on the Management of Wastes from the LWR Fuel Cycle, CONF-76-0701, sponsored by the Energy and Research Development Administration, Denver, Colo., July 1976.

11. Harmon, "Decommissioning Nuclear Facilities"; William R. Greenaway and Richard A. Martineit, Report on Decontamination Technology for Nuclear Power Plant, NUS-TM-284 (NUS Corporation).

12. Stouky and Ricer, San Onofre Decommissioning Procedures; and Manion and LaGuardia, Engineering Evaluation of Decommissioning Alternatives.

13. Manion and LaGuardia, Engineering Evaluation of Decommissioning, Alternating, p. 7.

CHAPTER 22: COSTS AND FINANCING

DRAFT

ESTIMATES OF DECOMMISSIONING COSTS

Reactors

Despite the paucity of actual decommissioning experience and the lack of detailed, specified decommissioning procedures, estimates of the costs of reactor decommissioning have been ventured, as seen in Figures V-3 and 4. These figures present some interesting conclusions:

- Utility estimates for today's larger reactors (700-900 MWe) tend to center around $100 million (in today's dollars) for total dismantling.
- Estimates by federal authorities or contractors associated with federal agencies tend to be much lower than utility estimates.
- The widely-quoted Atomic Industrial Forum (AIF) study produced the lowest estimates ($27-31 million) of all those collected.

Implications. The Task Force has been able to gather relatively little information on the detailed analyses underlying most of the cost estimates presented. Credibility varies: some of these estimates are probably based on little more than simple extrapolation from or repetition of the estimates provided by others, while other estimates (for example, those for San Onofre 1 and those in the AIF report) appear to have been the result of substantial analytical effort.

FIGURE V-3
UTILITY COST ESTIMATES FOR DECOMMISSIONING

Plant Operator Location	Reactor Size (MWe)	Reactor Type	First Operation	Dollar Cost (Millions)	% of Original Cost
Beaver Valley I Duquesne Light Shippingport, Pa.	852	PWR	1976	\$ 50[a]	10%[a]
Three Mile Island I Met. Ed., JCP&L, Penn. El. Goldsboro, Pa.	792	PWR	1974	\$ 95.8('77)[b]	
Three Mile Island II Met. Ed., Penn. El. Goldsboro, Pa.	880	PWR	1978	\$ 94.5('77)[b]	
Turkey Point III Florida P&L Florida City, Fla.	666	PWR	1972	\$100[c]	19%[d]
Millstone I Northeast Utilities Waterford, Conn.	652	BWR	1970	\$ 59.5[e]	
Millstone II Northeast Utilities Waterford, Conn.	828	PWR	1975	\$ 59[e]	
Connecticut Yankee Northeast Utilities Haddon Neck, Conn.				\$ 48.7[e]	
Farley I Alabama Power Dothan, Ala.	860	PWR	1977	\$100[c]	
Brunswick I Carolina P&L Southport, N.C.	821	BWR	1977	\$128.5[c]	
Arkansas Nuclear I Arkansas P&L Russellville, Ark.	836	PWR	1974	\$100[c]	
St. Lucie I Florida P&L Hutchinson Is., Fla.	803	PWR	1976	\$100[c]	
Hatch I Georgia Power Baxley, Ga.	786	BWR	1975	\$100[c]	

FIGURE V-3
(Continued)

Plant Operator Location	Reactor Size (MWe)	Reactor Type	First Operation	Dollar Cost (Millions)	% of Original Cost
Calvert Cliffs I Baltimore G&E Lusby, Md.	850	PWR	1975	$100[c]	
North Anna I Virginia Elec. & Power Mineral, Va.	934	PWR	1978	$ 75[f]	
San Onofre 1 SCE, SDG&E San Clemente, Ca.	436	PWR	1968	$ 63-78 ('77)[g]	
Diablo Canyon 1 PG&E Diablo Canyon, Ca.	1060	PWR	1978	$ 35 (no contamination considered)[h]	

SOURCES

a. Duquesne Light's Statement 11-1 before the Pennsylvania Public Utility Commission, RID 373, pp. 24-25, gives the utility's share (47.5 percent) of Beaver Valley I decommissioning at $24,275,675.

b. Updated cost estimate, May 20, 1977, by W. A. Verrochi in Pennsylvania Electric's Statement No. 4, Exhibit 4-D-1, before the Pennsylvania PUC, RID 392.

c. Testimony of G.R. Faust, Gilbert Associates, Inc., before the Connecticut Public Utility Commission on the matter of providing for the costs of decommissioning Millstone I and II.

d. Letter from William B. DeMilly, Florida Public Service Commission, to Ben H. Fuqua, Vice President, Florida Power & Light, April 3, 1974.

e. Nucleonics Week, January 6, 1977, pp. 5-6.

f. Final Environmental Impact Statement, April 1973, Nuclear Regulatory Commission, Docket 50-338, p. 8-8.

g. R. Jon Stouky and E. J. Ricer, San Onofre Nuclear Generating Station Decommissioning Alternatives, Report 1851, for Southern California Edison (NUS Corp., February 1977).

h. Testimony of Peter N. Skinner, New York State Law Department, to the New York State Public Service Commission, Case No. 26974, December 2, 1977, p. 21.

FIGURE V-4
GOVERNMENT AND INDUSTRY COST ESTIMATES FOR DECOMMISSIONING

Reactor Size (MWe)	Reactor Type	Dollar Cost (Millions)	% of Original Cost
1100	PWR	$27('75)[a]	
1100	BWR	$31('75)[a]	
*	*	$25-50[b]	
*	*	$36-60[c]	
1000	*	$35-50('76)[d]	
1150	*	*	24%[e]

*Not specified.

SOURCES

a. William J. Manion and Thomas S. LaGuardia, An Engineering Evaluation of Nuclear Power Reactor Decommissioning Alternatives, AIF/NESP-009SR (Atomic Industrial Forum, National Environmental Studies Project, November 1976).

b. Nucleonics Week, January 26, 1978, p. 15.

c. General Accounting Office, RED-76-7.

d. K. M. Harmon et al., "Decommissioning Nuclear Facilities," in Proceedings of the International Symposium on the Management of Wastes from the LWR Fuel Cycle, CONF 76-0701, sponsored by the Energy Research and Development Administration, Denver, Colo., July 1976.

e. See Figure V-3, reference (h).

Further efforts will be required to determine more fully the assumptions behind the estimates and possible deficiencies.

As noted, the utility estimates indicated that decommissioning a new 1,000 MWe reactor would cost more than $100 million. This is three times the AIF estimate (see Figure V-4) and higher than those of the governmental entities or their contractors. Future study on the financing of decommissioning might attempt to verify these cost estimates and determine the reasons for the non-uniformity.

Applicability to California Reactors. The detailed NUS study of San Onofre 1 provides what appears to be a very complete and accurate estimate for that facility. Rancho Seco, judging by its size (913 MWe) and type (pressurized water reactor, or PWR) might be decommissioned for somewhat more than $100 million, based on estimates for smaller PWRs elsewhere. Humboldt Bay is a small (63 MWe) boiling water reactor (BWR) of an early design: the pressure vessel is smaller and thinner than recent larger BWRs and its containment structure was not built to the same standards as required of today's reactors.[1] It is difficult to extrapolate from the collected estimates a cost for Humboldt, but a range of $10 to $20 million or higher might be reasonable. The estimated cost of dismantling Diablo Canyon 1 and 2 is $35 million each in 1972 dollars (Figure V-3). This number apparently reflects only the dismantling of a non-contaminated facility and may not include the costs associated with decontamination and the handling of radioactive materials. Based on the estimates for other plants, decommissioning Diablo Canyon 1 and 2 and San Onofre 2 and 3, which are all of the 1,000 plus MWe class, would cost substantially more than $100 million apiece in today's dollars.

Other Facilities

The General Accounting Office (GAO) reports the cost to decommission and decontaminate a federally owned accelerator at $485,000.[2] California's experience with several contaminated industrial facilities suggests costs of from $10,000 to $1 million per facility. Costs for medical facilities are generally expected to be substantially less because of the smaller quantities of radioisotopes involved and the generally short half-lives of radioactive materials used in medicine. However, there have been exceptions: trackage from a leaking radium brachytherapy source resulted in the expenditure of $1 million to decontaminate a hospital.

The Conference of Radiation Control Program Directors in their report on bonding of licensed nuclear activities suggested the following list of bond amounts to cover the decontamination and perpetual care costs for various State-licensed facilities.[3]

o Major processors (processors, handlers or manufacturers of large amounts of radioactive materials)	$100,000 to $5 million
o Radioactive waste handling licensees (collectors and processors of radioactive waste for disposal and operators of burial facilities)	$ 50,000 to $500,000
o Ore refineries or mills (processors of radioactive material ore)	$500,000 to $5 million
o Former NRC-licensed facilities (inoperative State-licensed reactors, fuel reprocessing plants, enrichment plants and critical mass experimental facilities)	$50,000 to $500,000 (covers only annual maintenance costs, no decontamination or decommissioning)

o Other specific licenses (users of small amounts of radioactive material may be exempted) $1,000 to $500,000

There are at least three reasons why reliable estimates for the costs of restoring State-licensed facilities are difficult to come by:

- The variety of State-licensed facilities, the range of radioisotopes they use, the amount of radioisotopes they handle, and the range of activities they are engaged in make it very difficult to produce accurate estimates of the site restoration costs without the availability of information on the specifics at each site.

- There is inadequate decontamination and decommissioning experience for all types and classes of licenses to help guide the estimation of costs.

- Facilities that have carried out decontamination work are often reluctant to disclose accurately the costs involved. Where costs are paid for by the operator, the costs may be understated to minimize the financial repercussions to the company operating the facility or to restrict the flow of this information to competitors. Where costs are paid by agencies other than the licensee, e.g., federal authorities, costs might be maximized for obvious financial reasons.

Problem Area: Uncertainty in Cost Estimates.

A large degree of uncertainty exists in today's estimates of the costs of

decontaminating and decommissioning reactors and State-licensed facilities and this uncertainty grows as costs are estimated for dates in the future.

Cost estimates are uncertain because of the uncertainties in the exact procedures involved, the relevant regulatory requirements, the future costs of labor and materials, and the lack of relevant experience.

The NRC is attempting to develop procedures for decommissioning NRC-licensed uranium fuel cycle facilities.* The development of detailed and specific procedures and relevant health standards (e.g., bulk material standards) plus the accumulation of additional experience will all help to decrease the present cost uncertainties.

FINANCING THE DECOMMISSIONING OF REACTORS

Reasons for Special Financing of Decommissioning

Of California's three licensed commercial power reactors, operators of Humboldt Bay and San Onofre 1 are now providing for the costs of decommissioning through a procedure known as straight line remaining life (SLRL) depreciation[4] (see below for explanation) but the operator of Rancho Seco, the Sacramento Municipal Utility District (SMUD), is setting aside no decommissioning monies.[5]

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* See footnote in Chapter 21.

Three factors argue that special efforts to provide for the eventual costs of decommissioning are warranted and necessary: the large costs of decommissioning, the necessity for equitable treatment of ratepayers, and the possibility of utility insolvency in the distant future.

Large Costs. The costs of decommissioning one of today's commercial reactors are a substantial expense for a utility to incur. Even at today's prices, costs could run to more than $100 million and complete dismantlement could take six to seven years to complete.[6] Any financing mechanism should provide for inflation, which, given a reasonable estimate of 4 to 8 percent per year, might increase the costs to from $300 million to $1 billion during the life of today's new reactors.*

Equitable Treatment of Ratepayers. Because the costs of decommissioning are large and because these costs are the direct and predictable result of operating a reactor to produce electricity, consideration should be given as to who should pay for the expense of decommissioning. If no mechanism is implemented to provide for the costs of decommissioning before the money is needed, the ratepayers of a utility at the time of decommissioning might be burdened with the costs of decommissioning a shutdown reactor from which they have derived little benefit (i.e., electricity). Since present knowledge and experience can enable us to anticipate and to provide estimate of the costs of

*Inflation rates of 4 to 8 percent, when compounded annually for 30 years, would produce cost increases of 224 percent and 906 percent, respectively. A decommissioning that costs $100 million today would, using these inflation rates, cost between $324 million and $1.009 billion 30 years from now.

decommissioning, it would not be unfair to expect the consumers of nuclear power to pay the costs of decommissioning the plant. This can best be accomplished by collecting funds for this purpose during the operating life of the reactor by means of some financing mechanism.

Utility Solvency in the Distant Future. While the cost of decommissioning a reactor today might be a substantial expense, few commercial reactors may actually require decommissioning in the near future. Decommissioning of today's reactors may not take place until 30 to 130 years from now. Therefore, the future ability of utilities to pay the future costs of decommissioning may be the more important issue. As a result, consideration should be given to the possibility that a utility, while perhaps capable of handling the expense, today, may be unable because of unforeseen future financial and/or economic events to meet the costs of decommissioning (inflated over time) at that point in the future when decommissioning is most likely to be necessary. If in the future a utility with a decommissioning obligation is no longer present as a corporate or public entity, or is insolvent or otherwise unable to provide the necessary monies, the liability will probably fall to the State or the federal government. It may be wise to protect against such a situation by the implementation, now and over the entire operating life of the facility, of a mechanism to ensure that the necessary monies will be available in the future.

In conclusion, it seems reasonable that one requirement for any acceptable financing mechanism is that, in a fair and equitable manner, it collects from the consumers of the power the cost of decommissioning the power source before the need occurs, in a manner which reflects the true cost of providing the power.

Availability of Funds at Time of Decommissioning. Having established that some financing mechanism is required, the preceding argument regarding the future solvency of utilities also has implications for the type of mechanism chosen. In the event that provision was not made to cover the costs of decommissioning, a utility on shaky financial ground might have a hard time extracting the necessary monies from its operating revenues at the time when the work is to be performed. Even if the regulatory agency at that future time were to permit the utility to obtain the necessary monies from the ratepayers, the large amounts of money involved might further weaken the financial position of such a utility.

While it is possible that all utilities will still exist and be solvent at the time of decommissioning, this cannot be assured. Recent years have seen the financial position of many utilities slip substantially, from New York's giant Consolidated Edison to smaller utilities such as Public Service of New Hampshire and California's own San Diego Gas & Electric.* Given the period of time that will pass before today's new reactors may require decommissioning, it may be unwise to assume that all reactor operators will be able to remain financially secure. Additional unforeseen events might also weaken an individual utility. If a smaller utility with a large investment in one or two reactors was to experience an accident, earthquake, or other catastrophic

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* In 1974 Con Ed issued no dividends on its common stock and sold nuclear facilities to another power company to maintain stability. The ability of SDG&E to support a major share of the Sundesert Nuclear Project was officially challenged by the California Public Utilities Commission in May 1978 in its refusal to allow the utility to increase its rates to pay for Sundesert; SDG&E subsequently killed the project. For details on the case of Public Service of New Hampshire, see Nucleonics Week, December 8, 1977.

event that damaged its reactor, the utility might, in short order, find itself the possessor of an inoperative, non-revenue-producing reactor in need of immediate decommissioning.

In light of the possibility of future utility insolvency, it can be argued that in the selection of financing mechanisms for decommissioning, the anticipated future solvency of the reactor operator should be carefully examined. A future situation in which a utility might be unable to pay for decommissioning costs directly out of future revenue (see "Expensed" funding mechanism in Figure V-5) might be the same situation in which it would be unable to shift future revenue to pay for decommissioning funds that are in a depreciation account on the company's books (see SLRL Depreciation Account mechanism in Figure V-5). It could be argued that if uncertain future events justify the imposition of any financing mechanism, then they justify the imposition of one that does not depend on utility operating revenues at the time of decommissioning as the source of actual decommissioning monies.

An additional wrinkle is added to the problem of providing decommissioning funds if one considers the time interval between reactor shutdown and the actual dismantlement of the reactor. Assume that some mechanism has accumulated decommissioning monies from the consumers of the reactor's power. After the reactor is retired and shut down, no more money should be extracted from the ratepayers, in keeping with the previous arguments regarding their equitable treatment. Yet even if reactor decommissioning proceeded at a maximum pace, it might be 10 years after shutdown before the work would be completed. The AIF study suggested a delay of 100 years after shutdown before dismantlement is attempted, to permit a decrease of radiation levels. Whatever

funds have been accumulated must, therefore, be capable of covering the costs of decommissioning not at the time of shutdown but at times up to 10 years or perhaps more than 100 years after shutdown. If after reactor shutdown the decommissioning costs continue to inflate (in line with general prevailing inflationary trends), either more monies will have to be extracted from non-benefited ratepayers or else the accumulated monies must be able to grow by some other means in order to keep [illegible] with inflation. This other means might be the investment of these funds in income-producing securities or some similar mechanism.

In conclusion, there are reasons why one might want to select a financing mechanism of the kind that sets aside liquid assets rather than one that sets aside funds only on the company books, which must be supplied by future revenues. However, the costs of the various alternative financing methods may also impact the decision as to which method is selected.

Premature Shutdown. Even though a financing mechanism may be capable of accumulating the necessary monies for decommissioning by the end of a reactor's estimated life, the mechanism may still be inadequate. It is the nature of most proposed financing mechanisms that they accumulate funds in a exponential fashion over time (see Figure V-7). As a result, the accumulated reserve funds approach the costs of decommissioning only at the end of the estimated reactor life, and are appreciably below the required amount until the final expected years of operation. Thus, if the estimate of the length of reactor lifetime is in error and shutdown comes prematurely, the accumulated assets may fall substantially short of the amount required to completely decommission at that time.

The life expectancy of a reactor may be shortened for a number of reasons. In California, the Humboldt Bay reactor is being considered for permanent shutdown because of the recent discovery of suspected earthquake faults near the site.[7] This reactor is only 14 years into its expected 30-year life. The Dresden I reactor in Illinois, while only 17 years old, has high levels of in-plant radiation that have curtailed the operator's ability to perform routine maintenance; unless costly decontamination is successful it too may have to be prematurely retired.* An accident such as the partial core meltdown at the Fermi I plant in Michigan might force premature shutdown. Even accidents that do not greatly threaten public safety may be so costly to repair that shutdown may be economically preferable.

The assumption that all reactors will meet the anticipated operating life of 30 to 40 years may not be made with certainty insofar as there has been insufficient long-term experience in this area. No commercial reactor has operated this long: In fact, the whole industry is hardly 30 years old. Given our brief experience, the question of the accuracy of estimates of reactor lifetime(s) is a legitimate one.

Since there appears to be doubt about the absolute reliability of reactor lifetime estimates, the question arises as to how financing mechanism might protect ratepayers or the public in general from the need to make up the

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* California's Rancho Seco, while having been in operation only a few years, has also reported in-plant radiation levels higher than anticipated.

deficit in accumulated decommissioning funds in a case of premature shutdown. Whatever financing procedure is adopted should be capable of providing sufficient monies to decommission even if the reactor is forced to shut down prematurely.

Uncertain Estimates. Assuming for the moment that an estimate has been made of the cost of decommissioning a particular reactor at some expected future date and that a mechanism has been devised to collect the required monies by the predicted time of shutdown and at all times in between in case of premature shutdown, what other requirements might be warranted? A financing mechanism should be capable of accommodating errors not only in the estimated reactor lifespan but also in the original estimate of decommissioning costs.

The initial estimate of decommissioning costs may be predicated on certain assumptions regarding the inflation rate between now and shutdown, the relevant government regulations that will be in force at shutdown, and the procedures that will be followed and the technology that will be employed to accomplish this decommissioning. All of these factors (and others) can and will quite likely change between now and the time of decommissioning.

Such uncertainties have led some to argue that the uncertainties of decommissioning are so great that we should do nothing at the present.[8] It has been further argued that the costs might eventually prove to be much lower than expected, and we might, therefore, needlessly collect more funds than necessary. Unfortunately, recent examples in the nuclear field as well as other new high-technology fields have shown that unknowns and uncertainties are often resolved at the expense of more regulation and higher costs. It

would be imprudent to do nothing regarding decommissioning until all uncertainties are resolved, for these will, ultimately, only be resolved after a larger body of decommissioning experience has been accumulated (see Chapter 21). There are, however, modifications that can be made to financing mechanisms that can attempt to cope with whatever cost uncertainty exists.

The resolution of this apparent dilemma is fairly simple: annual reassessments of the future estimated costs, the future inflation rate, and/or the rate of return on invested monies and the remaining reactor life could all be factored into the financing mechanism to provide a readjustment of the amount of funds that would need to be accumulated that year. Such an "adjustable" financing mechanism would have the feature of "homing in" on the eventual decommissioning costs and, therefore, any mechanism adopted should have the ability to be periodically readjusted for changes in the estimated costs of decommissioning.

Summary of Criteria for Selecting Financing Mechanisms. In summary, factors that should be considered in selecting a financing method should include:

- Collection of all funds from the consumers of the reactor's electricity;

- Maintenance of the funds in cash, negotiable securities, or other liquid assets to protect against future utility insolvency;

- Provisions to ensure that the total decommissioning costs will be available at any time in case of premature shutdown; and

o Ability to readjust the rate of accumulation to account for uncertainties in original cost estimates.

Mechanisms for Financing Decommissioning

The discussion above focused on four criteria by which potential financing mechanisms may be evaluated and compared. A large number of potential schemes for accumulating decommissioning costs can be constructed from the possible combinations of financing features which attempt to deal with the four criteria. It would be extremely laborious to discuss and evaluate all possible combinations but a sample of representative and distinctive financing possibilities will be considered in this section. As displayed in Figure V-5, there are several mechanisms, and these are discussed below in the following groups: (1) expensed, (2) funded, including lump sum funded account and sinking fund account, (3) depreciation account (straight line remaining life method), and (4) bonding including premature-shutdown insurance and surety bonds. Figure V-6 demonstrates that a variety of mechanisms can be constructed that are of either the funded or depreciation account type.

(1) Expensing: Future Power Users Pay Decommissioning Costs. As argued above, whatever mechanism is adopted, it must be structured to obtain decommissioning funds to the greatest degree possible from the ratepayers during the operating life of the reactor. While it is theoretically possible that decommissioning costs could be expensed and paid at the time they are incurred (see Figure V-5), such an approach would be inequitable given the substantial costs that would be borne by non-benefiting future ratepayers. Additionally, such a mechanism might increase the possibility of the state or other govern-

mental body becoming financially responsible. The financing option of simply expensing and paying for decommissioning at the time of dismantling is, therefore, rejected as an inequitable alternative.

(2) Funded Mechanisms: Real Assets Accumulate to Pay for Decommissioning.
Funded schemes are, for the purposes of this report, briefly defined to be those financing methods in which cash or negotiable assets readily convertible into cash such as stocks and bonds, are accumulated by the utility to pay the costs of decommissioning (see Figure V-5). Such monies, collected from the ratepayers, are not available to the utility for their general operating needs and may be spent only for decommissioning.

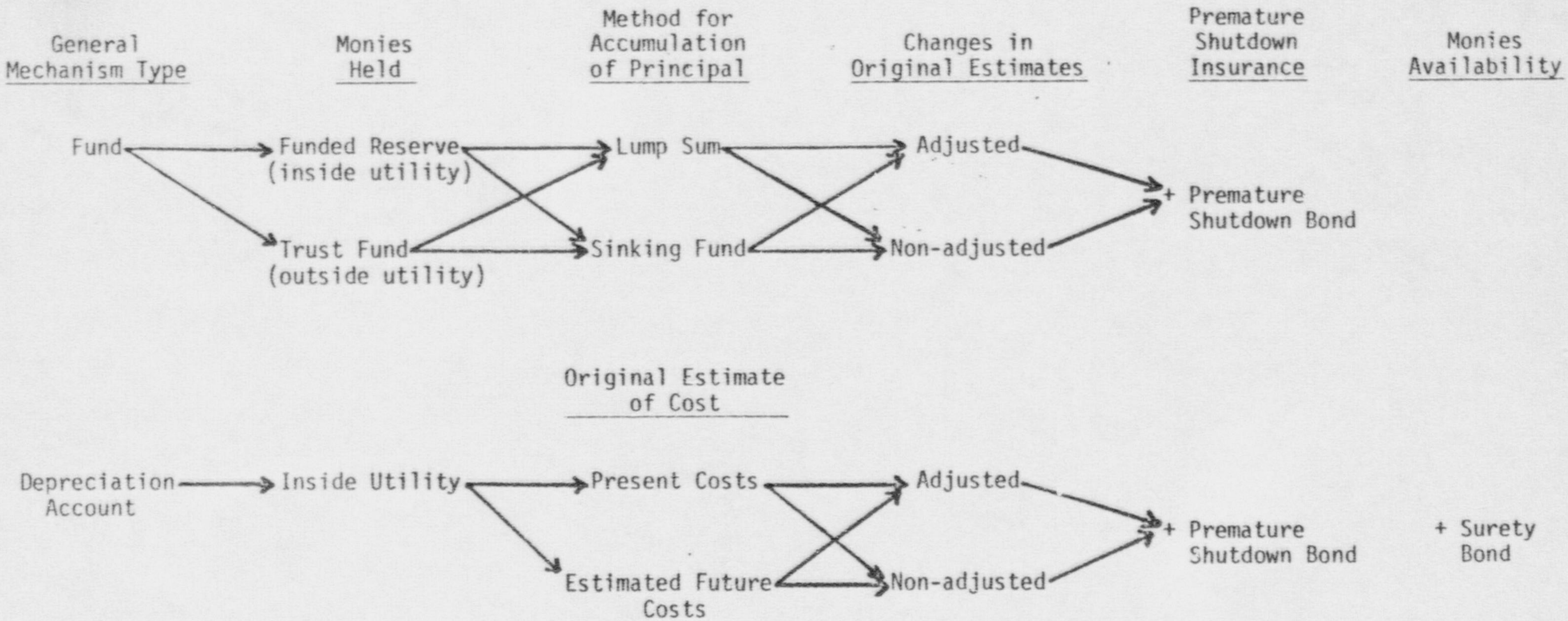
The money accumulated by a funded-type mechanism could either (a) be held under the direct control of the utility, but as a separate account or fund, or (b) the monies could be turned over to a third party, such as a bank, to be held essentially as a trust fund. Such collected monies would not be allowed to sit idly but would be invested or otherwise put to work to earn interest or other income. This would enable the accumulated monies to keep pace with the inflating costs of decommissioning. If the rate of return earned by this invested money was greater than the inflation rate, the income from investment would also help the total worth of the fund increase and thereby decrease the amount of funds that future-year ratepayers would have to add. While there is some risk that some of the investments could lose value, the investments could be made in high-grade securities and spread over a diverse group of issues to minimize the potential for any loss.

The funds established either inside or outside the utility could be structured so that the rate at which monies are collected from ratepayers over the

Figure V-5
MECHANISMS FOR FINANCING DECOMMISSIONING

Financing Mechanism	Who Pays	Handles Changing Cost Estimates	Accumulated Funds at Premature Shutdown	Funds Availability at Shutdown
. Expensed - Costs expensed when they are incurred. Pennsylvania PUC method.	Ratepayers at time of retirement.	No	None	None
a. Lump Sum Funded Account - Lump sum of cash deposited at reactor start in investment account. Principal plus accumulated interest will cover estimated cost.	Ratepayers at beginning of service.	Not without additions to principal.	Some, but full amount not accum. until anticipated shutdown.	Funds exist as liquid assets.
b. Sinking Fund Account - Equal installments of cash are deposited each year of plant operation. Principal plus accumulated interest will cover estimated cost. (Duquesne Light - Beaver Valley I proposal)	Ratepayers at time of service.	Can be periodically readjusted.	Some, but full amount not accum. until anticipated shutdown.	Funds exist as liquid assets.
. SLRL Depreciation Account - Estimated costs are depreciated over plant life by straight line remaining life method.	Ratepayers at time of service.	Can be periodically readjusted.	Some, but full amount not accum. until anticipated shutdown.	Funds exist only on books of utility, depend on income at time of shutdown.
a. Premature Shutdown Insurance - Bond is purchased to cover the decreasing difference between the funds accumulated by some other mechanism and the estimated cost at that point in time.	Stockholders or ratepayers at time of service.	Can be periodically readjusted.	Guarantees through third party insurer that full funds available at any time.	Insurance value decreases to zero at anticipated shutdown.
b. Surety Bond - Bond is purchased to guarantee that monies equivalent to those collected by a depreciation mechanism will be available at the time of decommissioning.	Stockholders or ratepayers at time of service.	Indirectly, through adjustments of depreciation mechanism.	Guarantees only that monies accum. by depreciation will be available, though these may be insufficient.	Guarantees that funds accumulated by another mechanism will be available as liquid assets when needed.

Figure V-6
SOME POSSIBLE FINANCING SCHEMES



reactor's life could vary considerably. At one extreme would be the lump sum method (see Figure V-5). Estimates are first made of the present costs of decommissioning, the inflation rate between now and the time of decommissioning, and the expected rate of return on invested income over the same period. The estimated future costs are then calculated, as well as the present amount of money that, when invested earning the estimated rate of return, will grow to equal the predicted cost at the expected time of decommissioning. This calculated amount of principal is then provided at the start of reactor operation and, if all estimates are correct, no future money need be extracted from the ratepayers.

In order to spread the contribution of funds over the entire reactor lifetime, a mechanism known as a sinking fund could be established (see Figure V-6). Given the same information and predictions of inflation and investment return, calculations can be performed that will determine the amounts of money that ratepayers might pay on a yearly basis over the reactor life than when totaled, along with interest earned, would equal the anticipated final decommissioning costs. Sinking funds, as commonly calculated, require that the yearly additions to the principal of the fund by ratepayers will be equal over the expected reactor life. If inflation continues during the life of a reactor, it might be argued that the ratepayers in later years of reactor life will be making their contributions to the sinking fund in dollars that are inflated and, therefore, worth less than those contributed by ratepayers in the early years. It should be possible to calculate a sinking fund, however, that incorporates some inflation rate for the value of money. In this manner later-year ratepayers might make a larger dollar contribution to the fund but one whose constant dollar worth is close to that of earlier contributors.

Since either the lump sum or the sinking funds can be originally calculated for certain estimates of decommissioning cost inflation, investment return and reactor life, it might be possible to set these mechanisms in motion and leave them unchanged until the date of anticipate shutdown is reached. If, however, the estimates of the parameters of inflation, return, and lifetime are off, even by small amounts, the amount of funds accumulated and the time course of this accumulation may be substantially different from the eventual time and funds required. For this reason either of these funded mechanisms could be implemented in an "adjusted" manner to accommodate these uncertainties.

An adjusted fund, either lump sum or sinking, would be one in which periodic (yearly, for example) reassessments are made of present estimates of future inflation rates, rates of return, and remaining reactor life. Using the amount of funds accumulated at that point in time plus the above new estimates, the funds could be recalculated and new figures for the amount and schedule of additions to principal could be produced. As a result, an addition or reduction might be necessary in the principal contained in the lump sum fund or in the yearly installments of a sinking fund. For either mechanism, periodic readjustments should guarantee that the funds accumulated will approximate the eventual amount required, barring some sudden and unexpected premature shutdown.

That even an adjusted fund might be unable to accumulate sufficient monies in the event of premature shutdown may not be immediately obvious. Figure V-7 graphically displays the rate at which funds would accumulate under a variety of mechanisms for one set of assumptions. The assumptions made are:

Figure V-7

A COMPARISON OF THE RATE AT WHICH SEVERAL FINANCING MECHANISMS ACCUMULATE DECOMMISSIONING MONIES

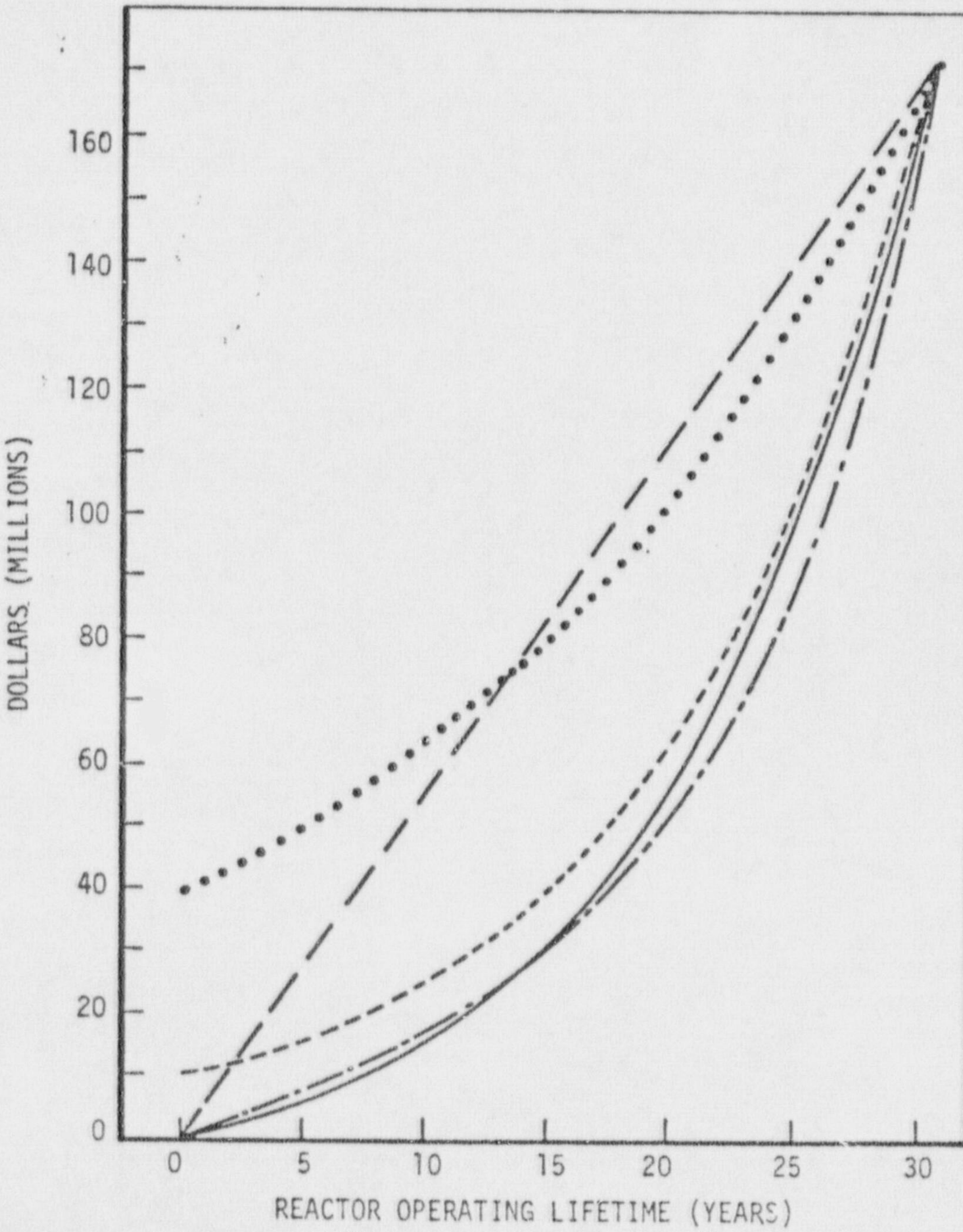
•••• Decommissioning Costs (5% Annual Inflation)

— — Non-adjusted SLRL Depreciation

- - - Lump Sum Fund (10% Annual Return on Investment)

—— Sinking Fund (10% Annual Return on Investment)

-·- Adjusted SLRL Depreciation



Based on the model presented in "Accounting Today for Future Nuclear Plant Decommissioning Cost" by Benjamin J. Ewers, Jr., presented at A.G.A. - E.E.I. Accounting Conference, Dearborn, Michigan, May 1977.

- If the reactor in question were decommissioned immediately after construction, the cost would be $40 million at that time;

- The expected reactor lifetime is 30 years;

- The costs of decommissioning will inflate at 5 percent per year;

- Money invested will return 10 percent per year tax free; and

- Present tax laws applicable to utilities remain for the next 30 years.

Looking first at the line for decommissioning costs, one can see that the cost grows exponentially to a value of $172.8 million after 30 years, more than a four-fold increase. The lump sum fund under these assumptions would require $9.9 million in Year 0 to accumulate $172.8 million in principal and earnings in 30 years, while a sinking fund with equal yearly payments by the ratepayers would require the addition of $1.05 million per year to do the same.

For either fund, only within the last few years of reactor life do the accumulated monies come close to equaling the cost of decommissioning. If the reactor shuts down 15, 10, or even 5 years prematurely, the monies accumulated would be substantially deficient and non-benefiting ratepayers, utility shareholders, or the public would have to provide the difference. It is for this reason that consideration should be given to the addition of a bond to any fund; section (4) below discusses bonding.

<u>(3) Depreciation Account: Decommissioning Funds Exist Only on Utility's Books</u>. An alternative to setting aside funds or gradually accumulating funds

for decommissioning is the depreciation account mechanism. Briefly, a utility, upon collection of monies for decommissioning from ratepayers but finding that the monies are not needed for 30 or more years, might decide to use these funds for the general operation of the company or the purchase of new equipment. While the actual money collected would be spent for non-decommissioning purposes, the utility would keep track on its books of the dollar amount of the accumulated depreciation. The transformation of this "accumulated depreciation" into cash to pay the costs of decommissioning would not occur until the actual work was performed and would be accomplished by using utility income at that future time.

To explain more fully, depreciation is a procedure for recovering the original costs of the investment in a piece of equipment or building by means of an equitable series of charges spread over the useful life of the property. These charges do not result in an actual outflow of cash but rather are considered as expenses for purposes of calculating tax liabilities or financial statements. Under this procedure an estimate is made of the usable lifetime of the item and manner in which its value decreases with time. One commonly employed form of depreciation assumes that the value of an object decreases linearly over the estimated remaining useful life of the item. This method of calculating depreciation is termed straight line remaining life (SLRL).

In the case of a reactor, the operating utility estimates that over the anticipated life (usually 30 years), the value of the plant will decline to a worth less than zero. This results from the fact that when a reactor is no longer useful, it cannot simply be abandoned at no cost to the utility but

must be decommissioned, requiring an additional expenditure of funds. As a result, its worth decreases not just to zero but actually crosses zero to become a negative amount symbolizing these decommissioning costs.

Using SLRL depreciation, a utility would claim that for a reactor with a 30-year life, one-thirtieth of the original construction cost plus eventual decommissioning costs must be recovered each year from the ratepayers so that not only the original costs can be recovered, but also money for decommissioning will be available at shutdown.

In the case of the fund-type mechanisms previously discussed, the use made in the interim of money collected for eventual decommissioning was specific and restrictive. The incoming money would be kept separate from other utility income and invested to earn a rate of return in a manner which would permit ready conversion back into cash. For depreciation-type methods, the interim use of money collected during the reactor's operating life is not restricted. The money may be treated as ordinary income and used as such to pay any expenses the utility might have or to invest in capital improvements, such as new non-reactor facilities and equipment. The amount of the decommissioning money collected under these depreciation procedures would be denoted on the company books in an account for "accumulated depreciation." Since the actual money collected from ratepayers was spent shortly after collection for non-decommissioning purposes, the payment of decommissioning expenses, when they are finally realized, would have to be made out of utility income at that time. An important component of the depreciation-type mechanism that deserves particular attention, therefore, is the expected ability of a utility to

generate at the time of decommissioning income sufficient not only to meet normal operating needs at that time but also sufficient to meet the costs of decommissioning without burdening those future ratepayers.

Depreciation-type mechanisms keep the accumulated decommissioning monies inside the utility--as opposed to the funded mechanisms, which might be set up either within the utility or with outside agencies. Figure V-6 shows that the depreciation approach can be of either the adjusted or nonadjusted variety. In a nonadjusted SLRL format, the estimated costs of decommissioning are simply divided by the years of remaining life and that amount is added to the depreciation account each year. Adjusted mechanisms, as with the funded approach, periodically reevaluate the magnitude of estimated costs and the expected remaining life. A new number may thereby be derived for the yearly amount depreciated for purposes of decommissioning. Nonadjusted deprecia' methods suffer the same fault as nonadjusted funds: if the original gue s prove to be inaccurate, the funds eventually accumulated may differ substantially from the required amount.

Either adjusted or nonadjusted depreciation methods might in theory be established that use, as their basis for calculating the initial rate of asset accumulation, either the estimates of decommissioning costs at the present time or an estimate of costs at the future time of decommissioning. For a nonadjusted depreciation method, use of the estimated future costs is essential if the utility hopes to be even close to the eventual costs incurred. This results from the enormous increase in costs over 30 or more years for even low rates of annual inflation (see Figure V-7). While an adjusted depreciation mechanism should, at least on paper, accumulate the

proper amount of money by the time of expected reactor retirement, if the present cost is used as the basis for calculating depreciation at the start, the rate of accumulation will be slow until the last few years of reactor life. In this case the difference between accumulated money and decommissioning costs in the event of premature shutdown will be greater than if some estimate of inflated future costs were originally used as the basis for depreciation at the outset.

Just as with funded methods of providing for decommissioning, the depreciation methods are generally inadequate to handle the possibility of premature shutdown, especially if present costs are used as the initial basis for calculating depreciation. As a result, the depreciation approach might also be benefited by the addition of a performance bond or other mechanism to cover the deficit in the event of premature shutdown.

(4) Bonding: Insurance of Sufficiency of Funds to Pay for Decommissioning. The preceding discussion has focused on financing mechanisms in which all monies for decommissioning would be accumulated by the reactor operator. There is another approach to ensuring that in certain unusual circumstances, monies will not have to be extracted from the public or non-benefiting ratepayers and that is the use of a bond. While there might be many uses of bonding as components of a complete financing mechanism for reactor decommissioning, this report will focus on two.

Premature-Shutdown Insurance. As discussed previously, if the financing of decommissioning relied solely on the use of the funded or depreciation mechanisms, it is likely that in the event the reactor is forced to shut down

before the anticipated end of its normal life, insufficient monies would have been accumulated to cover the costs of premature decommissioning. With funded or depreciation mechanisms, the accumulated monies reach the full amount required only at the originally predicted date of shutdown (see Figure V-7). Given the past and present experience in the commercial reactor industry, it is not unlikely that there may be instances in the future in which a reactor is forced to shut down prematurely. One possible method to ensure that the public or non-benefitting ratepayers will not be asked to make up any deficiency in required funds would be to require that the reactor operator purchase a bond that would provide the money necessary to cover the deficit in this event.

Surety For Availability of Accumulated Decommissioning Monies. As was previously pointed out, depreciation-type financing mechanisms depend upon the income of the utility at the time of decommissioning to provide the monies to cover this expense, and financial or economic difficulties might restrict the availability of such income. A bond might be obtained by the utility that would require the bonding institution to provide monies in an amount up to the amount collected previously by the utility from ratepayers for decommissioning under depreciation in the event that the financial position of the utility at the time of decommissioning will not enable the utility to generate sufficient cash from income to equal the amount it had collected under depreciation. The coupling, therefore, of (a) a requirement to obtain a bond to cover the accumulated monies in the event of non-payment by the utility and (b) some kind of premature-shutdown insurance could provide increased assurance that no part of the ultimate costs will be borne by the public or post-shutdown ratepayers.

It would appear that this use of bonding has been recently adopted by the Connecticut Public Utilities Control Authority in their decision permitting Connecticut Light & Power to use a depreciation mechanism to provide for the eventual costs of mothballing Millstone I and II. Connecticut Light & Power was required to file annually with the Connecticut PUCA a corporate surety bond to ensure that monies collected by depreciation will be used for decommissioning.[9]

The use of bonds in the manner described above may not be that dissimilar to the bonding authority that seven states presently have to require bonding of the operators of state licensed facilities to ensure the eventual decontamination of these facilities.[10] The State of Kentucky is considering the use of bonding to ensure that the operator of a low-level waste burial facility in that state will pay both the costs of decommissioning that facility and of its perpetual care to protect future public health.[11] The NRC presently requires bonding of new licensees who operate uranium mills to similiarly guarantee that decommissioning these facilities will be funded by the licensee.[12]

Costs of Bonding. Further study of the concept of bonding will be required in order to better determine who might be potential suppliers of such decommissioning bonds, what the exact costs of such bonds might be, and the factors that will affect these costs.

Costs of the Financing Mechanisms

All mechanisms under certain circumstances will recover the total expense of decommissioning, but some mechanisms may better reduce the risk that parties

other than the ratepayers consuming the electricity will pay in the event of less than ideal circumstances. Estimating the total costs to the ratepayer and utility of possible funding mechanisms is a complex and arduous task.[13] Since the primary reason for implementing any special procedures for gathering monies for reactor decommissioning is to provide some level of insurance that the total costs will be borne by the appropriate parties, it seems more important at the present level of this review to concentrate on the benefits and disadvantages of different mechanisms rather than on the net costs to ratepayers of implementing different mechanisms. In this light, detailed discussion of the comparative costs of implementing various mechanisms will be deferred for future analysis. It is appropriate at the present time, however, to give some indication as to the number of factors than can influence the eventual implementation costs.

From the previous discussion of various financing mechanisms, it should be clear that two important factors in predicting the total costs of implementing any mechanism are the future inflation rates and the future rate of return of invested income. The estimated total costs of any mechanism involving a fund or a depreciation account are very sensitive to the predicted inflation rate since inflation compounded is an exponential function and one property of exponential functions is that their value at some future point can be drastically altered by small changes in the rate at which they increase (i.e., the inflation rate). As an example, a 4 percent annual inflation rate over 30 years will produce a 224 percent increase in the original cost of an item. Doubling the rate to 8 percent per year does not simply double the 30-year increase to 448 percent but rather to 906 percent.

For funded procedures, such as the sinking fund or the lump sum fund, the expected rate of return from investing the accumulated principal is similarly sensitive since, if accumulated principal and interest are reinvested, the total accumulated funds will grow exponentially. If the original estimate of the amount of total funds that will result from interest or other income earned from investing the ratepayers contribution is even slightly inaccurate, the eventual amount that ratepayers must contribute to the fund, and therefore the total cost to ratepayers, may change dramatically.

In addition to these two factors, tax laws play a large part in determining the total costs to ratepayers. For mechanisms such as the depreciation account, present tax laws do not permit the utility to subtract the yearly funds set aside for decommissioning from that year's income. As a result income taxes must be paid on the money received from ratepayers for decommissioning. Since taxes are in theory almost half of income (48 percent) for utilities, almost $2 must be collected from ratepayers in order to have $1 after taxes to put aside for decommissioning.[14] The situation may be even more complex. The ratepayers may receive a credit based on the interest the utility would have had to have paid to go outside the company to borrow money equivalent to the collected decommissioning monies it was allowed to use. In addition, there may be future tax credits piled on top of this credit.

For a mechanism involving a fund, the total costs are affected by whether or not tax has to be paid on the interest earned from investing the collected principal. If investments are made in tax-free securities or if a special tax break were allowed this interest income, the effective rate of return would altered. The California PUC staff has pointed out in a recent decommissioning

action regarding San Onofre 1 that, under present tax law, when decommissioning is actually performed the utility will have a large tax deductible expense and consequently will have a tax break that will benefit the utility's shareholders or its post-decommissioning ratepayers but not those ratepayers who actually paid the decommissioning costs.[15] Handling this tax break equitably will not be easy. The costs of a bond used to cover premature shutdown might also be difficult to predict since, if original predictions of the frequency of premature shutdown and the costs of decommissioning at those times prove inaccurate, the annual fees for the bonds will have to be adjusted just as would the annual premiums of an insurance policy.

Present California Approach to Financing Decommissioning

PUC Approach. California reactor operators under the jurisdiction of the Public Utilities Commission (PUC) are presently using the straight line remaining life (SLRL) depreciation method. The cost of decommissioning or plant removal is reflected in utility rates as one of the elements in the allowance for depreciation. SLRL is used to recover the original cost of utility plant, including estimated future net salvage,* over the useful life

*When a power plant reaches the end of its useful life and is disposed of, the monies received or spent on the sale, dismantling, or other disposition of the plant constitute its salvage value. If the plant or components of the plant can be sold for more than the expenses of dismantling and removal, the net salvage value is positive. A net negative salvage value results when disposal costs exceed the remaining worth of the plant or its components. This is expected to be the case with commercial nuclear power plants, which because of the expense of decontamination and dismantling are expected to have decidedly negative salvage value.

of the property. Under SLRL an estimate for future net salvage is made, and the future cost of plant removal (decommissioning) is then calculated based on several decommissioning procedures set forth in NRC Regulatory Guide 1.86 (see Chapter 21 or Appendix B). Estimates of future net salvage are periodically updated to reflect any changes in future gross salvage and cost of removal. The SLRL method permits monies collected as an allowance for depreciation in order to meet decommissioning costs to be usefully employed in providing utility service insofar as such monies are not immediately required for decommissioning.

The California PUC has assumed little or no estimated negative salvage until recently for two reasons: first, the lack of regulations for decommissioning nuclear power plants (Regulatory Guide 1.86 was not published until June 1974); second, the lack of definitive studies for estimating the costs of decommissioning.

In the past two years, with the increased availability of cost estimates (as explained in the first section of this chapter), revisions in the estimated cost of removal are now being proposed for the San Onofre plant as shown in Figure V-8. No change is contemplated for Pacific Gas & Electric's Humboldt reactor for two reasons:

- o PG&E's Diablo Canyon 1 and 2 may begin commercial operation soon. These new plants are much more expensive than Humboldt. As a result, if a negative 10 percent salvage value from these two new plants is added to that from Humboldt, the salvage value of Humboldt will

Figure V-8

DEPRECIATION DATA

San Onofre

(80% Southern California Edison, 20% San Diego Gas & Electric Co.)

Ac. No.	Description	1977 Average Service Life (A)	Mortality Curve Type (B)	Estimated Salvage (C)	Depr. Rate (D)
	Nuclear Production				
321	Structures & Improvements	28	IR½	(10)	3.76
322	Reactor Plant Equipment	28	IR½	-	3.65
323	Turbogenerator Units	28	IR½	-	3.56
324	Accessory Electric Equip.	26	IR1	5	3.65
325	Misc. Power Plant Equip.	28	IR½	25	3.62
	Composite	-	-	(0.50)	3.62

San Onofre

(80% SCE; 20% SDG&E)

Ac. No.	Description	1978 Average Service Life (E)	Mortality Curve Type (F)	Estimated Salvage (G)	Est. Depr. Rate (H)
	Nuclear Production				
321	Structures & Improvements	28	IR½	(31.12)	6.30
322	Reactor Plant Equipment	28	IR½	(46.41)	6.37
323	Turbogenerator Units	28	IR½	(31.50)	5.31
324	Accessory Electric Equip.	26	IR1	(4.00)	5.33
325	Misc. Power Plant Equip.	28	IR½	(3.33)	5.40
	Composite	-	-	(28.75)	5.89

Humboldt

(100% Pacific Gas and Electric Company)

Ac. No.	Description	1977 Average Service Life (I)	Mortality Curve Type (J)	Estimated Salvage (K)	Depr. Rate (L)
	Nuclear Production				
321	Structures & Improvements	30	R2	(10)	4.23
322	Reactor Plant Equipment	30	R2	(10)	3.74
323	Turbogenerator Units	30	R2	-	3.26
324	Accessory Electric Equip.	30	R2	-	3.58
325	Misc. Power Plant Equip.	30	R2	10	3.00
	Composite	-	-	(6)	3.60

From "Report on the Results of Operation of Southern California Edison Company: 1978 Estimated: Test Year 1979" Cal. (Inverse Item)

become minor. The depreciation of Diablo Canyon 1 and 2 will adequately cover the unaccumulated costs of decommissioning Humboldt.

- Uncertainty of retirement of Humboldt. If the NRC decides not to renew the operating license for Humboldt and recommends decommissioning, then it is moot whether the negative salvage value for depreciation is increased or not.

The California PUC has stated its position on federally imposed funding mechanisms when it filed comments to the NRC on September 30, 1977, regarding Docket No. PRM 50-22.

SMUD Approach. The Sacramento Municipal Utility District (SMUD), which operates under the provisions of the Municipal Utility District Act, is governed by a five-member board of directors serving four-year staggered terms and is not responsible to the California PUC. For recovering the estimated cost of removal of Rancho Seco, SMUD utilizes straight line total life depreciation. At the present time SMUD utilizes 30-year service life and zero salvage for nuclear production plants, based upon current information. Therefore, SMUD is setting aside no monies to cover the costs of decommissioning.[16]

Present Approach to Financing Decommissioning Outside California

The treatment of decommissioning investor-owned nuclear power plants in other states is left to the review of individual regulatory commissions.

Pennsylvania allows no negative salvage; any cost of removal upon the retirement of plant is expensed at the time of retirement.[17] The Federal Energy Regulatory Commission (formerly the Federal Power Commission) in its Uniform System of Accounts, allows negative salvage:

> The utility shall keep such records of property and property retirements as will reflect the service life of property which has been retired and aid in estimating probable service life by mortality, turnover, or other appropaite methods; and also such records as will reflect the percentge of salvage and costs of removal for property retired from each account, or subdivision thereof, for depreciable electric plant.[18]

In a 1977 petition to the NRC for rulemaking (Docket No. PRM 50-22), the Public Interest Research Group, and others requested the NRC to promulgate regulations for nuclear power plant decommissioning that would require plant operators to post performance bonds and/or establish sinking funds (see discussion above) prior to each plant's operation, which would insure that funds would be available for proper and adequate isolation of radioactive material upon each plant's decommissioning. The regulations would apply to existing and future plants. The NRC presently requires only that a prospective reactor operator demonstrate to the NRC's satisfaction that it has sufficient financial strength to pay the costs of decommissioning at the time of reactor retirement.

While the Task Force has not been able to obtain from all the other states their procedures (if any) to assure that reactor operations will be able to pay their decommissioning costs, several states have apparently adopted some

form of a depreciation account mechanism.* The Connecticut Public Utilities Control Authority has also recently ordered Connecticut Light & Power to post a bond annually to guarantee that the monies collected from ratepayers by a depreciation mechanism to cover the mothballing costs of Millstone I and I and Connecticut Yankee will be available at the time mothballing takes place.[19] Also while the Pennsylvania PUC, on the basis of a Pennsylvania court decision, will not allow any advance accumulation of funds to cover decommissioning, Duquesne Light has petitioned to permit the establishment of a sinking fund annunity to provide for the costs of decommissioning its share of Beaver Valley I.[20]

RECOMMENDATION V-7:

STATE SHOULD STUDY EXISTING AND ALTERNATIVE

DECOMMISSIONING FINANCING MECHANISMS

Continued study and consideration should be given to the adequacy of the financing mechanisms for reactor decommissioning presently employed in

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*The 1976 Annual Report on Utility and Carrier Regulation of the National Association of Regulatory Utility Commissioners lists a number of state utility regulatory agencies as using some form of depreciation mechanism to recover negative salvage costs. The states listed include California, Georgia, Hawaii, New Mexico, Oregon, Texas, Utah, Kentucky, and Vermont, plus the District of Columbia. In addition, personal communication with the Connecticut Public Utilities Control Authority and Iowa Commerce Commission confirms that these two states also use a depreciation mechanism.

California and to alternative financing mechanisms such as the ones that have been discussed in this report. This continued deliberation might be performed as a joint effort of the California Energy Commission and the California Public Utilities Commission.

The Energy Commission and the CPUC both have responsibilities impinging upon the need for a special reactor decommissioning financing procedure and the method of implementation of any such procedure. The present financing practices of the operators of commercial power reactors in California have been questioned with regard to the source of funding reactor decommissioning in the event of premature reactor shutdown and the future financial viability of these operators. Continued study of reactor decommissioning financing mechanisms could help resolve these concerns.

RECOMMENDATION V-8:

FINANCING MECHANISMS SHOULD INCORPORATE PERIODIC REEVALUATION AND READJUSTMENTS

Because of the uncertainty in reactor decommissioning cost estimates, the rate at which monies are accumulated by whatever mechanism is used by a licensee to accumulate decommissioning funds should be periodically reevaluated and readjusted to reflect current cost estimates and to ensure that adequate funds will be available.

RECOMMENDATION V-9:

NUCLEAR REACTOR OPERATORS SHOULD HAVE AN EQUITABLE, ADEQUATE FINANCING MECHANISM FOR DECOMMISSIONING

Presently in California, not all commercial reactor operators are setting aside funds to cover the eventual costs of decommissioning. Administrative or legislative remedies should be enacted to ensure that all operators are employing equitable and adequate financing mechanisms so as to protect the people and the State of California from any financial liability or hazards to health.

The operator of Rancho Seco reactor, the Sacramento Municipal Utility District, is presently setting aside no funds to cover its decommissioning cost. SMUD is also self-regulated and therefore is not under the jurisdiction of the CPUC. There may occur similar situations in the future if, for example, the Los Angeles Department of Water and Power builds a reactor. Action needs to be taken to ensure that for all contaminated facilities adequate funds will be available to cover the necessary costs for decommissioning and that they were obtained from the people of California in an equitable manner. (See also Recommendations V-10 below and V-11 and V-12 in Chapter 23.)

FINANCING THE DECOMMISSIONING OF FACILITIES OTHER THAN COMMERCIAL REACTORS

For facilities licensed by the State of California, the Department of Health has the limited ability to attach a lien to real property owned by a licensee as an attempt to recover funds to cover the costs of decontaminating

facilities when the licensee fails to fulfill that obligation.[21] This limited power is inadequate to protect the state from having to help pay the costs of facility decontamination.* In instances where a licensed operator would fail, because of bankruptcy or other reason to decontaminate a terminated facility, the State is quite likely to find inadequate real property to attach a lien to. Additionally, because costs of decontamination could run into the millions of dollars, the financial vulnerability of the State is considerable (see Chapter 23). California might consider itself fortunate that the Department of Health has to date found itself having to pay for unperformed decontamination on the order of only tens of thousands of dollars.

This inadequate funding assurance mechanism (i.e., the ability to attach a lien) was enacted in response to a request by the Department of Health for a much stronger and more adequate mechanism consisting of the power to require the bonding of licensees to cover the costs of decontamination. This bonding approach (see pages V-53 and 54 above) would empower the DOH to require that state licensees post bonds to cover the possible decontamination costs for the restoration of their respective type of facility at the time of site transfer or license termination. The amounts of the bonds would approximate those estimated costs listed at the beginning of this chapter. Legislation has been

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*The power of the Department of Health to attach a lien has severe time constraints and is severly restricted as to the circumstances in which it may be used. It can only be used to recover money from the owner of the contaminated structure and then only if the property owner is the person responsible for the contamination and only to the extent of the interest an owner has in the property.

passed in at least seven states (New York, South Carolina, North Carolina, Arkansas, Utah, New Mexico, and Nevada) and is pending in Tennessee to provide some bonding authority along these lines to the appropriate state agencies.[22]

RECOMMENDATION V-10:

STATE LICENSEES SHOULD BE REQUIRED TO

POST BONDS FOR DECONTAMINATION COSTS

The State should enact legislation giving the Department of Health authority to require the posting of bonds by State licensees to cover the estimated costs of decontamination.

Present DOH legal resources to ensure that decontamination will be carried out are inadequate and some bonding authority, similar to that enacted by other states, is needed.

REFERENCES

Chapter 23: Costs, Financing, and Liability

1. Personal communication with R. Jon Stouky, NUS Corporation.

2. Cleaning Up the Remains of Nuclear Facilities: A Multibillion Dollar Problem, EMD-77-46 (U. S. General Accounting Office, June 1977).

3. "Task Force Report on Bonding and Perpetual Care of Licensed Nuclear Activities," Conference of Radiation Control Program Directors, April 5, 1976.

4. Personal communiciation with Kevin Coughlan, California Public Utilities Commission.

5. Ibid.

6. Stouky and Ricer, San Onofre Decommissioning Procedures; and Manion and LaGuardia, Engineering Evaluation of Decommissioning Alternatives.

7. Nucleonics Week, August 11, 1977, p. 4.

8. Pennsylvania Public Utilities Commission Order, RID 170/171, June 22, 1976, p. 41.

9. Decision by Connecticut Public Utilities Control Authority on the Application by Connecticut Light & Power to Increase Rates to All Customers, Docket No. 770319, October 25, 1977, p. 45 (decision being appealed by CL&P on technical grounds).

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11. Stephen A. Johnston and John L. Warren, Financial Analysis of Perpetual Care and Maintenance for the Maxey Flats Low-Level Nuclear Waste Disposal Site, RF 23U-1492 (Kentucky Legislative Research Commission, September 1977).

12. Nuclear Regulatory Commission, Regulatory Guide 3.5, "Standard Format and Content of License Applications for Uranium Mills," Sec. C5.5.

13. A more thorough discussion of the costs of some financing alternatives can be found in Benjamin J. Ewers, Jr., of Northern States Power, Minneapolis, "Accounting Today for Future Nuclear Plant Decommissioning Cost," presented at the American Gas Association-Edison Electric Institute Accounting Conference, Dearborn, Mich., May 1977.

14. Ibid.

15. Report on the Results of Operation of Southern California Edison Company: 1978 Estimated; Test Year 1979, staff report, Application No. 57602 (California Public Utilities Commission, Operations Division, February 3, 1978).

16. See note 4 above.

17. See note 8 above.

18. Federal Energy Regulatory Commission, Uniform System of Accounts, Acct. 403, Para. (b)

19. See note 9 above.

20. Nucleonics Week, October 13, 1977.

21. California Health and Safety Code, Sec. 25863.

22. See note 10 above.

CHAPTER 23: STATE LIABILITY

DRAFT

The California Energy Commission is responsible for licensing all new thermal electric generating facilities in California, including new nuclear plants.[1] The California Department of Health continues to be responsible for "licensing persons to receive, possess, or transfer radioactive materials, or devices or equipment utilizing such materials."[2] The Department of Health's jurisdiction covers non-reactor uses, for example, industrial and medical uses of radioactive isotopes. The Department of Health derives its authority to license these uses of radioactive materials from the federal government as a so-called Agreement State.[3] Although the Department of Health's jurisdiction is exclusive for the licenses it issues, the Energy Commission shares concurrent jurisdiction for the issuance of licenses for new nuclear power plants with the U. S. Nuclear Regulatory Commission.

LIABILITY FOR INJURIES AND OTHER INCIDENTS

The Price-Anderson Act, which is federal legislation, provides for limited operator and federal government liability for nuclear incidents occurring at licensed facilities.[4] "Nuclear incident" is defined as "any occurrence ... causing . . . bodily injury, sickness, disease, or death, or loss of or damage to property, or loss of use of property, arising out of or resulting from the radioactive, toxic, explosive, or other hazardous properties of source, special nuclear, or by-product material."[5]

The Price-Anderson Act protection extends only to public liability arising out of or in connection with NRC-licensed activities. The maximum of insurance

under the act is required only of licensees operating large commerical reactors and fuel fabrication plants.[6] For operators of other types of facilities and holders of materials licenses only, the amount of insurance required is discretionary with the NRC. Therefore, once a reactor is mothballed or partially decommissioned and the operating license in terminated, the amount of insurance required of the holder of the remaining "possession only" or materials license is discretionary with the NRC. In any event, in these cases the maximum liability of the federal government for a nuclear incident is $540 million.

The Price-Anderson Act has been held unconstitutional as a deprivation of due process by a federal district court in North Carolina.[7] The U. S. Supreme Court is reviewing the decision of the lower court. The State of California, through the Secretary for Resources, submitted an amicus curiae brief in the case arguing that the Price-Anderson Act is unconstitutional. A decision by the Supreme Court that the act is unconstitutional would have two impacts upon liability. First, for the operator of the facility, liability would be unlimited. Second, there would be no indemnification guarantee or liability on the part of the federal government for the $500 million for which it currently is obligated.

With regard to State law, neither the Energy Commission nor the Department of Health can be held liable for torts (injuries) or other incidents arising out of the licensing of persons or facilities handling radioactive material. The California Tort Claims Act of 1963 provides that a public entity is not liable for an injury that was caused by the issuance, denial, suspension, or

revocation of any permit, license, certificate, approval, order, or similar authorization if the entity or an employee thereof was authorized by law to determine whether such authorization should be issued, denied, suspended, or revoked.[8]

In addition, a public entity is not liable under the Tort Claims Act for an injury that is caused by its failure to make an inspection of any property other than its own property, for the purpose of determining whether the property complies with or violates any enactment or whether it contains or constitutes a hazard to health or safety.[9] ("Property of a public entity" means real or personal property that is owned or controlled by a public entity.)[10] The immunity granted by this provision is absolute.[11]

Therefore, it appears that unless a facility or radioactively contaminated site is owned by, or has come under the control of, the State, no liability for torts would accrue to the State. As will be discussed in greater detail below, the Department of Health may impound or seize any radioactively contaminated object, building, structure or premises in order to decontaminate it.[12] It could be argued that if the government seizes control of a radioactive facility under this section, then it is under an obligation to proceed with due care for the public health and safety, and would be removed from the immunity provisions of the California Tort Claims Act.

In summary, unless the State seizes control of a radioactively contaminated object, structure, or site, it appears that the state has no legal liability if persons are injured by the radioactivity. The legal liability would seem to remain with the owner or operator of the facility or site.

RECOMMENDATION V-11:

LEGAL LIABILITY OF STATE FOR FACILITIES NOT

UNDER STATE CONTROL SHOULD BE STUDIED

Further study should be undertaken to confirm that the State has no legal liability in the event that the State does not seize control of a contaminated object, structure, or site.

LIABILITY FOR COSTS OF DECOMMISSIONING

As for the obligation to pay for decommissioning of a facility, the primary obligation is, of course, on the owner or operator of a facility. The Department of Health has the authority to determine if any object, building, structure or premises contaminated with radioactive material constitutes a hazard to the public health.[13]

If so, the DOH must order the person who has control of the facility to decontaminate the facility. The Health and Safety Code also provides that if the owner or operator of the facility does not decontaminate it, then the Health Department may seize control of the facility, decontaminate it, and recover the cost of decontamination from the owner.[14] Although this provision was probably not designed specifically for nuclear reactors, the language of the statute seems broad enough to cover these facilities as well.

If the owner of a facility defaults on his obligation to decommission, the question arises as to the federal or state government's obligations.

No federal or state statute seems to establish such an obligation. In the case of the West Valley reprocessing plant in New York, a dispute has ensued over the responsibility for decontaminating the facility and disposing of the wastes left there when Nuclear Fuel Services, the facility's owner, went out of business. The situation is somewhat peculiar in that New York State was a part owner with NFS and had certain contractual obligations regarding waste disposal. The General Accounting Office (GAO) has asserted that New York is thus liable for the $90 million to $600 million expenditure required to decommission the facility and dispose of the waste.[15] New York is disputing its liability, claiming that the federal government is liable for a portion of the costs and that the obligation to decommission is a shared one.[16]

This case is slightly different from the normal light-water reactor case where the facility is licensed by both the state and federal government, with neither governmental entity having a contractual obligation for the operation of the facility with the private owner. Therefore, in the usual case, the determination as to whether liability falls to the state or the federal government in the case of a defaulting owner would be even more unsettled.

It is possible that a state would wish to appropriate funds through its legislature to pay for decommissioning and disposal of waste. This may be appropriate, but is certainly not required by any existing statute. A better solution, of course, is to require some funding mechanism to ensure that money will be available for decommissioning and decontamination whether or not the owner is in existence at the time decommissioning or decontamination are required.

RECOMMENDATION V-12:

LIABILITY OF STATE FOR DECONTAMINATING OR

DECOMMISSIONING ABANDONED FACILITIES SHOULD BE STUDIED

The extent to which the State might be liable for the decontamination or decommissioning of facilities handling radioactive materials within California in the event that the licensee failed to provide for such services warrants further study.

While it appears that the State's liability from a strictly legal perspective may be limited if the State does not own, control, or seize a contamination facility, this conclusion awaits further confirmation and does not address the impact on liability of the State's responsibility to protect health and safety in the case of contaminated facilities that are abandoned.

REFERENCES

Chapter 23: State Liability

1. Public Resources Code, Sec. 25500 et seq.

2. Health and Safety Code, Sec. 25815.

3. "The Agreement between the United States Atomic Energy Commission and the State of California for Discontinuance of Certain Commission Regulatory Authority and Responsibility within the State Pursuant to Section 274 of the Atomic Energy Act of 1954, as Amended," codified in the California Health and Safety Code, Sec. 25875 et seq.

4. 42 U.S.C. Secs. 2012(i), 2014, and 2210.

5. Ibid., Sec. 2014(q).

6. Ibid., Sec. 2210(b).

7. South Carolina Study Group, Inc. v. AEC, 431 F.Supp. 203 (W.D.N.C. 1977), appeal docketed sub nom., Duke Power Co. vs. Carolina Environmental Study Group, Inc., 46 U.S.L.W. 3300 (U.S. November 8, 1977).

8. Government Code, Secs. 818.4 and 821.2.

9. Ibid., Sec. 818.6.

10. Ibid., Sec. 830(c).

11. Holman v. State (1975), 53 Cal. App. 3d 317, 124 Cal. Rptr. 773.

12. Health and Safety Code, Secs. 26862-26863.

13. Health and Safety Code, Sec. 25862.

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15. General Accounting Office, Issues Related to the Closing of the Nuclear Fuel Services, Inc. Reprocessing Plant at West Valley, New York, EMD 77-27 (March 8, 1977), pp. 30-31.

16. Richard Lester and David Rose, "The Nuclear Wastes at West Valley, New York," Technology Review, May 1977.

APPENDIX B:

U. S. NUCLEAR REGULATORY COMMISSION

REGULATORY GUIDE 1.86

June 1974

U.S. ATOMIC ENERGY COMMISSION

REGULATORY GUIDE

DIRECTORATE OF REGULATORY STANDARDS

REGULATORY GUIDE 1.86

TERMINATION OF OPERATING LICENSES FOR NUCLEAR REACTORS

A. INTRODUCTION

Section 50.51, "Duration of license, renewal," of 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires that each license to operate a production and utilization facility be issued for a specified duration. Upon expiration of the specified period, the license may be either renewed or terminated by the Commission. Section 50.82, "Applications for termination of licenses," specifies the requirements that must be satisfied to terminate an operating license, including the requirement that the dismantlement of the facility and disposal of the component parts not be inimical to the common defense and security or to the health and safety of the public. This guide describes methods and procedures considered acceptable by the Regulatory staff for the termination of operating licenses for nuclear reactors. The Advisory Committee on Reactor Safeguards has been consulted concerning this guide and has concurred in the regulatory position.

B. DISCUSSION

When a licensee decides to terminate his nuclear reactor operating license, he may, as a first step in the process, request that his operating license be amended to restrict him to possess but not operate the facility. The advantage to the licensee of converting to such a possession-only license is reduced surveillance requirements in that periodic surveillance of equipment important to the safety of reactor operation is no longer required. Once this possession-only license is issued, reactor operation is not permitted. Other activities related to cessation of operations such as unloading fuel from the reactor and placing it in storage (either onsite of offsite) may be continued.

A licensee having a possession-only license must retain, with the Part 50 license, authorization for special nuclear material (10 CFR Part 70, "Special Nuclear Material"), byproduct material (10 CFR Part 30, "Rules of General Applicability to Licensing of Byproduct Material"), and source material (10 CFR Part 40, "Licensing of Source Material"), until the fuel, radioactive components, and sources are removed from the facility. Appropriate administrative controls and facility requirements are imposed by the Part 50 license and the technical specifications to assure that proper surveillance is performed and that the reactor facility is maintained in a safe condition and not operated.

A possession-only license permits various options and procedures for decommissioning, such as mothballing, entombment, or dismantling. The requirements imposed depend on the option selected.

Section 50.82 provides that the licensee may dismantle and dispose of the component parts of a nuclear reactor in accordance with existing regulations. For research reactors and critical facilities, this has usually meant the disassembly of a reactor and its shipment offsite, sometimes to another appropriately licensed organization for further use. The site from which a reactor has been removed must be decontaminated, as necessary, and inspected by the Commission to determine whether unrestricted access can be approved. In the case of nuclear power reactors, dismantling has usually been accomplished by shipping fuel offsite, making the reactor inoperable, and disposing of some of the radioactive components.

Radioactive components may be either shipped offsite for burial at an authorized burial ground or secured

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on the site. Those radioactive materials remaining on the site must be isolated from the public by physical barriers or other means to prevent public access to hazardous levels of radiation. Surveillance is necessary to assure the long term integrity of the barriers. The amount of surveillance required depends upon (1) the potential hazard to the health and safety of the public from radioactive material remaining on the site and (2) the integrity of the physical barriers. Before areas may be released for unrestricted use, they must have been decontaminated or the radioactivity must have decayed to less than prescribed limits (Table I).

The hazard associated with the retired facility is evaluated by considering the amount and type of remaining contamination, the degree of confinement of the remaining radioactive materials, the physical security provided by the confinement, the susceptibility to release of radiation as a result of natural phenomena, and the duration of required surveillance.

C. REGULATORY POSITION

1. APPLICATION FOR A LICENSE TO POSSESS BUT NOT OPERATE (POSSESSION-ONLY LICENSE)

A request to amend an operating license to a possession-only license should be made to the Director of Licensing, U.S. Atomic Energy Commission, Washington, D.C. 20545. The request should include the following information:

a. A description of the current status of the facility.

b. A description of measures that will be taken to prevent criticality or reactivity changes and to minimize releases of radioactivity from the facility.

c. Any proposed changes to the technical specifications that reflect the possession-only facility status and the necessary disassembly/retirement activities to be performed.

d. A safety analysis of both the activities to be accomplished and the proposed changes to the technical specifications.

e. An inventory of activated materials and their location in the facility.

2. ALTERNATIVES FOR REACTOR RETIREMENT

Four alternatives for retirement of nuclear reactor facilities are considered acceptable by the Regulatory staff. These are:

a. **Mothballing.** Mothballing of a nuclear reactor facility consists of putting the facility in a state of protective storage. In general, the facility may be left intact except that all fuel assemblies and the radioactive fluids and waste should be removed from the site. Adequate radiation monitoring, environmental surveillance, and appropriate security procedures should be established under a possession-only license to ensure that the health and safety of the public is not endangered.

b. **In-Place Entombment.** In-place entombment consists of sealing all the remaining highly radioactive or contaminated components (e.g., the pressure vessel and reactor internals) within a structure integral with the biological shield after having all fuel assemblies, radioactive fluids and wastes, and certain selected components shipped offsite. The structure should provide integrity over the period of time in which significant quantities (greater than Table I levels) of radioactivity remain with the material in the entombment. An appropriate and continuing surveillance program should be established under a possession-only license.

c. **Removal of Radioactive Components and Dismantling.** All fuel assemblies, radioactive fluids and waste, and other materials having activities above accepted unrestricted activity levels (Table I) should be removed from the site. The facility owner may then have unrestricted use of the site with no requirement for a license. If the facility owner so desires, the remainder of the reactor facility may be dismantled and all vestiges removed and disposed of.

d. **Conversion to a New Nuclear System or a Fossil Fuel System.** This alternative, which applies only to nuclear power plants, utilizes the existing turbine system with a new steam supply system. The original nuclear steam supply system should be separated from the electric generating system and disposed of in accordance with one of the previous three retirement alternatives.

3. SURVEILLANCE AND SECURITY FOR THE RETIREMENT ALTERNATIVES WHOSE FINAL STATUS REQUIRES A POSSESSION-ONLY LICENSE

A facility which has been licensed under a possession-only license may contain a significant amount of radioactivity in the form of activated and contaminated hardware and structural materials. Surveillance and commensurate security should be provided to assure that the public health and safety are not endangered.

a. Physical security to prevent inadvertent exposure of personnel should be provided by multiple locked barriers. The presence of these barriers should make it extremely difficult for an unauthorized person to gain access to areas where radiation or contamination levels exceed those specified in Regulatory Position C.4. To prevent inadvertent exposure, radiation areas above 5 mR/hr, such as near the activated primary system of a power plant, should be appropriately marked and should not be accessible except by cutting of welded closures or the disassembly and removal of substantial structures

and/or shielding material. Means such as a remote-readout intrusion alarm system should be provided to indicate to designated personnel when a physical barrier is penetrated. Security personnel that provide access control to the facility may be used instead of the physical barriers and the intrusion alarm systems.

b. The physical barriers to unauthorized entrance into the facility, e.g., fences, buildings, welded doors, and access openings, should be inspected at least quarterly to assure that these barriers have not deteriorated and that locks and locking apparatus are intact.

c. A facility radiation survey should be performed at least quarterly to verify that no radioactive material is escaping or being transported through the containment barriers in the facility. Sampling should be done along the most probable path by which radioactive material such as that stored in the inner containment regions could be transported to the outer regions of the facility and ultimately to the environs.

d. An environmental radiation survey should be performed at least semiannually to verify that no signficant amounts of radiation have been released to the environment from the facility. Samples such as soil, vegetation, and water should be taken at locations for which statistical data has been established during reactor operations.

e. A site representative should be designated to be responsible for controlling authorized access into and movement within the facility.

f. Administrative procedures should be established for the notification and reporting of abnormal occurrences such as (1) the entrance of an unauthorized person or persons into the facility and (2) a significant change in the radiation or contamination levels in the facility or the offsite environment.

g. The following reports should be made:

(1) An annual report to the Director of Licensing, U.S. Atomic Energy Commission, Washington, D.C. 20545, describing the results of the environmental and facility radiation surveys, the status of the facility, and an evaluation of the performance of security and surveillance measures.

(2) An abnormal occurrence report to the Regulatory Operations Regional Office by telephone within 24 hours of discovery of an abnormal occurrence. The abnormal occurrence will also be reported in the annual report described in the preceding item.

h. Records or logs relative to the following items should be kept and retained until the license is terminated, after which they may be stored with other plant records:

(1) Environmental surveys,

(2) Facility radiation surveys,

(3) Inspections of the physical barriers, and

(4) Abnormal occurrences.

4. DECONTAMINATION FOR RELEASE FOR UNRESTRICTED USE

If it is desired to terminate a license and to eliminate any further surveillance requirements, the facility should be sufficiently decontaminated to prevent risk to the public health and safety. After the decontamination is satisfactorily accomplished and the site inspected by the Commission, the Commission may authorize the license to be terminated and the facility abandoned or released for unrestricted use. The licensee should perform the decontamination using the following guidelines:

a. The licensee should make a reasonable effort to eliminate residual contamination.

b. No covering should be applied to radioactive surfaces of equipment or structures by paint, plating, or other covering material until it is known that contamination levels (determined by a survey and documented) are below the limits specified in Table I. In addition, a reasonable effort should be made (and documented) to further minimize contamination prior to any such covering.

c. The radioactivity of the interior surfaces of pipes, drain lines, or ductwork should be determined by making measurements at all traps and other appropriate access points, provided contamination at these locations is likely to be representative of contamination on the interior of the pipes, drain lines, or ductwork. Surfaces of premises, equipment, or scrap which are likely to be contaminated but are of such size, construction, or location as to make the surface inaccessible for purposes of measurement should be assumed to be contaminated in excess of the permissable radiation limits.

d. Upon request, the Commission may authorize a licensee to relinquish possession or control of premises, equipment, or scrap having surfaces contaminated in excess of the limits specified. This may include, but is not limited to, special circumstances such as the transfer of premises to another licensed organization that will continue to work with radioactive materials. Requests for such authorization should provide:

(1) Detailed, specific information describing the premises, equipment, scrap, and radioactive contaminants and the nature, extent, and degree of residual surface contamination.

(2) A detailed health and safety analysis indicating that the residual amounts of materials on surface areas, together with other considerations such as the prospective use of the premises, equipment, or scrap, are unlikely to result in an unreasonable risk to the health and safety of the public.

e. Prior to release of the premises for unrestricted use, the licensee should make a comprehensive radiation survey establishing that contamination is within the limits specified in Table I. A survey report should be filed with the Director of Licensing, U.S. Atomic Energy Commission, Washington, D.C. 20545, with a copy to the Director of the Regulatory Operations Regional Office having jurisdiction. The report should be filed at least 30 days prior to the planned date of abandonment. The survey report should:

(1) Identify the premises;

(2) Show that reasonable effort has been made to reduce residual contamination to as low as practicable levels;

(3) Describe the scope of the survey and the general procedures followed; and

(4) State the finding of the survey in units specified in Table 1.

After review of the report, the Commission may inspect the facilities to confirm the survey prior to granting approval for abandonment.

5. REACTOR RETIREMENT PROCEDURES

As indicated in Regulatory Position C.2, several alternatives are acceptable for reactor facility retirement. If minor disassembly or "mothballing" is planned, this could be done by the existing operating and maintenance procedures under the license in effect. Any planned actions involving an unreviewed safety question or a change in the technical specifications should be reviewed and approved in accordance with the requirements of 10 CFR §50.59.

If major structural changes to radioactive components of the facility are planned, such as removal of the pressure vessel or major components of the primary system, a dismantlement plan including the information required by §50.82 should be submitted to the Commission. A dismantlement plan should be submitted for all the alternatives of Regulatory Position C.2 except mothballing. However, minor disassembly activities may still be performed in the absence of such a plan, provided they are permitted by existing operating and maintenance procedures. A dismantlement plan should include the following:

a. A description of the ultimate status of the facility

b. A description of the dismantling activities and the precautions to be taken.

c. A safety analysis of the dismantling activities including any effluents which may be released.

d. A safety analysis of the facility in its ultimate status.

Upon satisfactory review and approval of the dismantling plan, a dismantling order is issued by the Commission in accordance with §50.82. When dismantling is completed and the Commission has been notified by letter, the appropriate Regulatory Operations Regional Office inspects the facility and verifies completion in accordance with the dismantlement plan. If residual radiation levels do not exceed the values in Table I, the Commission may terminate the license. If these levels are exceeded, the licensee retains the possession-only license under which the dismantling activities have been conducted or, as an alternative, may make application to the State (if an Agreement State) for a byproduct materials license.

TABLE I

ACCEPTABLE SURFACE CONTAMINATION LEVELS

NUCLIDE[a]	AVERAGE[b c]	MAXIMUM[b d]	REMOVABLE[b e]
U-nat, U-235, U-238, and associated decay products	5,000 dpm α/100 cm^2	15,000 dpm α/100 cm^2	1,000 dpm α/100 cm^2
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100 dpm/100 cm^2	300 dpm/100 cm^2	20 dpm/100 cm^2
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1000 dpm/100 cm^2	3000 dpm/100 cm^2	200 dpm/100 cm^2
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.	5000 dpm β-γ/100 cm^2	15,000 dpm β-γ/100 cm^2	1000 dpm β-γ/100 cm^2

[a]Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides should apply independently.

[b]As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[c]Measurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each such object.

[d]The maximum contamination level applies to an area of not more than 100 cm^2.

[e]The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally and the entire surface should be wiped.