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AS LOW AS IS REASONABLY ACHIEVABLE (ALARA) STUDIES RELATIVE TO THE NWTS PROGRAM

MASTER

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FOREWORD

This report was prepared under a subcontract with Union Carbide Corporation, Nuclear Division, as U.S. Department of Energy (DOE) contractor. This subcontract was administered by the Office of Waste Isolation (OWI), program manager for the National Waste Terminal Storage (NWTS) Program. The principal objective of the NWTS Program is to provide facilities in various deep geological formations at multiple locations in the United States that will safely dispose of the radioactive waste generated by commercial operations and that must be delivered to a federal repository for terminal storage. These federal repositories will be licensed by the Nuclear Regulatory Commission (NRC).

The concept of keeping radiation exposures to a practical minimum or "as low as is reasonably achievable" (ALARA) has been applied by NRC to nuclear power plants. The ALARA concept most likely will be applied to federal repositories for nuclear wastes. The purpose of the present study is to provide prospective OWI contractors on the NWTS Program up to date information on the potential nature and scope of the ALARA requirements so that these requirements can be properly evaluated.

Much of the discussion in this report on the present status and future development of ALARA criteria is based on direct contacts and discussions with numerous people within the various agencies involved. However, the assumptions, views, and conclusions expressed in this report are those of the authors and are not to be interpreted as those of Union Carbide Corporation, Nuclear Division or of DOE.

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I. INTRODUCTION AND SUMMARY

Part 20 of Title 10 of the Code of Federal Regulations (10CFR20) establishes standards for protection against radiation hazards arising out of activities under licenses issued by the Nuclear Regulatory Commission (NRC). The concept of keeping radiation exposures "as-low-as-is-reasonably achievable" (ALARA) has been incorporated into 10CFR20, has been applied to nuclear power plants, and will also be applied to Federal respositories for nuclear wastes. This report presents the history of development of the ALARA concept and ALARA criteria as applied to both off-site (environmental) and on-site (occupational) exposures at nuclear power plants. It presents the current status of activities within the various federal agencies directed toward developing ALARA criteria for other areas of the nuclear fuel cycle. Based on the historical development, the present activities, and on discussions with numerous people involved in this area, the authors speculate on the future development of ALARA criteria and implications for the NWTS Program.

Section II discusses environmental ALARA criteria which relate to minimizing radiation to the surrounding population. A set of non-generic, and probably non-numerical environmental criteria are being developed by the NRC, applicable to Federal repositories. The criteria will apply to the various time phases of repository operation and will provide qualitative guidance on procedures, equipment to be used, operational philosophy, monitoring requirements, etc., related to repository operation. A number of studies are being performed by and for the NRC and the EPA which will directly impact on the ALARA criteria being developed. Before the criteria are promulgated, expected to be sometime after mid-1978, public hearings will probably be held. Table I-1 generally summarizes the characterization and development of conceptual repository environmental ALARA criteria.

TABLE I-1

REPOSITORY ENVIRONMENTAL ALARA CRITERIA:
CHARACTERIZATION AND DEVELOPMENT

(1) Nature and Application of Repository ALARA Criteria

- Sets of criteria are being developed by NRC
  - above ground facilities (short-term*)
  - below ground facilities (short-term and long-term*)
  - waste type (e.g., high-level wastes, spent fuel)
  - decommissioning (short-term)
- Qualitative guidance applicable to plant design, plant operation, off-site radioactivity monitoring and control
- Non-generic, i.e., repository specific
- Non-numerical for long-term and probably non-numerical for short-term
- Cost-benefit analysis on a case-by-case basis
- Conformance with EPA requirements

(2) Development of Environmental ALARA Criteria

- Establishment of goals
- Performance of studies
  - Site suitability criteria
  - Solid waste performance criteria
  - Design and operating criteria
  - Monitoring techniques
  - Acceptable risks
  - Impact analyses
  - Development of standards
- Review and modifications
- Public hearings

TABLE I-1
(Continued)

(2) Development of Environmental ALARA Criteria (Continued)

- Formal Issuance of the ALARA criteria
- Periodic updating of criteria based on new studies and experience

(3) Past ALARA Experience Applicable to Repository ALARA

- Appendix I development and implementation (light-water reactors)
- ALARA studies on other parts of the fuel cycle (milling, fuel fabrication and reprocessing)

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* During the long-term period of repository operation, i.e., the post decommissioning phase, the ALARA criteria will be more stringent than during the short-term active phase, which includes disposal of wastes and decommissioning of the repository.

The information presented above is based on NUS' best judgment relating to the development of repository ALARA criteria. The criteria under development are expected to be applicable but are subject to change as their development progresses.

Section III discusses current occupational ALARA criteria and guidelines for risk-benefit assessments that are under development. The criteria and guidelines are only indirectly applicable to waste repository operations. Regulatory Guide 8.10 revised by NRC presents operational philosophy that is applicable to all specific licensees, which will include waste repository operators. A number of studies are being performed. The DOE study evaluates nuclear power plant experience and is to develop technical guidelines for a specific power plant. One NRC sponsored study is developing data on dose commitments for all segments of the fuel cycle and another NRC study has recommended strengthening of the regulatory base. An interagency study is reviewing the Federal Radiation Council (FRC) guideline limits. AIF is sponsoring a study of methodology that can be utilized for specific jobs, primarily at power plants. The results of these studies are expected to provide methodology and technical guidance for the future development of occupational ALARA criteria applicable to waste repository operations. Table I-2 generally summarizes the study programs.

Section IV discusses recommendations to assure that evolving ALARA concepts are periodically brought up to date and that such concepts be made available to those subcontractors who have responsibility for design and operation of a repository. The rationale for including training programs and audits are given.

One of the main objectives of this study is to identify reports, articles, testimony, and other sources discussing ALARA criteria that may be pertinent to the NWTS program. Section V presents an annotated bibliography of some 83 sources giving information on ALARA criteria and its application. The sources in the bibliography cover the time period from 1970 to the present and were selected from some 4000 abstracts that were reviewed. The bibliography is not intended to contain all sources referring to the

TABLE I-2

PROJECTED REPOSITORY OCCUPATIONAL ALARA CRITERIA;
CHARACTERIZATION AND DEVELOPMENT

(1) Nature and Application of Criteria

- Fuel Cycle Facility Criteria being developed will be generally applicable
- Criteria will contain qualitative guidance on design, equipment, and operating philosophy
- A repository Radiation Safety Officer will be required with authority to enforce safe plant operation
- Criteria will be non-numerical
- Each Licensee will develop his own ALARA program for NRC review and approval, must conform with EPA requirements
- A regulatory guide, similar to 8.8, for repositories will be developed to provide generic guidance to licensees.

(2) Study Programs in Progress

- Technical Guideline development for power plant (areas similar to repository where guidelines would be applicable)
  - fuel pool and cask handling
  - waste collection, processing, packaging
  - pool water cleanup system resin disposal
  - ventilation system filter handling
- Fuel Cycle Facility Dose Commitment Data collection (to be expanded to include shallow burial of low-level waste)
- NRC plans to strengthen the Regulatory Base
- Interagency study of FRC dose commitment guideline limits
- Job specific study of methodology and cost to minimize dose commitment

TABLE I-2
(Continued)

The information presented in Table I-2 is based on NUS' best judgment relating to the development and application of ALARA criteria. The criteria are expected to be applicable but are subject to change as their development progresses.

ALARA concept, but represents the authors' judgment as to those sources that were the most useful and informative on this topic. In several cases references were omitted if it was felt that the information was adequately covered by another source already cited. The annotated bibliography is indexed by author in Section V.A and by keyword in Section V.B.

II. ENVIRONMENTAL "AS LOW AS IS REASONABLE ACHIEVABLE" (ALARA) CRITERIA FOR WASTE REPOSITORIES

Environmental ALARA criteria are being developed by the Nuclear Regulatory Commission (NRC) which will be applicable to the Federal repositories for high-level nuclear wastes. The ALARA concept will be applied to these repositories to assure that public radiation doses are minimized during all phases of repository operation, including the short-term while wastes are being buried and the subsequent repository decommissioning, and the long-term after decommissioning. It is the purpose of this section to provide the Office of Waste Isolation (OWI) with a prognostication as to the form that the ALARA concept will take and how it will be applied. It should be noted that repository ALARA concepts have not yet been firmly established.

At this time much effort is being expended by both the Environmental Protection Agency (EPA) and the NRC which will have a direct impact on the ALARA criteria that will ultimately be applied to waste repositories. The EPA is presently in the process of developing criteria and standards relative to waste repository operation. The standards are expected to place upper limits on off-site doses and effluent releases. The NRC, which has the responsibility to define ALARA, must assure that any ALARA criteria it promulgates fall within the EPA umbrella. This is analogous to the situation regarding power reactors in which the NRC Appendix I* guidelines (ALARA) will fall within the limits of EPA's 40CFR190** (Standards) when such standards become effective.

There is some difficulty in trying to predict the content and impact of future repository ALARA Criteria based on past experience. For the case of repositories there is no real data base from which to draw in developing ALARA criteria. This is in contrast to the case of light-water reactors in which

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* Appendix I to Part 50, Title 10, of the Code of Federal Regulations.

** Part 190 of Title 40 of the Code of Federal Regulations.

a good data base allowed a rather clearly defined ALARA approach to be taken, namely Appendix I. For the present study it has been found more productive to make direct contacts with a number of people at NRC, EPA and elsewhere in order to try to determine the probable course of ALARA development. While the bibliography on ALARA criteria presented in Section V does provide a basis for the thought process that is involved in ALARA development and applications, it is felt that the direct contacts have proved more productive in tracing the probable course of ALARA as applied to waste repositories. On occasion, apparent conflicting information was obtained from such contacts; in such cases best judgments had to be made for the purposes of this study.

A. History of "Environmental" As Low As Is Reasonably Achievable (ALARA) Criteria

The concept of ALARA traces back to the "1949 report" of the National Council on Radiological Protection and Measurements (NCRP) - National Bureau of Standards Handbook 59. In the handbook it is stated that "exposure to radiation be kept at the lowest practicable level in all cases". In December of 1970 the Atomic Energy Commission (AEC) published in the Federal Register (35 F.R. 18387) a new section 20.1(c) in Part 20 of its regulations. This section introduced the concept of the provision for "as far below the limits specified in this part as practicable" into the Code of Federal Regulations and provided qualitative guidance for its use. The term "as far below the limits specified in this part as practicable" means as low as is practicably achievable taking into account the state of technology, and the economics of improvements in relation to benefits to the public health and safety and in relation to the utilization of atomic energy in the public interest. The term was commonly referred to "as low as practicable" (ALAP) but later changed to "as low as is reasonably achievable" (ALARA).

The actual implementation of environmental ALAP criteria or essentially what is an acceptable implementation as viewed by the AEC and its successor, the Nuclear Regulatory Commission (NRC), has only been developed for light-water-cooled reactors and is presented in Appendix I of 10CFR50. The AEC had planned that similar guidance for other fuel cycle facilities would be developed after completion of the rulemaking action that provided numerical guidance for LWR effluents. Recognizing that a sound technical base is required for selecting such values, the AEC contracted with Oak Ridge National Laboratory (ORNL) in 1973 to initiate a comprehensive technical study of fuel cycle facilities, including uranium mills, UF_6 refineries, mixed oxide fuel fabrication facilities, and fuel reprocessing plants. In reports of these studies,[1,2,3,4,5] ORNL evaluated radiation source terms and process equipment capabilities, estimated process equipment costs, and calculated potential doses to individuals and populations in the region of a site. After reviewing the information in these reports, the NRC concluded that the technical data and information presented in the reports were insufficient to provide technical bases for selecting generic ALARA numerical guidelines.

The historical development of the Appendix I criteria will be briefly discussed since there are presently no such detailed criteria for the other parts of the fuel cycle and it is expected that similar considerations, although perhaps a different approach, will be applied to that part of the fuel cycle dealing with waste disposal.

In December 1970, the AEC published in the Federal Register (35 F.R. 18385), new sections 50.34a and 50.36a in Part 50 of its regulations, specifying design and operating requirements for nuclear power reactors to keep levels of radioactivity in effluents "as low as practicable". The amendments provided qualitative guidance, but no numerical criteria, for determining when design objectives and operations met the specified requirements.

On June 9, 1971, the AEC published in the Federal Register (36 F.R. 11113) for public comment proposed amendments to 10CFR50 which would supplement sections 50.34a and 50.36a with a new Appendix I. The proposed Appendix provided numerical guides for design objectives and technical specification requirements for limiting conditions for operation of light-water-cooled nuclear power reactors.

A subsequent notice, published in November 1971 (36 F.R. 2275) announced a public rulemaking hearing on the proposed amendments. The hearing began in January, 1972, and was concluded in December, 1973. During this time, the hearing had been suspended for eighteen months (May 1972 - November 1973) pending preparation and review of an Environmental Impact Statement. During the course of the rulemaking the AEC staff prepared a new proposed version of Appendix I,published in February, 1974; and the ICRP, in publication 22,replaced the term "as low as practicable" with the concept of "as low as is reasonably achievable" (ALARA).* The present version of Appendix I, representing the opinion of the NRC Commissioners, was published May 5, 1975 (40 F.R. 19439) which, in addition to numerical dose guides, included the requirement of a cost-benefit analysis. An amendment, published September 4, 1975 (40 F.R. 40816), provided an option to dispense with the cost-benefit requirement under certain conditions. Table II-1 provides a summary of the several versions of Appendix I including the requirements therein.

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* The term "as low as readily achievable" was actually used; however, the introduction in Publication 22 clearly implies that "readily" and "reasonably" can be taken to mean the same thing.

TABLE II-1

RADIOLOGICAL EFFLUENT GUIDELINES
10CFR50 - APPENDIX I
DESIGN OBJECTIVES - NUMERICAL GUIDES

	June 9, 1971 10CFR50 - Appendix I Proposed Amendments Per Site		February 20, 1974 Regulatory Staff Hearing Position Proposed Rule Per Site	May 5, 1975 NRC Rule 10CFR50 - Appendix I Per Reactor
A.	Liquid Effluents (annual)		A. Liquid Effluents (annual)	A. Liquid Effluents (annual)
	1. Total Quantity (except tritium)	5 curies (max.) each reactor	1. Total quantity, all pathways: 5 mr-wholebody (dose) 5 curies - (quantity)	1. Total quantity (each reactor), all pathways: 3 mr - wholebody (dose) 10 mr - any organ (dose)
	2. Avg. concentration prior to release (except tritium)	2×10^{-5} micro curies/ milli-liter -each reactor		
	3. Avg. concentration of tritium prior to release	5×10^{-3} micro curies/ milli-liter-each reactor		
	4. Exceptions	Higher releases may be authorized if dose to individ. (wholebody) or organs < 5 mr per site		
B.	Gaseous Effluents (annual)		B. Gaseous Effluents (annual)	B. Gaseous Effluents (annual)
	1. Site boundary air dose	10 mr (max.)	1. 10 mr (max)-gamma/20 mr (max)-beta air dose	1. 10 mr (max)-gamma/20 mr (max) - beta air dose
	2. Radioiodines and airborne particulates with half-lives > 8 days	10CFR values 100,000	2. 15 mr (max) - any organ of any individual. 1 curie quantity limit on iodine 131-each reactor	2. 15 mr (max) - any organ of any individual from iodines and particulates
C.	Exceptions		C. Exceptions	C. Exceptions
	1. Higher releases may be authorized if doses to individual (wholebody) or organ < 5 mr per site		1. Dose limit of A.1 controlling if in plant control measures taken	1. B.1 limits could be lower if individual dose is greater than 5 mr wholebody.
			2. Higher B.1 limits may be acceptable if individual exposures will be less than 5 mr wholebody and 15 mr skin and conversely, B.1 levels may be lowered if doses exceed 5 mr & 15 mr.	2. B.1 limits could be higher if individual dose limits were less than 5 mr whole-body and 15 mr skin.
			3. Iodine limits 4 times B.2 possible with commitment to baseline control measures.	3. In addition to satisfying A&B, applicant must include in rad waste systems all items of reasonable demonstrated technology shown through cost benefit to achieve one man-rem (whole-body or thyroid) reduction in population exposures/$1000 or less.

NOTE: The September 4, 1975 amendment to the final version of Appendix I (May 1975) provides the applicant with the option of dispensing with the cost-benefit analysis if the proposed or installed radwaste systems and equipment satisfy the requirements of the February 20, 1974 version of Appendix I proposed by the AEC Staff. Such an option is only available to applications docketed on or after January 2, 1971, and prior to June 4, 1976.

It is to be emphasized that Appendix I does not develop new standards, but merely defines the implementation of the ALARA criteria specified in 10CFR20. Its application is limited to light-water reactors, but its concept, development, and final adoption might give some indication as to how other parts of the fuel cycle will be treated when addressing environmental ALARA.

B. Status of Environmental ALARA Criteria Development

1. Overview

For the case of waste repositories, several sets of environmental ALARA criteria are being developed by the NRC. These include ALARA criteria as applied to different time frames such as short-term (operational, including decommissioning) and long-term (post decommissioning) and also as applied to wastes being treated in above-ground facilities and wastes in their burial locations. Consideration is also being given to the possibility that spent fuel will have to be buried. This could impact on ALARA criteria, especially during the operational phase of a repository when spent fuel may provide a greater potential for gaseous releases than glass-encapsulated wastes from a reprocessing plant.

The EPA is presently developing generic criteria and standards relating to repository operation. As in the case of NRC's development of ALARA criteria, the EPA criteria and standards are expected to cover various time frames, waste locations (above and below ground), and types of waste (e.g., spent fuel). The EPA criteria will be non-numerical; the standards are expected to include numerical emission limits on repository effluents as well as dose limits to the public. On the other hand the ALARA criteria being developed by the NRC will, in all probability, not include numerical

limits, but will rather consist of numerous "qualitative guidance" criteria which mirror the ALARA philosophy, i.e., a listing of things that should be done to assure that any effluent releases from a repository be kept to levels that are as low as is reasonably achievable. If numerical limits were included, they would only be specified for the operational, or short-term period, during which a low, but non-zero amount of radioactive effluent is expected.[6]

Because of the close relationship between the development of EPA's standards and NRC's ALARA criteria, it is felt appropriate to discuss the actions that have been and will be taken by both of these organizations. Such a discussion will allow one to focus better on how ALARA criteria are being developed and also hopefully to obtain a clearer picture of what will ultimately evolve from such developments. Even though various studies are being conducted separately by the NRC and EPA regarding repository operations, the protection of the public is a common goal.

2. EPA Criteria and Standards on Waste Disposal

- Background of Standard Development

  Under Reorganization Plan Number 3 of 1970 of the Atomic Energy Act of 1954, as amended, the responsibility for establishing "generally applicable environmental standards for the protection of the general environment from radioactive material" was transferred from the AEC to the EPA. It is on that basis that the EPA has had the area of waste disposal under continuing study for a number of years. It was also under this delegation of responsibility that the EPA issued 40CFR190, Environmental

Radiation Protection Standards for Nuclear Power Operations, January 1977, which ocvers much of the uranium fuel cycle,* but does not include mining, transportation, plutonium recycling, or radioactive waste disposal. President Ford's message, October, 1976, on reprocessing and the export of nuclear technology, specifically required EPA to set generic numerical standards for high-level waste by the middle of calendar year 1978. The EPA is attempting to achieve this goal by two distinct but interrelated program efforts. The first of these is to develop non-numerical criteria on which to base the standards. In parallel and some time after the criteria are developed, a technical environmental assessment of high activity, long-lived wastes will be used within the framework of the criteria to arrive at numerical standards for these wastes. Such standards probably will not be restricted to the uranium fuel cycle as is 40CFR190, although it is possible that the first version of the standards will be limited to that fuel cycle only. Proposed criteria and standards for waste disposal are to be issued later this year (1977). As indicated above, final versions of the criteria and standards are to be completed on or before mid-1978.

Development of the criteria and standards has included, but has not been limited to, environmental impact studies conducted by Arthur D. Little, Inc., and two workshops to elicit public

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* Includes the milling of uranium ore, chemical conversion of uranium, isotopic enrichment of uranium, fabrication of uranium fuel, generation of electricity by light-water reactors using uranium fuel, and reprocessing of spent fuel.

concerns held in Reston, Virginia (February 3-5, 1977)[7] and Albuquerque, New Mexico (April 12-14, 1977).[8] The results of the various studies and the information obtained at the workshops are being used to develop the criteria and standards. It is quite probable that a rulemaking public hearing will be held before the proposed standards are finalized. It is virtually certain that EPA will have to prepare an environmental impact statement.

- Contents of EPA Standards

The exact contents and format of the EPA standards are not known at this time. As indicated before, the standards are expected to cover the various time frames of repository operation and the corresponding activities and locations of high-level waste during such time frames. Individual and population doses are to be considered. The standards will be much more restrictive after repository decommissioning than during active repository operation, the latter including that period of time when wastes are received and disposed of in geologic formations. The philosophy used in developing 40CFR190 is expected to be applied in developing the waste disposal standard. This would include a cost-effectiveness approach to assure that limits are low enough to limit the number of health effects, but are still capable of technological attainment at a reasonable financial burden. The numerical limits on offsite doses and effluent release quantities during repository operation could be similar to those given in 40CFR190; however, no decision has yet been made on this. For the post operational period any numerical limits that would be promulgated would have to be extremely

small; the public would demand this for a repository that has been chosen based on its ability to retain wastes for an extremely long period of time. Stringent long-term limits would also be required because of the strong general feeling that the disposers of the wastes have a moral obligation to assure the safety of future generations. The EPA is giving careful consideration to including accident or abnormal situations in its standards, although a final decision as to how this will be done has not been reached.

The waste disposal standard will require very active monitoring during the operating phase of the repository in order to assure that the specified environmental radiation limits are not exceeded. After repository decommissioning, active monitoring would be maintained for an additional period of perhaps a couple of decades, after which more limited monitoring may be required for a longer period of time to confirm that waste isolation was indeed maintained. A panel of the National Academy of Sciences/National Research Council on radioactive waste management is undertaking a nine month study, funded by EPA, on monitoring to be completed in the spring of 1978. The results of the study should clarify any monitoring requirements or recommendations.

It should be noted that the NRC will have the responsibility to implement the EPA standards. The standards are expected to change somewhat with time as more information becomes available. This is consistent with typical standard development philosophy.

3. NRC Development of ALARA

- General Remarks

As indicated above, the NRC is developing a set of environmental ALARA criteria to be applied to high-level waste repository operations. The ALARA criteria will probably not be generic, but rather will treat each repository on a case-by-case basis although many of the criteria are expected to be applicable to all repositories. They will generally apply to normal repository operations rather than accident situations.* The approach to be taken will be quite different from that applied to light-water reactors (Appendix I to 10CFR50) in that no numerical values are expected to be specified. Instead, qualitative guidance criteria are being developed. Though unlikely, it is possible that numerical limits will be specified for the short-term active operation of the repository. For the long-term case, it is almost certain that no numerical values will be specified. The ALARA criteria will have to be consistent with, and fall under the umbrella of, EPA's waste disposal criteria and standards.

- Previous ALARA Developments

The NRC learned of the difficulties inherent in trying to establish ALARA criteria during the development of Appendix I. Two versions of Appendix I were proposed before a final version was promulgated. About four years elapsed between the appearance of the first proposed version and the one that was

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* The ALARA philosophy can be extended to the reduction of risks associated with accidents although one usually associates ALARA with normal operations.

finally adopted. The preparation of an environmental impact statement, a public hearing, and much confusion took place during this time. Instead of just qualitative guidance, Appendix I specifies in a quantitative manner what the NRC considers to be ALARA when dealing with light-water reactors. The NRC issued a series of regulatory guides (which have been updated) to assist in implementing Appendix I.[9-13] These guides provide information on source terms, dose models, meteorological and hydrological dispersion, and cost-benefit techniques. The only reason that quantitative ALARA can be applied to the case of light-water reactors is that there is a fairly large data base of information from which to draw.

For other parts of the fuel cycle, such as fabrication of fuel, milling and reprocessing - but not necessarily including waste disposal, the NRC had hoped to develop generic ALARA criteria. A series of reports was prepared by Oak Ridge National Laboratory to assist in this endeavor.[1-5] However, because the reports were based on theoretical rather than empirical analyses, the NRC decided that they could not be used for generic ALARA rulemaking actions - the technical data base just doesn't exist for parts of the fuel cycle other than light-water reactors.[14] The Oak Ridge reports are still considered extremely useful documents from which information can be drawn when considering those parts of the fuel cycle covered by the reports; as such, these reports were reviewed by the EPA during development of 40CFR190. It is understood that the NRC is considering having 40CFR190 serve as the basic definition of ALARA for those parts of the uranium fuel cycle covered by the 40CFR190 standard.*

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* Not including light-water reactor operations already covered by Appendix I.

Whether such a definition will actually be applied by the NRC is not yet known, but in any event it must be remembered that 40CFR190 does not address the problem of radioactive waste disposal.

- Waste Disposal ALARA Development

The NRC is engaged in a very rigorous effort to develop ALARA criteria that will be applicable to the Federal repositories for nuclear wastes. Based upon a set of "guiding principles", a special task group developed a report discussing proposed goals for development, deployment, and operation of a waste management system.[15] That report lists and discusses a number of factors or goals which are deemed directly relevant to an adequate, publicly acceptable, solution to the problem of waste management. The factors/goals are considered essential to an adequate definition of the waste management problem and to the comprehensive evaluation of proposed systems, facilities and technologies. Related to the goals are a set of criteria being developed under NRC's direction which will relate to actual repository operation. These include the following: (1) Site Suitability Criteria; (2) Solid Waste Performance Criteria; and (3) Design and Operating Criteria. The first two are being developed by Lawrence Livermore Laboratory and the third by The Analytical Sciences Corporation. The criteria should be completed during the first quarter of 1978.

Another important study relating to the development of waste disposal ALARA is being conducted for the NRC by Lawrence

Livermore Laboratory and its subcontractor, the National Council on Radiological Protection and Measurements (NCRP). This study, which should be available sometime during the late summer of 1978, concerns the topic "acceptable risks" associated with repository operation and relates to accident considerations. This would include broad cost-effectiveness analyses which are being performed to determine equipment that should be used, and operating procedures to be followed, to assure that repository operation will be conducted within the framework of ALARA philosophy.* Since Federal repositories are to be constructed and operated under DOE's National Waste Terminal Storage (NWTS) Program, the study is expected to have a direct impact on this DOE Program. DOE obviously will have to follow developments of this study quite closely while it considers alternate designs and methods of repository operation.

It is expected that the NRC would perform, or require to be performed, a cost-benefit analysis for every repository to be built, i.e., on a case-by-case basis. This analysis would be even more refined than that associated with the "acceptable risk" study mentioned above. A cost-benefit analysis applied to a repository is anything but straightforward. Not only is a good data base not available on which to weigh the costs

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* This is an example where ALARA philosophy is applied to accident considerations; the usual application is to normal operations.

versus the benefits derived, but a philosophical dilemma presents itself when considering the long-term disposal situation. Some view that the benefits of nuclear power will be short-term, while the potential costs will be both short-term and long-term. Thus it would appear that a unique and perhaps as yet uninvented, type of scale would have to be used in order to weigh risks versus benefits. Since there are too many uncertainties involved when one considers the "long-term" time period (sophistication and stability of civilization, degree of containment of buried wastes, etc.), there probably isn't any single approach on which everyone making present decisions would agree. Perhaps the way to extricate the disposers of high-level wastes from a moral "hangup" would be to require that equipment and procedures associated with waste disposal be based on current information and to apply any cost-benefit analysis on that basis, with perhaps a little "extra" being required on the cost side of the equation. There should be no reason that future generations should expect anything more, especially if one argues that by utilizing nuclear power now, the present generation is put into a better position to pass on a better life to its progenies.

It is expected that any ALARA criteria developed for waste disposal will include in them provisions for environmental monitoring. Such efforts would be required to assure that the ultimate definition of ALARA is indeed being met. As in the case of the EPA standards being developed for waste disposal, there is no consensus as to how long into the future such monitoring should take place. Also, similar to the case of the EPA standards, it can be assumed that the ALARA criteria

will be dynamic rather than static in nature, with some modifications taking place as updated information becomes available.

It is probable that a rulemaking public hearing will be held prior to promulgation of ALARA criteria.

C. Recapitulation

A set of environmental ALARA criteria are being developed by the NRC which will be applicable to all phases of the storage of high-level radioactive wastes in Federal repositories. The criteria will not be generic in nature, but rather will treat each repository on a case-by-case basis although many criteria will be common to all repositories. The criteria are not expected to include numerical values for either the short-term (active repository operation and subsequent decommissioning) or the long-term (post-decommissioning of a repository); if indeed numerical values are included in the criteria, they would apply only for the short-term case. The ALARA criteria will provide qualitative guidance on procedures, equipment to be used, operational philosophy, monitoring requirements, etc., related to repository operation.

The NRC is currently performing, or having performed for it, several studies relating directly to the development of environmental ALARA criteria. These include studies on "acceptable risks" associated with repository operation; site suitability criteria; solid-waste performance criteria; and design and operating criteria. These studies will impact directly on the ALARA criteria being developed. Also impacting on the criteria will be the generic numerical standards for high-level wastes being prepared by the EPA; the ALARA criteria must fall under the "umbrella" of such EPA standards.

Since several of the ongoing ALARA related studies, as well as the final form of the EPA standards, are not expected to be completed until the middle of 1978, the complete set of ALARA criteria cannot be expected to be issued until after mid 1978. This does not preclude the issuance of some ALARA criteria before that time although the overall schedule is not known. Public hearings on the ALARA criteria are a distinct possibility because the disposal of high-level wastes represents a very "delicate" area of concern. The holding of such hearings would also have an effect on the date of issuance of the criteria.

The ALARA criteria are expected to be modified as the discovery of new relevant technical information becomes available.

D. References

1. Finney, B. C., Blanco, R. E., et al., "Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle for Use in Establishing 'As Low As Practicable' Guides - Nuclear Fuel Reprocessing", ORNL-TM-4901, May 1975, Revised January, 1977; issued as ORNL/NUREG/TM-6.

2. Pechin, W. H., Blanco, R. E., et al., "Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle for Use in Establishing 'As Low As Practicable' Guides - Fabrication of Light-Water Reactor Fuel from Enriched Uranium Dioxide", ORNL-TM-4902, May 1975.

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5. Groenier, W. S., Blanco, R. E., et al., "Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle for Use in Establishing 'As Low As Practicable' Guides - Fabrication of Light-Water Reactor Fuels Containing Plutonium", ORNL-TM-4904, May 1975.

6. NUREG-0116, "Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle", U.S. Nuclear Regulatory Commission, October 1976.

7. Proceedings: A Workshop on Issues Pertinent to the Development of Environmental Protection Criteria for Radioactive Wastes, ORP/CSD-77-1, Reston, Virginia, February 3-5, 1977.

8. Proceedings: A Workshop on Policy and Technical Issues Pertinent to the Development of Environmental Protection Criteria for Radioactive Wastes, ORP/CSD-77-2, Albuquerque, New Mexico, April 12-14, 1977.

9. Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10CFR50, Appendix I", U. S. Nuclear Regulatory Commission, March 1976 (updated version of Regulatory Guide 1.AA, September, 1975).

10. Regulatory Guide 1.110, "Cost-Benefit Analysis for Radwaste Systems for Light-Water-Cooled Nuclear Power Reactors", U.S. Nuclear Regulatory Commission, March 1976 (updated version of Regulatory Guide 1.FF, September, 1975).

11. Regulatory Guide 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors", U.S. Nuclear Regulatory Commission, Revision 1, July 1977 (updated version of Regulatory Guide 1.DD, September, 1975).

12. Regulatory Guide 1.112, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors", U.S. Nuclear Regulatory Commission, April 1976 (updated version of Regulatory Guides 1.BB and 1.CC, September 1975).

13. Regulatory Guide 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I", U.S. Nuclear Regulatory Commission, Revision 1, April 1977 (updated version of Regulatory Guide 1.EE, December 1975).

14. Kastner, Jacob, U.S. Nuclear Regulatory Commission, "The Rationale For and Implementation of ALARA For the Nuclear Fuel Cycle", paper presented at ANS-AIChE Topical Meeting, Controlling Air-Borne Effluents from Fuel Cycle Plants, August 5-6, 1976.

15. Bishop, W. P., U.S. Nuclear Regulatory Commission, et al., "Proposed Goals for Nuclear Waste Management", Report to the USNRC by a Special Task Force, December 21, 1976.

III. OCCUPATIONAL ALARA CRITERIA

Occupational ALARA criteria and guidelines for risk-benefit assessments are being developed, but they are primarily directed toward reactor facilities rather than to Federal repositories for nuclear wastes. Similar ALARA concepts undoubtedly will be applied to waste repositories to assure that dose commitments to radiation workers are minimized during the short-term when packaged wastes are received, inspected, encapsulated (spent fuel), and placed in the repository as well as during the longer term while the wastes are in passive underground storage after the surface facilities have been decommissioned. The occupational ALARA concept will also be applicable during the retrieval of spent fuel, deencapsulation, and shipment to a reprocessing site for recovery of the fuel values. It should be noted that repository operational ALARA concepts have not been firmly established.

DOE, NRC, EPA and AIF are all expending considerable effort on studies that are expected to have a direct impact on occupational ALARA criteria and on methodology that may ultimately be applicable at least in part to waste repositories. DOE is conducting a three-phase program which has the goal of preparation of ALARA criteria for initiating programs to reduce occupational doses and to identify research needs. NRC has the responsibility to assure any ALARA criteria it issues will be within the EPA criteria and is studying occupational health protection from all radiation sources, including the nuclear fuel cycle, i.e., wastes. NRC is studying dose reduction vs. systems and/or procedural changes. EPA is working with an interagency committee on a program to determine the adequacy of occupational exposure guidelines for radiation workers in peacetime as published by the Federal Radiation Council (FRC). It was recognized by the FRC that knowledge did not provide a firm basis within a factor of two or three for the

selection of any particular numerical value in preference to another value. The Atomic Industrial Forum is conducting a basic study to develop methodology to quantify ALARA under their National Environmental Studies Project.

As with environmental ALARA, there is some difficulty in predicting the future contents of repository occupational ALARA criteria based on past experience since there is no data base from which to draw. The methodology being developed for nuclear power plants may be partially applicable but no information was uncovered in the present NUS study to indicate that any organization has worked or is working on methodology or criteria specifically directed toward waste repository operations. The citations in the bibliography applicable to ALARA for occupational exposure are almost exclusively directed toward nuclear power plant operations. A waste repository differs from a nuclear power plant in regards to occupational exposure in that a repository is not faced with the need for annual reactor fueling; periodic maintenance of highly contaminated equipment, and exposure to high radiation fields associated with coolant pumps and piping which result in significant occupational doses to a large number of personnel especially during outages and for steam generator repair. The waste repository surface facilities are similar to certain power plant areas such as the spent fuel pool; the cask handling area; the waste processing, collection, packaging and storage areas; the ventilation systems and filter areas for parts of the power station other than the containment; and the spent ion exchange resin storage and packaging operations. These areas have relatively low radiation levels and exposures to operators and maintenance personnel are minimal. The repository underground facility is a warehousing type of operation with all containers sealed to prevent release of radioactive material. The HLW canisters and encapsulated spent fuel canisters are expected to be transferred in shielded transfer vehicles from the elevator shaft to the emplacement positions. Exposure to operators during normal operations will be minimal.

Contacts with DOE, NRC, EPA and AIF revealed that several methodologies may be forthcoming within the next year that may be applicable to waste repositories. Details of the methodologies were not available since draft reports were just being presented and copies of the first of these reports would not be available until late 1977.

A. History of Occupational ALARA Criteria

In 1934 international agreement was reached on a value for a tolerance dose for radiation workers of 0.2 roentgens (R) per day measured at the surface of the body - roughly 60R per year. In the U.S., there was an established practice of measuring the dose in air and the value for the tolerance dose was established at 0.1 R per day or about 30R per year. The Advisory Committee on X-ray and Radium Protection, which developed into what is now known as the National Council on Radiation Protection and Measurements (NCRP), published these guideline limits in its third protection report in early 1936. There was no important difference between the U.S. and international values other than the mode of measurement. In 1949, the basic value for radiation workers was lowered from 0.1R per day to 0.3R per week or an equivalent of about 15R per year - a reduction by a factor of 2 from the 1936 values. The decision to lower the values was not based on any new biomedical information, but was in recognition of the fact that more people were being exposed to many different kinds and quantities of radiation. There still have been no cases to date of development of tumors related to radiation exposure for people working under either the 1936 level of 30R per year or the 1949 level of 15R per year.

Growing international concern on effects of radioactive fallout from atmospheric testing of nuclear weapons resulted in accelerated studies in 1956

on biological effects. The principal emphasis was on the genetic effects of radiation with studies based largely on experiments with fruit flies. The National Academy of Science, the International Commission on Radiation Protection (ICRP), and NCRP justified reducing the permissible dose for radiation workers to an average value of 0.1 rem per week or 5 rem per year based on the experimental results with fruit flies. NCRP introduced the age-proration concept through which a radiation worker would be limited to a cumulative lifetime exposure of 5 rems exposure for each year of his age over age 18.

The Federal Radiation Council was established in 1959 to directly report to the President of the United States. After an extended study early in its existence, the Council adopted standards for radiation workers that are essentially the same as proposed by the NCRP in 1956. These standards were published in FRC Report No. 1 in 1960. These guideline standards are now under study by an interagency committee headed by the EPA to determine the adequacy of these occupational exposure limits.

The Recommendations of the International Commission on Radiological Protection (1966),published as ICRP Publication 9,contained paragraph 52 which reads as follows:

> "As any exposure may involve some degree of risk, the Commission recommends that any unnecessary exposure be avoided, and that all doses be kept as low as is readily achievable, economic and social considerations being taken into account. It should be noted that the dose limits are intended for planning the design and operation of sources leading to foreseeable conditions of exposure; the setting of 'action levels' for exposures from uncontrolled sources depends on other considerations.."

In December 1970, the Atomic Energy Commission published in the Federal Register (35FR18387) a new Section 20.1(c) in part 20 of the regulations that states,in part, that licensees should make every reasonable effort to maintain radiation exposures as far below the limits specified in that part as practicable.

In April 1973, the International Commission on Radiological Protection published ICRP Publication 22.titled "Implications of Commission Recommendations that doses be kept as low as readily achievable". The purpose of Publication 22 was to clarify the implications of paragraph 52 of ICRP Publication 9 which was published in 1966. Publication 22 stated that recommendations of the Commission and others for many years have included requirements to keep all radiation exposures as far below the limiting values as can be reasonably achieved. The report points out that the form of the words has differed from time to time and place to place, but the intention has been consistent. The word "possible" has been successively replaced by "practicable" and "readily achievable". The recommendation was also expanded to identify two considerations that are to be taken into account. These are economic and social considerations.

In July 1973, the U.S. Atomic Energy Commission issued Regulatory Guide 8.8 titled "Information Relevant to Maintaining Occupational Radiation Exposure As Low As Practicable (Nuclear Reactors)". The guide has subsequently been reissued, revised, and expanded by the U. S. Nuclear Regulatory Commission and the latest revision, Revision 2, was published in March 1977. The guide provides information relevant to attaining goals and objectives for planning, designing, constructing, and operating a light-water reactor nuclear power station to meet the criterion that exposures of station personnel to radiation during routine operation of the station will be "as low as is reasonably achievable". (ALARA)

The AEC published Regulatory Guide 8.10 "Operational Philosophy for Maintaining Occupational Radiation Exposures As Low as Practicable", in April 1974 which was subsequently revised and reissued by the NRC. Revision 1.R is dated September 1975 with the cover page revised in May 1977. It discusses operating philosophy for maintaining occupational radiation exposures ALARA and applies to all specific licensees. It describes an operating philosophy that the NRC staff believes all licensees should follow to keep occupational exposures to radiation ALARA. Regulatory Guide 8.10 presents the philosophy of operation including such subjects as management commitment to ALARA, periodic audits to determine where exposures may be lowered, establishment of radiation protection supervision and authority, and training programs for workers. For each facility, a position of radiation safety officer (RSO) should be established with authority to enforce safe plant operation.

A two part overview summary of the occupational exposure situation at U. S. nuclear power plants was presented in the July 1977 and September 1977 issues of Nuclear News.

B. Status of Occupational ALARA Criteria Development

1. Overview

There are a number of areas in the operation of a waste repository for potential radiation exposure and for which occupational ALARA criteria may apply. A waste repository may include surface facilities to receive spent fuel, high activity level solid wastes (HLW), cladding wastes (CW), and intermediate level wastes (ILW), and low activity level transuranic (TRU) solid wastes. Spent fuel, CW, HLW, and ILW will be received in shielded containers that must meet transportation regulations. Unloading

into pits or underwater storage pools will maintain operator exposure at a very low level. Subsequent handling, encapsulation and testing of HLW and spent fuel will be conducted in hot cells which will also maintain minimal operator exposure levels. Routine activity releases, if any, within the cells will be limited to surface contamination, primarily from spent fuel assemblies. Experience with reactor or reprocessor fuel pool operations will be similar to what would be expected at a waste repository. Some exposure would be expected during maintenance of tools, cranes, manipulators, and other in-cell equipment, the handling of pool cleanup resin beds, changing of ventilation system filters and the solidification and packaging of wastes generated on-site. Voluntarily submitted dose data from rad waste operations were somewhat higher than were expected by the NRC during their occupational health protection study.

2. DOE - Technical Guideline Development

The Division of Operational Safety of ERDA (now DOE) contracted with Pacific Northwest Laboratory during the last half of fiscal year 1976 to conduct a three phase program on occupational safety to develop technical guidelines in order to maintain occupational exposure ALARA.

Phase 1 of the program consisted of on-site reviews of DOE facilities to identify and characterize sources of reasonably avoidable exposure.

Phase 2 consisted of an indepth analysis of data, development of methods of dose reduction, and an analysis of the cost-effectiveness of implementing changes in facilities, equipment or procedures needed to effect the dose reduction. Phase 3 was to prepare ALARA criteria for initiating the dose reduction programs, to judge those criteria already in existence and to identify research needs.

PNL is now about half way through the contract and is expected to finish in late fiscal year 1978. DOE has not received any written progress reports and only expects to receive a final report. Provided PNL has followed the original scope, criteria for ALARA occupational exposure may be forthcoming within the next year.

3. NRC - Occupational Health Protection

The Office of Standards Development, Occupational Health Protection Branch of NRC has conducted a study of dose data from medical X-rays, source manufacture, and all of the various segments of the fuel cycle industry. They have received voluntarily submitted dose data for 1975 and have a draft summary. The NRC has not decided how to issue the information or even selected a title. A copy of the draft may possibly be available by late 1977. The draft will permit comparisons between different types of licensees. The information collected for this report indicated somewhat higher dose commitments than was expected from rad waste systems. A detailed study on shallow burial sites has not been started but is planned in the near future.

Testimony[1] given by Mr. Robert Alexander of the Office of Standards Development summarized a total of 18 recommendations the task group planned to submit to the Commissioners of the NRC. The primary problem identified was the need to strengthen the regulatory base for occupational ALARA. The recommended or preferred way was to specify guidance criteria in plant design and operation, compliance with which would be sufficient evidence to judge plant operation to be in accordance with ALARA. To accomplish this, one approach would be for each licensee to be required to develop their own ALARA programs for NRC review and approval for all parts of the fuel cycle. Other recommendations included such things as

increased training, preparation of new Regulatory Guides, similar to 8.8 but applicable to other fuel cycle facilities, development of a standard review plan for licensee ALARA programs, and identification of high risk areas in individual facilities. The program has been initiated as discussed above.

4. NRC - Radiation Protection Section

The Radiation Protection Section of the Radiological Assessment Branch has contracted with United Nuclear Industries (UNI) to conduct a project on the reduction of dose commitments through system and procedural changes. The project is being conducted by UNI during fiscal years 1977 and 1978 and is being applied to the Hanford-N reactor. NRC has been receiving routine internal reports on the project, but they have no plans to publish these. The final report at the end of the project will be published as a NUREG report. Since the work is directed to a specific power reactor, only the methodology and possibly data on some segments of the plant may be applicable to a waste repository.

5. EPA - Federal Guidance Section

Under the authority transferred to EPA from the Federal Radiation Council, the EPA, Federal Guidance Section, coordinates an interagency committee that has under review the basic guidelines for occupational exposure published by the Federal Radiation Council in 1960.[2] The committee is studying the adequacy of the occupational exposure guidelines published in FRC Report No. 1 and plans to develop a methodology, a framework, and a philosophy in order to provide guidance to Federal agencies in the preparation of regulations. The result of this work is hoped to be reported within the next six months. EPA is not working on Occupational ALARA criteria.

6. AIF - Quantification of ALARA

The AIF has contracted with Science Applications Inc. (SAI) to conduct a basic study under the AIF's National Environmental Studies Project. The study is to develop methodology by looking at particular jobs that require additional workers to maintain dose commitment limits. Each job is unique and site specific for determination of costs to achieve specific exposure levels. The study is not looking at health effects. The costs under study are the incremental costs incurred, e.g., to repair a specific piece of equipment. The methodology is primarily applicable to certain key high activity level areas where a worker would reach his dose limit before the job is completed and must be replaced by another worker. The methodology may be applicable to waste repository operations even though this study is directed to specific reactor high risk (of exposure) areas. The first draft of the report "Quantification of ALARA - Economic Considerations" has been received by AIF for the AIF task force review and is not available for release at this time.

C. Recapitulation

Occupational ALARA criteria and methodology are under development for power reactors which may be applicable to the waste repository operations at a Federal repository. Criteria expected to be developed by PNL for fuel cycle facilities may also be applicable to a waste repository. It may be necessary for each licensee or operator for a Federal waste repository to develop his own occupational ALARA program for submission to the NRC for review and approval. Any criteria developed are not expected to include numerical values but are expected to provide qualitative guidance on plant design, equipment to be used, operating procedures and philosophy, and monitoring (reporting) requirements related to repository operation.

The operating philosophy put forth in Regulatory Guide 8.10 Revision 1-R (May 1977) is considered applicable to waste repository operations. Specific requirements of this regulatory guide should be factored into the NWTS Program planning.

D. References

1. Advisory Committee on Reactor Safeguards, Subcommittee Meeting on Occupational Radiation Exposures, August 7, 1975 transcript.

2. Federal Radiation Council, Staff Report No. 1, "Background Material for the Development of Radiation Protection Standards", May 13, 1960.

IV. RESEARCH RECOMMENDATIONS

Since there is so much ongoing work in the development of ALARA criteria and standards and since the applicability of such developments to waste repositories is still speculative, it is recommended that the situation be reviewed and that this report be updated during the last quarter of calendar year 1978 based upon expected results of studies now in progress that are expected to be published in early or mid-1978. In addition, it is recommended that the report be periodically updated on an annual basis to assure that any modifications or additions to the criteria are brought to the attention of OWI.

OWI should insure that the ALARA concept and its implications are well known to its subcontractors and should insure that subcontractor's proposed designs and operating procedures receive technical review by engineering designers, health physicists, and/or environmental engineers who are well versed in dealing with the ALARA concept. Training programs for repository operators should be developed to include awareness of ALARA criteria. The programs should be maintained current as regulatory changes are implemented. Internal and external audit programs should be designed to assure that ALARA oriented operating procedures are being followed.

V. ENVIRONMENTAL/OCCUPATIONAL ALARA BIBLIOGRAPHY

The following bibliography was developed by computerized searches of pertinent data bases and selective review of in-house documentation related to waste repository study work. The "Orbit" system of System Development Corporation (SDC) Search Service data bases were reviewed and eight data bases were selected and searched. In addition Nuclear Safety Information Center (NSIC) in Oak Ridge performed a search of their data base. The Radiation Shielding Information Center (RSIC) performed a search using ERDA's (now DOE) RECON information retrieval system to add both Nuclear Science Abstracts and the ERDA data bases to the ORBIT and NSIC searches. In addition, the NUS' Licensing Information Service (LIS) sent a listing of materials in their files on Appendix I to 10CFR50 and available copies of NRC meeting summaries and ACRS transcripts dealing with Appendix I. A total of over 4000 titles, abstracts, and papers were reviewed and more than 100 were selected for a more detailed review. Copies of the reports and papers were obtained. The final review eliminated those that were not applicable and minimized duplication, resulting in the 83 titles that were finally selected for the bibliography. Information contained in these publications was combined with the results of personal contacts in preparing the previous sections of this report. The bibliography was assembled alphabetically by primary author and numbered to present preparation of the author index (Section V.A). Each report or paper was reviewed for content and NUS prepared the key work index (Section V.B).

(1) Albersheim, S.R., (and others), "Appendix I Analysis, Crystal River Nuclear Unit", Prepared for Florida Power Corporation, NUS-1721 (Revision 2), June, 1976.

The Crystal River facility is evaluated re its ability to meet the requirements set forth in Section II of Appendix I to 10CFR50 (ALARA). It is concluded that the maximum radiation dose as calculated for off-site individuals from all normal sources is well within the requirements of Appendix I to 10CFR50. Similarly, the integrated dose from all normal sources as a result of normal operation of the nuclear plant will have a negligible effect on the population radiation burden.

(2) Anders, W.A., (and others), United States Nuclear Regulatory Commission, "In the Matter of Rulemaking Hearing, Numerical Guides for Design Objectives and Limiting Conditions for Operations to Meet the Criterion, 'As Low as Practicable', for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents, Opinion of the Commission", Docket No. RM-50-2, April 30, 1975.

The Nuclear Regulatory Commission announces its decision in the rulemaking proceeding concerning numerical guides for design objectives and limiting conditions for operation to meet the criterion "as low as practicable" for radioactive material in light-water-cooled nuclear power reactor effluents. A history of the development of Appendix I along with the various rationale used in order to arrive at the "final" version is presented in detail. The basis for including a cost-benefit requirement is discussed.

(3) Bell, M.J., and Hewitt, W.M., Effluent Treatment Systems Branch, Division of Site Safety and Environmental Analysis, U.S. Nuclear Regulatory Commission, "Cost/Benefit Aspects of Appendix I to 10CFR50", paper presented at the ANS Annual Meeting, Toronto, Canada, June 13-18, 1976.

The means of achieving ALARA was highly subjective, until the publication of Appendix I to 10CFR50 on May 5, 1975. Prior to the issuance of Appendix I, determinations of ALARA were made using interim acceptance criteria which were proposed by the NRC staff. The paper provides a clear demonstration of how a cost/benefit analysis is performed in compliance with Section II.D of Appendix I. It was for the purpose of performing such analyses that Regulatory Guide 1.110, "Cost-Benefit Analysis for Radwaste Systems for Light-Water-Cooled Nuclear Power Reactors" was developed. The authors state that the limited experience they have had at the time their paper was prepared, indicates that in most cases the individual dose design of objectives of Sections II, A, B, and C will be more limiting than the cost-benefit analysis of Section II.D.

(4) Bellamy, Ronald R., U.S. Nuclear Regulatory Commission, "Recent Developments in NRC Guidelines for Atmosphere Cleanup System", paper presented at the 14th Air Cleaning Conference, Sun Valley, Idaho, August 2-4, 1976.

The Nuclear Regulatory Commission (NRC) maintains the policy of updating when necessary, its published guidance for the design of engineered safety feature (ESF) and normal ventilation systems. The guidance is disseminated by means of issuing new, or revisions to, existing Regulatory Guides, Standard Review Plans, Branch Technical Positions and Technical Specifications. NRC guidance is updated only when a strong technical basis exists, resulting from standards development, research developments, the determination of additional review areas that are found to be needed based on operating reactor experience, or the review of Safety Analysis Reports.

Since the 13th Air Cleaning Conference in 1974, NRC has added to and changed many of its guidelines for atmosphere cleanup systems. This paper discusses a revised Regulatory Guide, new Technical Specifications and new Standard Review Plans with Branch Technical Positions for atmosphere cleanup systems.

Regulatory Guide 1.52, "Design, Testing and Maintenance Criteria for Atmosphere Cleanup System Air Filtration and Absorption Units of Light Water Cooled Nuclear Power Plants", was issued in July 1973. Revision 1 to Regulatory Guide 1.52 reflects comments received from the industry, latest state-of-the-art technology, operating experiences and the requirements set forth in recently issued ANSI Standards N510-1975, "Testing of Nuclear Air Cleaning Systems", and ANSI N509 (draft), "Nuclear Power Plant Air Cleaning Units and Components."

Technical Specifications for ESF filter systems that require a variety of in-place tests for these systems have been issued to all operating reactors and those utilities receiving operating licenses. Standard Review Plan 11.3, "Gaseous Waste Systems", was issued December 22, 1975 and contains Branch Technical Position (BTP) Effluent Treatment Systems Branch (ETSB) No. 11-2, "Design, Testing and Maintenance Criteria for Normal Ventilation Exhaust System Air Filtration and Absorption Units of Light Water Cooled Nuclear Power Reactor Plants." BTP ETSB 11-2 outlines NRC guidance for normal ventilation exhaust systems that are designed to meet the "as low as is reasonably achievable" guidelines of Appendix I to 10CFR50, and contains NRC positions with respect to review procedures for HEPA filters for particulate removal and charcoal absorption units for low-concentration radioiodine removal.

This paper discusses the major comments received from the nuclear industry since the guide was issued in July 1973, NRC's experience in implementing the guide in recent license applications, status of operating plants in meeting the guidelines and NRC's continuing assessment of operating data and laboratory tests to assure that the guide reflects the latest technology.

(5) Belvin, E.A., (and others), Tennessee Valley Authority, Muscle Shoals, Alabama, "Control of Occupational Radiation Exposures in TVA Nuclear Power Plants - Design and Operating Philosophy", Proceedings of the Health Physics Society - 9th Midyear Symposium, Pages 639-646, February 1976.

TVA has some 21,000 MWe of nuclear generation in various phases of design, construction, or operation. When Browns Ferry was designed in the late 1960's, there were no guidelines available regarding in-plant radiation control features, so TVA relied on good engineering and health physics judgment in developing its design and operating criteria for radiation protection. After two years of operation at Browns Ferry, experience shows that the design criteria were in most cases adequate or more than adequate. However, several areas present continuing problems relative to radiation and contamination control. In view of the recent NRC ALARA guidelines, a program was instituted to ensure that the ALARA concept is made an integral part of design and operating plans. Administrative documents were issued giving management support to the ALARA concept. A 4-member management audit team consisting of representatives from design, operating, and radiation protection groups was established to review the effectiveness of radiation protection design features and operating activities on a plant-by-plant basis. Reports and recommendations from these audits are sent to top-level management staff. The goal is to maintain an audit-appraisal system consisting of in-plant awareness of radiation and contamination

conditions, assessment of trends in occupational radiation exposures, and feedback to designers regarding problems encountered during operation and maintenance activities.

(6) Bender, M., Union Carbide Corporation, Nuclear Division, Oak Ridge, Tennessee, " 'As Low As Practicable (ALAP)', Environmental Criteria, Judicial Travesty or Justifiable Rule in a Benefit-Risk/ Cost-Risk Context", Proceedings of Conference on Energy and Environmental Cost/Benefit Analysis, June 23-27, 1975, Published in "Energy", pages 640-654, Pergammon Press, 1976.

The logic of applying "as low as practicable" (ALAP) environmental criteria in a benefit-risk/cost-risk context is discussed. The premise is developed that environmental criteria have a probabilistic aspect that must be included in the balance between benefits and costs. The insurance definition of risk is used to develop the argument that environmental criteria are logically based on showing that the net risk of incurring environmental costs is in balance with the net risk of losing environmental benefits. Examples are discussed to show that excessive emphasis can sometimes be placed on long term environmental risks when compared to parallel uncontrollable risks of equivalent or greater significance. The constraints imposed by ALAP criteria are shown to be of appreciable importance in the benefit-risk/cost-risk assessment and to require careful examination to avoid inadvertent loss of environmentally beneficial resources.

(7) Bishop, William P., and Miraglia, Frank, J. Jr., (Editors) U. S. Nuclear Regulatory Commission, "Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle", NUREG-0116, October 1976.

This study deals with the reprocessing and waste management portions of the nuclear fuel cycle for uranium fueled reactors. The scope of the report is limited to the illumination of fuel reprocessing and waste management activities, and examination of the environmental impacts caused by these activities. Environmental impacts, including curie releases and doses resulting from the operation of a repository are presented and discussed.

(8) Bishop, W. P., U.S. Nuclear Regulatory Commission, (and others) "Proposed Goals for Nuclear Waste Management", Report to the USNRC by a Special Task Force, December 21, 1976.

This report proposes, for public consideration, certain guiding principles for the development, deployment, and operation of a waste management system. The purpose is to propose goals for the national waste management program in the hope that such goals will establish a policy basis for the guidance and coordination of the activities of government, business, and academic organizations whose responsibility it will be to manage radioactive wastes. It is noted that the crucial characteristic of nuclear wastes is that they are radioactive. Therefore, for all of the time during which there will be concern about radioactivity, the waste management system should operate in compliance with relevant radiation standards.

(9) Brown, W. S. and Lutz, R. J. Jr., Westinghouse Electric Corporation (PWR System Division), "The Impact of Environmental ALAP on PWRs", prepared for presentation at the Atomic Industrial Forum Seminar on Government Regulation of Nuclear Power - The Impact of Environmental Requirements on Facility Design and Operation, Washington D.C., September 7-10, 1975.

The pronouncement of the regulation in December, 1970 in the Code of Federal Regulations, 10CFR50, that radioactive material in effluents from nuclear power reactors shall be "As Low As Practicable" (ALAP), has had significant licensing, engineering, and economic impacts on the nuclear power industry. Most of the impacts resulting from the ALAP decision are common to both PWRs and BWRs. This paper summarizes what the authors perceive to be the major impacts of the environmental ALAP criteria on LWRs with special attention to PWR impacts.

In this paper the authors identify five major areas of impact of environmental ALAP on PWRs: Licensing, Design/Engineering, Plant Operations, Site Selection, and Marketing. Common to all of these is the economic impact. Examples of cost-benefit analyses are included in the paper.

(10) Campbell, C.M., (and others), U.S. Energy Research and Development Administration, "As Low As Practicable (ALAP) - What's Happening", Proceedings of the Health Physics Society - 9th Midyear Symposium, Pages 632-634, February 1976.

The concept of maintaining radiation exposures, As Low As Practicable, ALAP, as applied within ERDA and ERDA contractor facilities is discussed. ERDA policy and guidance is reviewed, followed by a sampling of approaches being used by ERDA contractors in their implementation of ALAP. Some examples of the application of ALAP techniques to specific tasks are included.

(11) Coco, Lawrence M., Westinghouse Electric Corporation, Nuclear Fuel Division, Pittsburgh, Pa., "An Analysis of Facility Design and Operation for Maintaining Personnel Exposures as Low as Reasonable Achievable", Proceedings of the Health Physics Society - 9th Midyear Symposium, Pages 647-653, February 1976.

Increasing NRC emphasis on maintaining personnel exposures as low as reasonable achievable (ALARA), has resulted in much confusion and discussion of the subject. Health physicists in operating facilities and designers of new facilities are faced with the responsibility of developing and/or implementing programs which will maintain personnel exposures ALARA, but have been given little regulatory guidance. Although several cost-benefit approaches have been recommended and general regulatory guidelines put forth in Regulatory Guide 8.8, the actual mechanics of situation analysis has not been clarified. The author has developed an ALARA program which, when used in conjunction with facility design and/or operation, anticipates potential problem areas and can contribute in reducing the total plant man-rem dose. The program provides the mechanics for analysis and evaluation of potential hazards, shielding and process design, and personnel usage.

(12) Davis, Owen H., Pacific Gas & Electric Company, "Policy and Technical Issues Pertinent to the Development of Environmental Protection Criteria for Radioactive Wastes, U.S. Environmental Protection Agency, ORP/CSD-77-2, Albuquerque, New Mexico, April 12-14, 1977.

There exists a knowledge base today from which EPA can set generally applicable criteria and standards for the geologic waste disposal of high-level and TRU wastes; that the standards set by EPA should define what is acceptable, and not attempt to define the optimum achievable result in site selection and repository design; that EPA can formulate an acceptable waste isolation index that bridges their standard

to the guidance needed by ERDA; and that these EPA general standards should not infringe either on ERDA's flexibility in achieving its programmatic goals within these EPA criteria, or on NRC's regulatory responsibilities for licensing. Concerning releases of activity from a repository, the only mechanisms that could cause a release fall into the categories of unplanned events or accidents.

(13) Dickson, H.W. (and others), Oak Ridge National Laboratory, "Application of the ALAP Concept to Occupational Exposure at Operating Light Water Reactors", Proceedings of the Health Physics Society - 9th Midyear Symposium, Pages 671-678, February 1976.

The application of the as-low-as-practicable (ALAP) concept to radiation exposure of workers at light-water reactors (LWR's) has recently received increased attention. The purpose of this project is to investigate the means by which occupational exposure at operating LWR's can be reduced to the lowest practicable levels. Nine LWR stations, including 16 operating reactors, were studied in Phase I of the project to identify significant sources of exposure and to determine the magnitude of the exposures. A complete site review consists of compiling information from safety analysis reports, plant technical specifications, and radiation exposure records coupled with an on-site visit for discussions with plant personnel, observation of procedures, and measurement of radiation levels. In Phase II, specific problem areas are being studied in-depth with regard to corrective measures to reduce exposure. Information has been collected on exposure from valve maintenance and repair. Corrective measures will be evaluated with respect to ease of application and cost effectiveness. The results of this study will serve as technical backup for the preparation of regulatory guides.

(14) Dickson, H.W., (and others), Oak Ridge National Laboratory, "Controlling Occupational Radiation Exposure at Operating Nuclear Power Stations," Nuclear Safety 18(4), pages 492-501, July-Aug. 1977.

The historical development of the philosophy of keeping the radiation exposure of workers at light-water reactors as low as reasonably achievable (ALARA) is presented. A review is made of some of the ALARA activities of the Nuclear Regulatory Commission (NRC), the Energy Research and Development Administration (ERDA), and various nuclear installations. Data compiled by the NRC shows that routine and special maintenance at light water reactors account for 65% of all occupational exposure at these sites. The role that Oak Ridge National Laboratory (ORNL) has taken in ALARA research is presented with emphasis placed on a study of valve malfunctions at light-water reactors. The valve study indicates a trend toward decreasing valve reliability over the past few years. Finally a cost-benefit analysis of radiation dose reduction is discussed. The rationale for assigning a cost per man-rem based upon the radiation exposure level that is encountered is presented.

(15) Englehart, R.W. (and others), NUS Corporation, "A Critique of the Current State of Radiation Standards Regulations for the Nuclear Power Industry", Proceedings of the Ninth Midyear Topical Symposium of the Health Physics Society, February 9-12, 1976, Denver, Colorado, pages 10-14.

The Nuclear Regulatory Commission's guidance on meeting ALAP for nuclear reactors (10CFR50, Appendix I) as being implemented and the Environmental Protection Agency's proposed Radiation Protection Standards for the Uranium Fuel Cycle are critically examined. NRC's proposed value of $1000 for a manrem appears to be too high and to have little effect on effluent control system design as compared to maximum individual dose limits. EPA appears to have vastly overestimated the effect, based on population dose and health effect risks, and underestimated the cost of

their proposed regulations to society. A return to industry regulation based on protection of maximally exposed individuals or critical groups and genetic protection for the population would probably achieve the same results as intended by those regulations based on population dose and at much less cost to society.

(16) Englehart, R.W., (and others), NUS Corporation, "Technical Assessment of Specific of EPA Proposed Environmental Radiation Standard for the Uranium Fuel Cycle (40CFR190) and Its Associated Documentation", Prepared for the Atomic Industrial Forum, Inc. AIF/NESP-011, February, 1976.

The Atomic Industrial Forum Working Group on Radiation Releases and ALAP Criteria performed a preliminary review of the proposed regulations and concluded that it would be in order to perform a more detailed review of the technical bases of the proposed regulations. This report has been prepared as a part of the more detailed review. The technical areas examined include dose models and calculations, effluent control cost effectiveness, and radio-biological effects.

The approach used in this study was to develop an understanding of EPA's technical approach, especially in the dose calculation area, and to critically compare these approaches with others such as ORNL's and those of industry, and to update technical information where more recent data are available. Many of the differences between EPA's analyses and those presented herein can be traced to the fact that EPA's are based on information which was current in the period 1971 to 1973; in some cases the analyses of this report use information becoming available as late as November, 1975 (such as health effect analyses from the final version of WASH-1400, and direct radiation dose measurements for BWR's from the Health and Safety Laboratories of ERDA).

(17) EURATOM Commission, "Proposal for a Council Directive (Euratom) to Amend the Directives Laying Down Basic Safety Standards for the Health Protection of the Population and Workers Against the Dangers of Ionizing Radiations", Official Journal of the European Committees 17(C78) pp. 1-43, July 5, 1974.

The proposed directive applies to the production, processing, handling, use, holding, storage, transport, and disposal of natural and artificial radioactive substances and to any other activity which involves a hazard arising from ionizing radiation. The proposal specifies maximum permissable doses for exposed workers and limits on partial body doses. Planned special exposures are discussed as are dose limits for the population. Fundamental principles governing protection of workers include classification of places of work into work areas, classification of workers into categories, and the implementation of control measures. Surveillance measures and instrumentation for workers and the populace are presented.

(18) Finney, B. C., (and others), "Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle for Use in Establishing 'As Low as Practicable' Guides - Nuclear Fuel Reprocessing", ORNL-TM-4901, May, 1975.

A cost-benefit study was made to determine the cost and effectiveness of radioactive waste (radwaste) treatment systems for decreasing the release of radioactive materials from a model nuclear fuel reprocessing plant which processes light-water reactor (LWR) fuels, and to determine the radiological impact (dose commitment) of the released materials on the environment. The study is designed to assist in defining the term "as low as practicable" in relation to limiting the release of radioactive materials from nuclear facilities. The base-case model plant is representative of current plant technology and has an annual capacity of 1500 metric tons of LWR fuel.

Additional radwaste treatment systems are added to the base-case plant in a series of case studies to decrease the amounts of radioactive materials released and to reduce the radiological dose commitment to the population in the surrounding area. The cost for the added waste treatment operations and the corresponding dose commitments are calculated for each case. In the final analysis, radiological dose is plotted vs. the annual cost for treatment of the radwastes. The status of the radwaste treatment methods used in the case studies is discussed. Much of the technology used in the advanced cases is in an early stage of development and is not suitable for immediate use. The methodology used in estimating the costs and the radiological doses, detailed calculations, and tabulations are presented in Appendix A and ORNL-4992.

(19) Finney, B. C., (and others), "Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle-Reprocessing Light-Water Reactor Fuel", ORNL-NUREG-TM-6, January, 1977.

This report is a revision and updating of the original study (ORNL-TM-4901).

(20) Gallagher, Frank E., University of California, "A New Facility for Processing and Storage of Radioactive and Toxic Chemical Waste", Proceedings of the Health Physics Society - 9th Midyear Symposium, pages 182-186, February 1976.

A new facility for the processing and storage of radioactive and toxic chemical waste is described. The facility is located in the science and engineering complex of the Santa Barbara campus of the University of California, near the Pacific Ocean. It is designed to provide a safe and secure processing and storage area for hazardous wastes, while meeting the high aesthetic standards and ecological requirements of campus and

community regulatory boards. The ventilation system and fire prevention features are described in detail. During the design phase, a small laboratory was added to provide an area for our radiation protection and industrial hygiene programs. Operational experience with this new facility is discussed.

(21) Gamertsfelder, Carl C., "Statement on the Selection of As Low As Practicable Design Objectives and Technical Specifications for Operation of Light Water Cooled Nuclear Power Reactors", AEC Staff Statement, January 20, 1972.

The statement discusses the operating experience of major light-water-cooled nuclear power reactors with respect to discharges of radioactive materials in liquid and gaseous effluents, including the composition and quantities of wastes eventually released; and the resulting doses to people at the boundary and elsewhere in the surrounding environment. The information forms a part of the basis for establishment of the numerical guides for design objectives in the proposed Appendix I.

(22) Groenier, W. S., (and others), "Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle for Use in Establishing 'As Low As Practicable' Guides - Fabrication of Light Water Reactor Fuels Containing Plutonium", ORNL-TM-4904, May, 1975.

A cost-benefit study was made to determine the cost and effectiveness of radioactive waste (radwaste) treatment systems for decreasing the release of radioactive materials from a model light-water plutonium recycle reactor fuel fabrication plant, and to determine the radiological impact (dose commitment) of the released materials on the environment. The study is designed to assist in defining the term "as low as practicable" in relation to limiting the release of radioactive materials from nuclear facilities. The base-case model plant is representative of current plant technology and has

an annual capacity of 300 metric tons of LWR plutonium recycle fuel. Additional radwaste treatment equipment is added to the base-case plants in a series of case studies to decrease the amounts of radioactive materials released and to reduce the radiological dose commitment to the population in the surrounding area. The cost for the added waste treatment operations and the corresponding dose commitment are calculated for each case. In the final analysis, radiological dose is plotted vs. the annual cost for treatment. Methods used in the case studies are discussed. Some of the technology used in the advanced cases is in an early stage of development and is not suitable for immediate use. The methodology used in estimating the costs and the radiological doses, detailed calculations, and tabulations are presented in Appendices A and B.

(23) Hall, T. M., United Nuclear Industries Inc., Richland Washington, "Practical Application of ALARA (ALAP) Philosophy, UNI-SA-26, April 28, 1976.

N-Reactor is the only dual-purpose reactor in the USA. It is located at the ERDA Hanford site in Washington State and produces plutonium for defense purposes and supplies steam for generation of electricity by the Washington Public Power Supply System in an adjacent station. It is owned by ERDA and is currently operated by United Nuclear Industries, Inc. The plant began operation in 1964. Monitoring of the primary coolant piping radiation levels indicated a build-up that was not linear with time. It was forming at an accelerating rate, and it was apparent that radiation exposure was going to be a significant factor in N-Plant operation. By 1967, connector piping radiation level was 1 rem/hr.

A radiation exposure reduction task force was chartered in 1967 to develop and carry out an exposure reduction plan. A decontamination task force was also chartered to determine how to chemically clean out the primary

piping to reduce radiation levels. In October 1967, the first reactor piping decontamination was performed, and connector radiation levels were reduced from 1 rem/hr to 20 mrem/hr. The task forces also attacked other radiation exposure problems with success.

In 1974, an exposure reduction program manager position was created to carry on the work of the task force efforts and to:

1. Provide more visibility to the exposure reduction activities

2. Provide formalized guidelines for exposure reduction to all work groups in the organization

3. Intensify exposure reduction training

4. Motivate participation of all personnel in the program

Out of this came the current effort for ALARA. By necessity, N-Plant operation has been applying the principles of ALARA (ALAP) since 1967. The methods have improved with time, new techniques have been put to use, and other discarded. The purpose of this paper is to describe how UNI has made practical the application of the ALARA (ALAP) principles.

(24) Hayes, John J., and Martin, Dan E., "Appendix I of 10CFR50, Cost Benefit Analysis of the Palo Verde Nuclear Generating Station and Reassessment of Maximum Individual Doses", prepared for Arizona Public Service Company, NUS-1651, February, 1976.

The objectives of the report are twofold: first to document a cost-benefit analysis which was performed to determine whether the present plant design would require additional augments justified by cost-benefit criteria and second, to reevaluate maximum individual and population doses using models as nearly identical as possible to those used by NRC.

(25) International Commission on Radiological Protection, "Implication of Commission Recommendations that Doses Be Kept As Low As Readily Achievable", ICRP Publication 22, Pergammon Press, New York, 1973.

For many years, the recommendations of the Commission and similar bodies have included requirements to keep all radiation exposures as far below the limiting values as can reasonably be achieved. The form of words has differed from time-to-time and from place-to-place, but the intention has been consistent. In practice, the qualitative requirement has given rise to some difficulties of interpretation and to requests for a more quantitative expression of the same objective. This report is an attempt by the Commission to give a more detailed explanation of its intention.

The system of dose limitation recommended by the Commission includes, but is not restricted to, the quantitative Maximum Permissable Doses and Dose Limits. As any exposure may involve some degree of risk, and thus some detriment, the comprehensive system of dose limitation is aimed at the following principal objectives:

a) to ensure compliance with the dose limits,

b) to avoid the use of unnecessary sources of exposure,

c) to provide for operational control of specific procedures, both individually and in combination, so that the resulting doses are ALARA, economic and social considerations being taken into account and,

d) to provide a more general framework to ensure that these doses are justifiable in terms of benefits that would not otherwise have been received.

It should be noted that the system of dose limitation is intended as a basis for the design and operation of facilities associated with sources leading to foreseeable conditions of exposure.

(26) Kansas Gas & Electric Company, "Response to Question 2.8 - Solid Waste Processing", SNUPPS PSAR, September 25, 1974.

The solid waste processing, handling and storing incorporates provisions for maintaining radiation exposures of operators as low as practicable with specific itemized references.

(27) Kastner, Jacob, U. S. Nuclear Regulatory Commission, "The Rationale For and Implementation of ALARA For the Nuclear Fuel Cycle", paper presented at ANS-AIChE Topical Meeting, Controlling Air-Borne Effluents from Fuel Cycle Plants, August 5-6, 1976.

An important part of the radiation protection regulations of the Nuclear Regulatory Commission is the admonition that exposures should be maintained as low as is reasonable achievable (ALARA) below the established radiation protection limits. The implementation of this regulation for environmental exposures requires a cost-effectiveness analysis of effluent control technology which may or may not be quantifiable on a generic basis. In the case of light-water reactors, the author explains how the NRC has been able to develop generic numerical design objectives that are amenable to the same cost-effectiveness analysis regardless of the station and site. On the other hand, from the lessons learned in the process of rulemaking for the control of releases from LWRs, the author feels that for the time being application of the principle of cost-effective control of effluent releases from other components of the nuclear fuel cycle will have to be carried out, as in the past, on a case-by-case basis until larger data bases are obtained. The author also feels that generic ALARA numerical guidelines for other parts of the nuclear fuel cycle than light-water reactors cannot be specified at this time because of an inadequate data base.

(28) Kniazewycz, B. G., and McArthur, W. C., "Reduction of In-Plant Exposures: Operating Experience as a Design Feedback", paper presented at the Twentieth Annual Meeting of the Health Physics Society, Buffalo, New York, July 13-17, 1975; abstracted in Health Physics, 29(6): 899, December 1975.

Concurrent with the growth of nuclear power, many problems are experienced and solved as engineering and operating experience is fed back into new plant design. With the advent of Regulatory Guide 8.8 "Information Relevant to Maintaining Occupational Radiation Exposure as Low as Practicable (Nuclear Reactors)" and Regulatory Guide 8.10, "Operating Philosophy for Maintaining Occupational Radiation Exposures as Low as Practicable", the importance of a concerted effort to reduce in-plant personnel exposure is emphasized.

Operating experience including job description and consequential personnel exposure is examined as a means of justifying and expanding many of the items presented in the paper "Design Methods for Reducing In-Plant Exposures" presented at the 19th Annual Health Physics Society Meeting.

(29) Kuhn, K., Hamstra, Jan, Munich, Germany, Petten, The Netherlands, "Geologic Isolation of Radioactive Wastes in the Federal Republic of Germany and the Respective Program of the Netherlands", proceedings of the International Symposium on the Management of Wastes from the LWR Fuel Cycle, CONF-76-0701, pp. 580-600, July 1976.

This paper describes radioactive waste disposal in geologic rock-salt formations in the Federal Republic of Germany. The Asse salt mine serves as the national research and development facility. A description of the plant is followed by a description and analysis of the operating experiences in the disposal of low- and intermediate-level wastes. Two future operations, the disposal of spent carbide fuel elements from a prototype high-temperature gas-cooled reactor and the test disposal of high-level wastes, are summarized.

The Asse prototype cavity is already under construction, whereas the Konrad iron-ore mine is at present under investigation for possible use in radioactive waste disposal. For the projected German "nuclear fuel cycle center", disposal of low- and intermediate-level wastes is planned in solution cavities and that of high-level wastes in a repository, both located in a salt dome underlying the center. The Dutch program pursues the same objectives.

(30) Lieberman, J. A., and Forbes, Ian A., Nuclear Safety Associates, Bethesda, Maryland and Energy Research Group, Inc., Framingham, Massachusetts, "Approaches to Criteria Development", paper presented at a Workshop on Issues Pertinent to the Development of Environmental Protection Criteria for Radioactive Wastes, ORP/CSD-77-1, Reston, Virginia, February 3-5, 1977.

The authors feel that within the context of general environmental protection from all radioactive wastes, a reasonable approach or first cut at criteria/standards could be quite similar to that taken by EPA in its promulation of Part 190 - Environmental Radiation Protection Standards for Nuclear Power Operations (40CFR190). The application of ALARA would be logically carried out by the NRC in its development of specific operational guidance or standards. Since EPA has a responsibility for overall environmental radiation impacts and effects, it is logical that it supply the broad quantitative guidance to other agencies on the overall levels of radiation in the environment consistent with acceptable risk to the population.

(31) Liverman, James L., Assistant Administrator for Environment and Safety, Energy Research and Development Administration, Staff Comments on Proposed EPA Regulation (40CFR190), "Environmental Radiation Protection Standards for Nuclear Power Operations" and Accompanying Draft Environmental Impact Statement, attachment to a letter to Russel E. Train, Environmental Protection Agency, September, 1975.

According to ERDA, the then-proposed EPA regulation would prescribe radiation standards for the uranium fuel cycle at levels far below the internationally and nationally established standards, on the basis of a cost-benefit analysis of the potential risk of radiation effects and the capabilities of control technology that EPA deems to be practicable. Assuming that this is an appropriate basis for developing such a standard, neither the technical justification for the numerical standards being proposed nor their cost-effectiveness are substantiated by the information presented in the "Notice of Proposed Rulemaking" or the Draft Environmental Impact Statement (DEIS) supporting the proposed rule. Also, it is ERDA's understanding that any such standards should adequately reflect the findings of the Nuclear Regulatory Commission as to the practicability of effluent controls.

(32) Liverman, James L., Assistant Administrator for Environment and Safety, U.S. Energy and Research Development Administration, "Statement on Proposed Rulemaking on Environmental Radiation Standards for the Uranium Fuel Cycle", for presentation at the EPA-sponsored public hearing, March 8-10, 1976.

The author states that ERDA does not agree either with the need for or the method of arriving at the proposed rulemaking for the following reasons: existing regulations and guidance are adequate, existing expertise was not involved in the formulation process, many uncertainties exist in the assumptions leading to the cost, risk and benefit estimates, and total cost and impact has not been assessed. ERDA recommended deferring the promulgation of the standards, making a comprehensive evaluation of all relevant biological data to arrive at a national or even international consensus for estimating health effects, analyzing total cost and environmental impact in more detail, evaluating the effect that such standards would have on "encouraging" other forms of energy production and the associated impacts, and reviewing the basis for the standards periodically as additional information becomes available.

(33) Mattson, Roger J., Director, Division of Siting, Health and Safeguards Standards, U.S. Nuclear Regulatory Commission, statement presented at EPA hearing on proposed 40CFR190, March 8, 1976.

The U. S. Nuclear Regulatory Commission feels that the (then) proposed EPA standard would provide little, if any, additional benefit beyond that provided by current regulatory practices, would impose substantial additional regulatory burden, and could prove to be impracticable in compliance by major components of the uranium fuel cycle. The NRC believes that an adequate technical data base is required for selecting the limit values in 40CFR190, if the limits are to be achieved practicably. The lessons learned in developing Appendix I concerning the practicality and feasibility of effluent controls imply that the proposed 40CFR190 is impracticable for those portions of the uranium fuel cycle in which undemonstrated effluent controls must be used to meet the proposed standard. The NRC feels that it would be impracticable to demonstrate compliance with present monitoring and surveillance programs.

(34) Mauro, John J., Porrovecchio, Joseph, EBASCO Service, Inc., New York, N.Y., "Numerical Criteria for In-Plant 'As Low As Is Reasonably Achievable'", proceedings of the Health Physics Society - 9th Midyear Symposium, pages 654-659, February 1976.

Due to the differences in the dose distributions as a function of age between the general population and the population of radiation workers, the calculated number of adverse effects per man rem in-plant is 63% of the calculated number of adverse effects per man rem off-site. The authors suggest that this ratio could be applied to off-site numerical criteria for "as low as is reasonably achievable" to obtain in-plant criteria.

(35) Maxey, Margaret N., Associate Professor of Bioethics, University of Detroit, "Nuclear Energy Politics: The Ethical Issues in Perspective", for public presentation at the meeting of the American Association for the Advancement of Science, Denver, Colorado, February 24, 1977.

The author states that "if self-appointed guardians of the public interest intend to serve the authentic public interest in an ethically responsible manner, then they will have to abandon subterfuge, fear strategies, and ideological politics. An ethical politics will require all of us to concentrate public debate and social conciousness upon a consideration of scientifically-established facts. It will also require us to recognize that risk/benefit and risk/risk assessments are a necessary condition for making wise social policies". Since the disposal of high-level wastes involves social as well as technical policies, the author's comments should receive consideration.

(36) Mulkin, Ray, (and others), Los Alamos Scientific Laboratory, University of California, "Occupational Exposure Estimates for Plutonium Fuel Conversion and Fabrication Operations", Proceedings of the Health Physics Society - 9th Midyear Symposium, pages 523-528, February 1976.

Estimates have been made for occupational exposure associated with operation of two commercial scale production plant models, one a plutonium conversion plant and the other a mixed-oxide fuel fabrication plant. The estimates were made by visualizing production and support operations through the viewpoint of a production manager responsible for scheduling and determining manpower requirements. Model plants were described in terms of design basis radiation zones and contamination zones. Control levels for airborne activity appropriate for plutonium operations were used to develop airborne concentrations. Airborne concentrations and dose rates were folded with occupational residence times in each type of zone to generate occupational dose

figures. The integrated dose for each occupational group was summed to generate a number for the plant population. Results were 300 man rem per year external exposure for the conversion plant, and 350 man rem per year external exposure for the fabrication plant. Average annual internal dose was greatest for the lung and was found to be 0.16 and 0.19 rem per man (lung dose) at the respective plants.

(37) Munson, Leo H., Freytag, Linda A., United Nuclear Industries, Richland, Washington, "An Auditable Program of Compliance with ALAP", proceedings of the Health Physics Society - 9th Midyear Symposium, pages 660-671, February 1976.

Increasing public and governmental pressure is being felt by all sectors of the Nuclear Industry to demonstrate compliance to maintaining occupational radiation exposures as low as practicable (ALAP). This paper describes a systematic approach to occupational radiation exposure reduction which will not only reduce radiation exposure usage but will provide an auditable record of compliance with ALAP. The essential features of the program include guidelines for: 1) identification and appreciation of tasks which use significant amounts of radiation exposure, 2) the contribution of the Health Physicist in reducing radiation exposure usage, and 3) a matrix for evaluation of feasibility, practicality and economics of each application.

(38) Murphy, Thomas D., Nehemias, John V., U. S. Nuclear Regulatory Commission, "Occupational Radiation Exposure Experience at Light Water Power Reactors", proceedings of the Health Physics Society - 9th Midyear Symposium, pages 529-534, February 1976.

The occupational radiation exposure data available to the NRC from power reactor licensees are described, discussed and summarized. These data, as reported in annual reports and the documents NUREG 75-032 and WASH-1311, have helped to identify those activities and design features which cause significant occupational radiation exposure in light-water reactor power plants. This identification provides a basis for the heal th physics community,

the utility industry and other components of the nuclear power industry to develop design and operational improvements which will maintain radiation exposures as low as is reasonably achievable, as required of licensees by 10CFR20. It also assists NRC staff in reviewing radiation protection programs of license applicants, in developing regulations and regulatory guidance, and in inspecting licensees, by focusing attention on those areas that are significant causes of occupational radiation exposure.

(39) National Academy of Sciences, National Research Council, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation", report of the Advisory Committee on the Biological Effects of Ionizing Radiations (BEIR Report), November, 1972.

This report of the National Academy of Sciences - National Research Council Advisory Committee on the Biological Effects of Ionizing Radiations (BEIR Committee) deals with the scientific basis for the establishment of radiation protection standards and encompasses a review and reevaluation of existing scientific knowledge concerning radiation exposure of human populations. The present basis of radiation protection is essentially the establishment of single upper limits for individual and population average exposures with the understanding that any biological risks should be offset by commensurate benefits and that these risks should be kept as low as practicable. It has become apparent that these current concepts of radiation protection may not be adequate in a future age of large-scale use of nuclear energy. Inadequacy arises because there is the potential for radiation exposure of entire populations and such exposure may be an alternative to other types of hazards as, for example, the substitution of radioactive contaminants from nuclear power plants for the combustion products from fossil fuel plants. Thus there is a need somehow to make comparisons of biological risks and benefits not only for radiation but for the alternative options. In this report it has not been

possible to deal with critical interacting factors such as socio-economics, energy needs, and comparative effects of other toxicological agents; nor to explore in detail technological matters such as sustained engineering performance of power reactors, large-scale waste disposal, or the problem of catastrophic accidents. Nevertheless, the report calls attention to these issues because ultimately, decisions will have to be made involving them, and public acceptance gained on the basis of providing society with the services that it needs at a minimum risk to health and the environment.

The BEIR Committee has endeavored to ensure that no sources of relevant knowledge or expertise were overlooked in its study and toward this end has established and maintained liaison with appropriate national and international organizations, and has solicited the opinions and counsel of individual scientists.

Particular subjects covered in this report include sources of ionizing radiation and population exposures, environmental transport and effects of radionuclides, genetic effects of ionizing radiation, effects of ionizing radiation on growth and development, and somatic effects of ionizing radiation.

(40) Nelsen, P.I., "Final Safety Analysis Report for the Atmospheric Protection System", Idaho National Engineering Laboratory, Idaho Falls, NTIS-NSC-01-01, 1976.

An Atmospheric Protection System (APS) has been constructed at the Idaho Chemical Processing Plant to minimize the release of radioactive particulate material to the atmosphere from non-routine occurrences. Existing off-gas cleanup systems remove radioactive particulates to well below allowable limits for controlled areas before release to the plant stack. Previously, all ventilation air from process cells was discharged to the stack without treatment. The APS provides continuous filtration of all ventilation air from process cells and backup filtration of all process off-gases before they are released to the atmosphere. The filter system for ventilation air consists of seven-foot deep fiberglass prefilters in series with separatorless high efficiency particulate air (HEPA) filters. This system is capable of filtering 150,000 cfm of ventilation air. The APS was found to withstand design basis natural phenomena and to be reliable under postulated accident conditions.

(41) Parker, H. M., consultant to Battelle Memorial Institute on its ERDA and other programs at Richland, "Statement on Proposed Rule-Making on Environmental Radiation Standards for the Uranium Fuel Cycle", for presentation at an EPA-sponsored public hearing, March 8-10, 1976.

In his statement, H. M. Parker suggests that the documentation supporting the proposed EPA rule-making is a most reasonable first step in applying ALAP principles to the entire nuclear fuel cycle. Due to the "arbitrary nature" of each component decision in an ALAP approach, and to their "multitudinous interactions", Dr. Parker expects it to be several years (arbitrarily about 5) before the required national wisdom will have been brought to bear to reach a sound solution. Major uncertainties in health effects predictions are discussed, international agreement on control of Kr-85 is stated to be of paramount importance, and a call for a national forum to better evaluate data relating to health effects is made.

(42) Pechin, W. H., (and others), "Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle for Use in Establishing 'As Low As Practicable' Guides-Fabrication of Light-Water Reactor Fuel from Enriched Uranium Dioxide", ORNL-TM-4902, May, 1975.

A cost-benefit study was made to determine the cost and effectiveness of radioactive waste (radwaste) treatment systems for decreasing the release of radioactive materials from a model enriched-uranium, light-water reactor (LWR) fuel fabrication plant, and to determine the radiological impact (dose commitment) of the released materials on the environment. The study is designed to assist in defining the term "as low as practicable" in relation to limiting the release of radioactive materials from nuclear facilities. The base-case model plant is representative of current plant technology and has an annual capacity of 1500 metric tons of LWR fuel. Additional radwaste treatment equipment is added to the base-case plants in a series of case studies to decrease the amounts of radioactive materials released and to reduce the radiological dose commitment to the population in the surrounding area. The cost for the added waste treatment operations and the corresponding dose commitment are calculated for each case. In the final analysis, radiological dose is plotted vs. the annual cost for treatment of the radwastes. The status of the radwaste treatment methods used in the case studies is discussed. Some of the technology used in the advanced cases is in an early stage of development and is not suitable for immediate use. The methodology used in estimating the costs and the radiological doses, detailed calculations, and tabulations are presented in Appendix A and ORNL-4992.

(43) Richardson, Allan C. B., Office of Radiation Programs, U.S. Environmental Protection Agency, "The Development and Impact of EPA Radiation Standards", presented at the AIF Seminar on Government Regulation of Nuclear Power... the Impact of Environmental Requirements on Facility Design and Operation, September 7-10, 1975.

This paper traces the history of EPA's proposed (at that time) standards for the uranium fuel cycle. The bases and rationale for the standards are given. The reaction of environmental groups and industry is discussed. The author addresses a number of issues that were raised by such groups. It is pointed out that the new standards will supercede the old 10CFR20 standards for the uranium fuel cycle part of the nuclear power industry.

(44) Rochlin, Gene I., Institute of Government Studies, University of California, Berkeley, "Long-Term Waste Management: Criteria or Standards?", paper presented at a Workshop on Issues Pertinent to the Development of Environmental Protection Criteria for Radioactive Wastes, ORP/CSD-77-1, Reston, Virginia, February 3-5, 1977.

The author can offer no suggestion as to how to convert the melange of waste disposal criteria into a simple and uniform set, let alone convert them into standards. Several of the criteria appear to be generally usable - the absence of water, seismic stability, irreversibility, and others. Any disposal method chosen will undoubtedly have other criteria specific to the type of waste or the operational conditions. The author cannot envision boiling these criteria down to a set of simple standards for release rate and dose commitment without "trivializing" both the criteria and the ethical basis for their establishment.

(45) Rochlin, G. I., University of California, Berkeley, "Nuclear Waste Disposal: Two Social Criteria", Science, Vol. 195, January 7, 1977.

Two criteria - technical irreversibility and site multiplicity - are suggested for use in establishing standards for the disposal of nuclear wastes. They have been constructed specifically to address the reduction of future risk in the face of inherent uncertainty concerning the social and political developments that might occur over the required periods of waste isolation, to provide for safe disposal without the requirement of a guaranteed future ability to recognize, detect, or repair errors and failures. The paper states that complete

irreversibility that precludes all possibility of recovery may not be the most desirable outcome. The author says that it can be argued that our obligation to the future extends to the preservation of options as well as the prevention of harm, that we have an obligation to try to avoid irreversible consequences of our actions. It may then be considered more desirable to dispose of the wastes by a method roughly as irreversible as the dispersal of uranium in present ores. This, according to the author, would at least partially correct the irreversible depletion of natural supplies of fissionable material.

(46) Roddy, J. W., (and others), "Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle-Fabrication of High-Temperature Gas-Cooled Reactor Fuel Containing Uranium-233 and Thorium", ORNL-NUREG-TM-5, September, 1976.

A cost/benefit study was made to determine the cost and effectiveness of various radioactive waste (radwaste) treatment systems for decreasing the release of radioactive materials from model High-Temperature Gas-Cooled (HTGR) fuel fabrication plants and to determine the radiological impact (dose commitment) of the released materials on the environment. The study is designed to assist the U.S. Nuclear Regulatory Commission in defining the term "as low as reasonable achievable" as it applies to these nuclear facilities. The base cases of the two model plants, a fresh fuel fabrication plant and a refabrication plant, are representative of current proposed commercial designs or are based on technology that is being developed to fabricate uranium, thorium, and graphite into fuel elements. The annual capacities of the fresh fuel plant and the refabrication plant are 450 and 245 metric tons of heavy metal (where heavy metal is uranium plus thorium), as charged to about fifty 1000-MW(e) HTGRs. Additional radwaste treatment systems are added to the base-case plants in a series of case studies to

decrease the amounts of radioactive materials released and to reduce the radiological dose commitment to the population in the surrounding area. The capital and annual costs for the added waste treatment operations and the corresponding reductions in dose commitments are calculated for each case. In the final analysis, the cost/benefit of each case, calculated as additional cost of radwaste system divided by the reduction in dose commitment, is tabulated or the dose commitment is plotted with cost as the variable. The status of each of the radwaste treatment methods used in the case studies is discussed. Much of the technology included in the advanced case studies has been utilized in either pilot-plant or industrial-scale operations, although no existing fabrication plant has used all of the treatment methods. The methodology used in estimating the costs is presented in Appendix A.

(47) Rodger, W. A., (and others), Nuclear Safety Associates, Bethesda, Md., "The Sins of the Fathers are Visited On the Children Even Unto the Third and Fourth Generations", American Nuclear Society Annual Meeting, Toronto, Ontario, June 14-18, 1976.

This paper is a satire on the development and meaning of Appendix I to 10CFR50. Although written as satire, it presents many interesting points and evaluates the meaning of Appendix I requirements on six nuclear facilities (not identified by name) for which the authors have performed Appendix I analyses. One facility is shown to require additional radwaste equipment in order to meet the cost/benefit requirements of Appendix I, four facilities are shown to require additional radwaste equipment to meet individual dose requirements of Appendix I, and all six facilities are shown to have radwaste equipment which is not <u>even needed</u> based on Appendix I requirements.

(48) Rogers, L., U.S. Atomic Energy Commission, "Discussion of Proposed Amendments to AEC Regulations on Radioactive Effluents from Light Water Cooled Nuclear Power Reactors", paper presented at the Atomic Industrial Forum Workshop on Radiation and Man's Environment, April 20, 1970, Buck Hill Falls, Pennsylvania.

This paper discusses the early approach of the concept of ALAP as applied to light-water cooled power plants. The Atomic Energy Commission announced on March 27, 1970 issuance of proposed amendments to its regulations in Part 20 and Part 50 to improve the regulatory framework for assuring that reasonable efforts are made to keep exposures to radiation and releases of radioactivity in effluents from light-water cooled power reactors as low as practicable. The proposed amendments provide quantitative values which ultimately were incorporated in Appendix I to 10CFR50.

(49) Ryon, A. D., and Blanco, R. E., "Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle for Use in Establishing 'As Low As Practicable' Guides - Appendix A. Preparation of Cost Estimates for Volume 1, Milling of Uranium Ores", ORNL-TM-4903, Vol. 2, May 1975.

This appendix presents the methodology and detailed calculations used in estimating the costs for treating the radwastes at the model uranium mills.

(50) Sagan, L. A., Palo Alto Medical Clinic, California, "Human Costs of Nuclear Power", Science, Vol. 177, pp. 487-493, August 11, 1972.

This analysis provides insights into the magnitude and distribution of the human costs of generating electricity from nuclear fuels. The analysis is based on estimates of the value of human life, lost productivity, and potential effects of radiation. Cost-benefit evaluations consider accidental injuries and deaths among individuals involved in the fuel cycle as well as potential health hazards incurred to those exposed to radiation. Assumptions are presented for the basis of assessments applied to uranium mining, fuel manufacture, reactor construction and operation, and fuel reprocessing.

(51) Sears, M. B., (and others), "Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle for Use in Establishing 'As Low As Practicable' Guides - Milling of Uranium Ores", ORNL-TM-4903, Vol. 1, May 1975.

A cost-benefit study was made to determine the cost and effectiveness of radioactive waste (radwaste) treatment systems for decreasing the release of radioactive materials from model uranium ore processing mills, and to determine the radiological impact (dose commitment) of the released materials on the environment. The study is designed to assist in defining the term "as low as practicable" in relation to limiting the release of radioactive materials from nuclear facilities. The base-case model mills are representative of mills which will process a major fraction of the ore in the next 20 years. Each mill processes 2,000 short tons of ore per day. Additional radwaste treatment techniques are applied to the base-case mill and the waste tailings area in a series of case studies to decrease the amounts of radioactive materials released and to reduce the radiological dose commitment to the population in the surrounding area. The cost for the added waste treatment operations and the corresponding does commitment are calculated for each case. In the final analysis, radiological dose is plotted vs the annual cost for treatment of the radwastes. The status of the radwaste treatment methods used in the case studies is discussed. Much of the technology used in the advanced cases will require development and demonstration and is not suitable for immediate use. The methodology used in estimating the costs, detailed calculations, and tabulations are presented in ORNL-TM-4903, Volume 2. The methodology and assumptions for the radiological doses are found in ORNL-4992.

(52) Southern California Edison Company and San Diego Gas and Electric Company, San Onofre Nuclear Generating Station Units 2 and 3, Applicants Environmental Report - Operating License Stage, Docket Nos. 50-361 and 50-362, Appendix 5A, "Radiological Cost-Benefit Analysis", March 21, 1977.

Section II.D. of Appendix I to 10CFR50 requires that liquid and gaseous radwaste systems for light water cooled nuclear power reactors include all items of reasonably demonstrated technology that, when added sequentially in order of diminishing cost-benefit return, can effect reductions of 50 mile population dose for less than $1,000 per man-rem or man-thyroid-rem on an annualized basis. An evaluation of possible system augments is made. It is shown that, based on the cost estimates of USNRC Regulatory Guide 1.110, no liquid or gaseous radwaste system augments can be justified on a cost-benefit basis.

(53) Stannard, J. N., Professor of Radiation Biology and Biophysics, Emeritus, University of Rochester Medical Center, Rochester, New York, Statement for Hearings on EPA Draft Environmental Statement on "Environmental Radiation Protection Requirements for Normal Operations of Activities in the Uranium Fuel Cycle" and Supplementary Information on Proposed Standards, Washington, D.C., March 8-10, 1976.

The paper is concerned with broad issues of radiation protection and philosophy with particular reference to the expression and treatment of this philosophy in the Draft Environmental Statement. The author states that the "low as practically achievable" admonitions has lead away from biomedical to technological considerations. The DES is suffering to a significant degree from overemphasis on technological feasibility with accompanying neglect of important biological considerations. The author feels that a national or even international effort should be undertaken to come up with a better standard.

(54) Stewart, J. E., Werner & Pfleiderer Corporation, Waldwick, New Jersey, "Reduction in Radiation Exposure and Volume Using Asphalt Solidification", proceedings of the Health Physics Society - 9th Midyear Symposium, pages 172-181, February, 1976.

The solidification of liquid and solid radioactive wastes from nuclear power plants with an extruder-evaporator using an asphalt binder minimizes both volume and radiation exposure. The automatic evaporation of water in liquid radwastes prior to incorporation into asphalt reduces the volume to be transported and disposed. In turn, the numbers of drums requiring handling is reduced 5 to 10 times thereby lessening the chances for radiation exposure. Also, the extruder-evaporator is self-shielded and contains only about one gallon of the radwaste. Dose rates at the surface of the equipment and filled containers from commercially operating systems for the past 10 years in Europe are given.

(55) Topp, S. V., E.I. du Pont de Nemours and Co., Savannah River Laboratory, "Summary of Alternatives for Long-Term Management of Defense High-Level Radioactive Waste", paper presented at a Workshop on Policy and Technical Issues Pertinent to the Development of Environmental Protection Criteria for Radioactive Wastes, U.S. Environmental Protection Agency, ORP/CSD-77-2, Albuquerque, New Mexico, April 12-14, 1977.

This document was prepared to provide other government agencies and the public information on possible alternatives which will be considered for the long-term management of Savannah River Plant high-level nuclear waste. It describes a number of alternative plans for long-term management or disposal of the high-level nuclear wastes now stored in tanks at the Savannah River Plant near Aiken, South Carolina. The description includes implementation technology, risks to the public, and preliminary budgetary cost estimates.

It does not, however, taken into account social and public policy issues. Instead, the document presents factual information on the aspects of alternatives that are possible to quantify (costs and risks) so as to serve as a basis for discussion and judgment in future decision making. No selection of an alternative for implementation is made in this document. Comments will be taken into account in selecting a proposed statement prepared to assess in detail the potential environmental impact of that proposed action. The selected program will be conducted in accordance with all environmental, health, and safety requirements.

(56) Trowbridge, G.F., firm of Shaw, Pittman, Potts, and Trowbridge, "Statement on Behalf of the Utility Group" at the EPA Public Hearing on Radiation Standards for Nuclear Power", March 8, 1976.

The statement is concerned with EPA's then-proposed standard of 25 mrem maximum dose to any individual from all sources within the fuel cycle. It is felt by the Utility Group that the standard is entirely unnecessary. For light water reactors, which are at present the only important nuclear facilities affected by the standard, Appendix I as adopted by the Nuclear Regulatory Committee is stated to be a completely adequate regulation. For reprocessing plants, which will not be in operation for some years and which will be few in number for an even longer time, adequate controls on radioactive effluents will be assured through application by the NRC of its as-low-as-reasonably-achievable licensing criteria. Potential problems between the proposed EPA standard and Appendix I are discussed.

(57) U.S. Atomic Energy Commission, "Concluding Statement of Position of the Regulatory Staff", Public Rulemaking Hearing On: Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion "As Low As Practicable" for Radioactive Material in Light-Water-Cooled Nuclear Power Reactors, Docket No. RM-50-2, February 20, 1974.

The Regulatory staff has prepared and submitted this Concluding Statement of its views of this rulemaking proceeding. The views are based upon a review of the entire evidentiary record. Appropriate consideration has been given to the views and arguments of all the participants. The Statement includes the technical bases for the views of the staff on the many technical issues involved in the rulemaking proceeding. The staff's recommendations are reflected in a draft modified Appendix I to Part 50 of Title 10 of the Code of Federal Regulations.

(58) U.S. Atomic Energy Commission, "Final Environmental Statement Concerning Proposed Rule Making Action: Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion "As Low As Practicable" for Radioactive Material in Light-Water -Cooled Nuclear Power Reactor Effluents", WASH-1258 (3 Volumes), July 1973.

The Final Environmental Statement evaluates the practicability and environmental impact of releasing radioactive material in effluents from light-water-cooled nuclear power stations within the levels set forth in the proposed (June 1971) Appendix I guides and also evaluates alternatives for providing guidance on limiting levels of radioactive material in effluents from light-water-cooled nuclear power stations to as low as practicable levels. The Statement does not set forth final AEC staff conclusions with respect to the specific rule making action or choose or identify preferable options among the alternatives to that action. Included in Volume 1 is the June 1971 proposed Appendix I.

(59) U. S. Atomic Energy Commission, Regulatory Guide 8.8, "Information Relevant to Maintaining Occupational Radiation Exposure as Low as Practicable (Nuclear Reactors)", July 24, 1973.

Licensees should make every reasonable effort to maintain radiation exposures and releases of radioactive materials in effluents to unrestricted areas as far below the limits specified in that part as practicable. This guide outlines the information needed in license applications and safety analysis reports for nuclear reactors concerning the maintenance of occupational doses as low as practicable.

(60) U.S. Atomic Energy Commission, Regulatory Guide 8.10, "Operating Philosophy for Maintaining Occupational Radiation Exposures as Low As Practicable", April 1974.

This Guide describes to licensees a general operating philosophy acceptable to the AEC Regulatory staff as a necessary basis for a program of maintaining occupational exposures to radiation as low as practicable. Both this guide and regulatory guide 8.8 deal with the concept of "as low as practicable" occupational exposures to radiation.

(61) U.S. Environmental Protection Agency, "Draft Environmental Statement For a Proposed Rulemaking Action Concerning Environmental Radiation Protection Requirements for Normal Operations of Activities in the Uranium Fuel Cycle", May 1975.

The Environmental Protection Agency proposes standards to limit radiation doses to the general public and quantities of long-lived radioactive materials in the general environment attributable to planned releases from operations contributing to the generation of electrical power through the uranium fuel cycle. These standards are proposed to apply to all operations within the fuel cycle, including the operations of milling, conversion, enrichment, fuel fabrication, light-water-cooled reactors, fuel reprocessing, and transportation of radioactive materials in connection with any of these operations. These operations may occur in any State, although milling operations are expected to occur primarily in Wyoming, New Mexico, Texas, Colorado, Utah, and Washington.

The bases and rationale for the proposed standards are presented in the draft environmental statement.

(62) U.S. Environmental Protection Agency, "Environmental Analysis of the Uranium Fuel Cycle", (Three parts: Part I, Fuel Supply, EPA-520/9-73-003-B, October 1973; Part II, Nuclear Power Reactors, EPA-520/9-73-003-C, November 1973; Part III, Nuclear Fuel Reprocessing, EPA-520/9-73-003-D, October 1973).

The generation of electricity by light-water-cooled nuclear power reactors using enriched uranium for fuel is experiencing rapid growth in the United States. This increase in nuclear power reactors will require similar growth in the other activities that must exist to support these reactors. These activities, the sum total of which comprises the uranium fuel cycle, can be conveniently separated into three parts: 1) the operations of milling, conversion, enrichment, fuel fabrication and transportation that convert mined uranium ore into reactor fuel, 2) the light-water-cooled reactor that burns this fuel, and 3) the reprocessing of spent fuel after it leaves the reactor.

The complete analysis comprises three reports: The Fuel Supply (Part I), Light-Water Reactors (Part II), and Fuel Reprocessing (Part III). High-level waste disposal operations have not been included in this analysis since these have no planned discharges to the environment. Similarly, accidents, although of potential environmental risk significance, have also not been included. Other fuel cycles such as plutonium recycle, plutonium, and thorium have been excluded. Insofar as uranium may be used in high-temperature gas-cooled reactors, this use has also been excluded.

The principal purposes of the analysis are to project what effects the total uranium fuel cycle may have on public health and to indicate where, when,

and how standards limiting environmental releases could be effectively applied to mitigate these effects. The growth of nuclear energy has been managed so that environmental contamination is minimal at the present time; however, the projected growth of this industry and its anticipated releases of radioactivity to the environment warrant a careful examination of potential health effects. Considerable emphasis has been placed on the long-term health consequences of radioactivity releases from the various operations, especially in terms of expected persistence in the environment and for any regional, national or worldwide migration that may occur. It is believed that these perspectives are important in judging the potential impact of radiation-related activities and should be used in public policy decisions for their control.

(63) U.S. Environmental Protection Agency, "Considerations of Health Benefit-Cost Analysis for Activities Involving Ionizing Radiation Exposure and Alternatives (BEIR II Report)", EPA 520/4-77-003, 1973.

The report of health benefit-cost analysis of exposure to low levels of ionizing radiation and the application of various methods of such analysis defines the overall problems of such analysis, describes the need, and applies the methods described to illustrative examples.

(64) U.S. Environmental Protection Agency, "Environmental Analysis of the Uranium Fuel Cycle, Part IV, Supplementary Analysis: 1976", EPA/520/4-76/017.

In 1973 the Office of Radiation Programs issued an environmental analysis of the uranium fuel cycle, which was issued in three volumes covering fuel supply, power reactors, and fuel reprocessing. Subsequent to the issuance of this analysis, the Agency proposed environmental radiation protection standards on May 29, 1975, for nuclear power operations of the uranium fuel cycle (40CFR190). The Agency held public hearings on these proposed

standards in Washington, D.C., on March 8-10, 1976. As a result of the ensuing comments, a number of areas were identified in which the development of additional information was necessary.

It is the objective of this new Part IV, entitled "Supplementary Analysis - 1976", to address several technical areas in which new information is available or which were discussed only briefly in previous reports. In the former category are sections pertaining to uranium milling and fuel reprocessing, while items such as transuranic effluents from recycled uranium and nitrogen-16 skyshine at BWRs fall into the second category. Finally, Part IV replaces and updates the technical discussions presented in the January 5, 1976, Supplementary Information document.

As in the original reports, the principal purposes of these analyses are to project the impact on man of the environmental releases of radioactive materials from the fuel cycle, and to assess the capabilities and costs of controls available to manage environmental releases of these materials.

(65) U.S. Environmental Protection Agency, "Environmental Radiation Dose Commitment: An Application to the Nuclear Power Industry", EPA-520/4-73-002, February 1974.

The concept of environmental dose commitment is developed and illustrated by application to projected releases of selected radionuclides from the nuclear power industry over the next fifty years. The concept encompasses the total projected radiation dose to populations committed by the irreversible release of long-lived radionuclides to the environment, and forms a basis for estimating the total potential consequences on public health of such environmental releases. Because of the difficulty of making projections of radio-nuclide transport on the basis of present knowledge, these potential consequences have been calculated only for the first one hundred-year

period following release. The particular radionuclides considered are tritium, krypton-85, iodine-129, and the actinides.

(66) U.S. Environmental Protection Agency, "Environmental Radiation Protection for Nuclear Power Operations", Proposed Standards, (40CFR190), Supplementary Information, January 5, 1976.

As a result of the review of comments received on these proposed environmental radiation protection standards for normal operations of activities in the uranium fuel cycle, the Agency has identified a number of areas in which additional information would be desirable in order to provide a reasonable basis for discussion and comment on this proposed rulemaking at the public hearing scheduled for February 17, 1976. This material has been developed to supplement that contained in the notice proposing these standards (40 FR 23420), as well as the draft environmental statement and technical reports made available at that time. It does not constitute a complete response to comments, since the public record is still open. Modifications of the original proposal made as the result of comments received and a complete response to comments will be contained in the final environmental statement and notice of final rulemaking, which will reflect all the information received, including that developed at public hearings.

Three categories of additional information are included in this Supplement:

(1) EPA's intent regarding implementation of the standards and further elucidation of the basis used for assessing potential health impacts.

(2) Technical considerations of multiple reactors on a single site, the nuclear energy center concept, transuranic effluents from recycled uranium, and N-16 skyshine doses and control at BWR's.

(3) Additional information concerning control methods, reprocessing and milling.

(67) U.S. Environmental Protection Agency, "Environmental Radiation Protection Standards for Nuclear Power Operations", 40CFR190, Federal Register, Vol. 42, No. 9, Thursday, January 13, 1977.

The regulations setting forth environmental radiation standards for the uranium fuel cycle are hereby promulgated in final form. The standards specify the numerical levels below which normal operations of the uranium fuel cycle are determined to be environmentally acceptable. Mining operations, transportation of radioactive material, and operations at waste disposal sites are excluded from these standards. The introduction to the standards says that the Environmental Protection Agency is addressing the development of criteria and standards for management of radioactive wastes as a separate matter.

(68) U.S. Environmental Protection Agency, "Final Environmental Statement, 40CFR190, Environmental Radiation Protection Requirements for Normal Operations of Activities in the Uranium Fuel Cycle", EPA 520/4-76-016, Volume 1, November, 1976.

Volume 1 of the statement summarizes the data base and judgments upon which the proposed environmental radiation standards for planned radioactive effluents from the uranium fuel cycle are based. It also provides an assessment of the anticipated impact of the proposed standards and of alternate courses of action on public health, the environment, the industry and government.

(69) U.S. Environmental Protection Agency, "Final Environmental Statement, 40CFR190, Environmental Radiation Protection Requirements for Normal Operations of Activities in the Uranium Fuel Cycle", EPA 520/4-76-016, Volume II, November 1, 1976.

This volume of the Final Environmental Statement addresses all comment letters submitted on the Draft Environmental Statement. Specific items of common concern to a number of commentors have been consolidated so that they could be addressed by a single response. Each comment is followed by code numbers to identify each of the letters which raised the issue covered by the comment. All of the comment letters are reproduced in the Appendix, together with an index which provides a guide to locating the comment letters by code number.

(70) U.S. Environmental Protection Agency, "Proceedings: A Workshop on Issues Pertinent to the Development of Environmental Protection Criteria for Radioactive Wastes", ORP/CSD-77-1, Reston, Virginia, February 3-5, 1977.

The purpose of the workshop was to elicit public concerns about radioactive wastes. Such concerns would be considered by EPA in the development of criteria and standards for waste disposal. A consensus was developed on many points as follows:

1. There is now sufficient information available for the development of criteria and standards and that the EPA should thus begin to develop them immediately.

2. Isolation of high level wastes in suitable geological formations was desirable.

3. The radioactive waste disposal method should be independent of the stability of society.

4. Safety of future generations should be a major factor in criteria development.

5. The criteria should specify levels of control which isolate wastes from the biosphere for the period of concern.

6. The criteria should not be keyed to any one method of disposal or form of radioactive waste.

7. Accidents and unplanned releases should be considered in the formulation of criteria.

8. The criteria should take into account the international implications of radioactive waste disposal.

9. Risk considerations must be taken into account when establishing the criteria.

10. Risks associated with radioactive wastes should be placed in the context of other risks from similar pollutants or environmental hazards.

11. The public, and state and local governments, should be involved in the decision making process on radioactive waste criteria and other such future regulation and criteria forming efforts.

(71) U.S. Environmental Protection Agency, "Proceedings: A Workshop on Policy and Technical Issues Pertinent to the Development of Environmental Protection Criteria for Radioactive Wastes", ORP/CSD-77-2, Albuquerque, New Mexico, April 12-14, 1977.

The purpose of the workshop was to elicit public concerns about radioactive waste. Such concerns would be considered by the EPA in the development of criteria and standards for waste disposal. There were many opinions expressed which either overlapped from working group to working group, or were generally applicable to the development of criteria for all radioactive wastes. These are summarized below without specific mention of the working group from which they evolved:

1. General agreement was reached that the criteria that EPA will be developing should apply to waste management and not address disposal alone.

2. A consensus was reached that all unplanned events and accidents should be considered by EPA in developing criteria and setting standards for radioactive waste.

3. Retrievability should be considered only when safety will not be compromised.

4. It was generally concluded that it is desirable to address radiation exposure, regardless of its source, and therefore it would not be appropriate to distinguish between waste types.

5. Wastes should be managed so that risk to future generations would be no greater than we are willing to accept for ourselves.

6. It was generally agreed that both maximum individual and population dose limitations should be considered.

7. It was suggested that EPA should make a considerable effort to broaden the general public's information base concerning radioactive waste so that more effective input would be possible.

(72) U.S. Nuclear Regulatory Commission, "Appendix I - Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low As Practicable' for Radioactive Material in Light Water Cooled Nuclear Power Reactor Effluents", 10CFR50, Appendix I, Federal Register, Vol. 40, No. 87, Monday May 5, 1975.

This appendix provides numerical guides for design objectives and limiting conditions for operation to assist applicants for, and holders of, licenses for light water cooled nuclear power reactors in meeting the requirements of paragraphs 50.34a and 50.36a of 10CFR50 that radioactive material in effluents released from these facilities to unrestricted areas be kept as low as practicable. Design objectives and limiting conditions for operation conforming to the guidelines of this Appendix shall be deemed a conclusive showing of compliance with the "as low as practicable" requirements of 10CFR50.34a and 50.36a.

(73) U.S. Nuclear Regulatory Commission, "Application of Cost-Benefit Analysis Requirements of Appendix I to Certain Nuclear Power Plants", 10CFR50, Appendix I, Federal Register, Vol. 40, No. 172, Thursday, September 4, 1975.

The Nuclear Regulatory Commission has adopted amendments to Appendix I of 10CFR50. Appendix I sets forth numerical guides for design objectives and limiting conditions for operation to meet the criterion "as low as practicable" for radioactive material in light-water-cooled nuclear power reactor effluents. The amendments provide persons who have filed applications for construction permits for light-water-cooled nuclear power reactors which were docketed on or after January 2, 1971, and prior to June 4, 1976, the option of dispensing with the cost-benefit analysis required by Paragraph II.D of Appendix I if the proposed or installed radwaste systems and equipment satisfy the Guides on Design Objectives for Light-water-cooled Nuclear Power Reactors proposed by the Regulatory staff in the rulemaking proceeding on Appendix I (Docket-RM-50-2).

(74) U.S. Nuclear Regulatory Commission, "Draft Model Technical Specifications for Boiling Water Reactors", May 7, 1976.

Guidance regarding the preparation of environmental Technical Specifications for boiling water reactors is given. This draft, although still under internal NRC review, supplies information to implement Section V.B.2 of Appendix I. Adherence to the requirements of the Technical Specifications will ensure that the releases of radioactive material to unrestricted areas are as low as is reasonable achievable.

(75) U.S. Nuclear Regulatory Commission, "Draft Model Technical Specifications for Pressurized Water Reactors", May 7, 1976.

Guidance regarding the preparation of environmental Technical Specifications for pressurized water reactors is given. This draft, although still under under internal NRC review, supplies information to implement Section V.B.2 of Appendix I. Adherence to the requirements of the Technical Specifications will ensure that the releases of radioactive material to unrestricted areas are as low as is reasonable achievable.

(76) U.S. Nuclear Regulatory Commission, Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10CFR50, Appendix I", March 1976.

To implement Appendix I, the NRC staff has developed a series of guides that provide methods acceptable to the staff for the calculation of preoperational estimates of effluent releases, dispersion of the effluents in the atmosphere and different water bodies, and estimation of the associated radiation doses to man. This guide describes basic features of these calculational models and suggests parameters for the estimation of radiation doses to man from effluent releases. The methods used are general approaches that the NRC staff has developed for application in lieu of specific parameters for individual sites. The use of site-specific values by the applicant is encouraged. However, the assumptions and methods used to obtain these parameters should be fully described and documented.

(77) U.S. Nuclear Regulatory Commission, Regulation Guide 1.110, "Cost-Benefit Analysis for Radwaste Systems for Light-Water-Cooled Nuclear Power Reactors", March 1976.

To implement the requirements of Appendix I, the NRC staff has developed a series of guides providing methods acceptable to the staff for the calculation of effluent releases, dispersion of effluents in the atmosphere and different water bodies, associated radiation doses to man, and cost-benefit aspects of treating radwastes. This regulatory guide describes a method for performing a cost-benefit analysis for liquid and gaseous radwaste system components.

The procedures and models provided in this guide will be subject to continuing review by the staff with the aim of providing greater flexibility to the applicant in meeting the requirements of Appendix I. As a result of such reviews, it is expected that alternative acceptable methods for calculation will be made available to applicants and that calculational procedures found to be unnecessary will be eliminated.

(78) U.S. Nuclear Regulatory Commission, Regulatory Guide 1.111, Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors", March 1976.

Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low As Is Reasonable Achievable' for Radioactive Material in Light Water Cooled Nuclear Power Reactor Effluents", to 10CFR50 provides numerical guidance for those design objectives and limiting conditions for operation for light-water-cooled nuclear power plants. To implement Appendix I, the NRC staff has developed a series of guides providing acceptable methods for the calculation of effluent releases, dispersion of the effluent in the atmosphere and water

bodies, and associated radiation doses to man. This guide describes basic features of calculational models and assumptions for the estimation of atmospheric transport and dispersion of gaseous effluents in routine releases from land-based light-water-cooled reactors.

(79) U.S. Nuclear Regulatory Commission, Regulatory Guide 1.112, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors", April 1976.

To implement the design objectives of Appendix I, the NRC staff has developed a series of regulatory guides that provide methods acceptable to the staff for the calculation of effluent releases, dispersion of the effluent in the atmosphere and different water bodies, and associated radiation doses to man.

This regulatory guide references two NUREG reports (0016 and 0017) that provide acceptable methods for calculating annual average expected releases of radioactive material in liquid and gaseous effluents from light-water-cooled nuclear power reactors. The procedures and models provided in the referenced NUREG reports will be subject to continuing review by the NRC staff with the aim of employing the best available experimental data and calculational models in order to achieve increased accuracy and realism. As a result of such reviews, it is expected that alternative acceptable methods for calculation will be made available to applicants and that calculational procedures found to be unnecessary will be eliminated. The guide supersedes portions of Regulatory Guide 1.42, Revision 1, "Interim Licensing Policy on as Low as Practicable for Gaseous Radioiodine Releases from Light-Water-Cooled Nuclear Power Reactors", which has been withdrawn.

(80) U.S. Nuclear Regulatory Commission, Regulatory Guide 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I", Revision 1, April 1977.

To implement Appendix I, the staff has developed a series of guides that present methods acceptable to the staff for calculating preoperational estimates of effluent releases, dispersion of the effluent in the atmosphere and different water bodies, and the associated radiation doses to man. This guide describes basic features of calculational models and suggests methods of determining values of model parameters for the estimation of aquatic dispersion of both routine and accidental releases of liquid effluents. The methods described herein are general approaches that the NRC staff has adopted for the analysis of routine and accidental releases into various types of surface water bodies. Models for the ground-water pathway are not covered in this guide. Those few cases where the ground-water pathway makes a significant contribution to the dose estimates will be analyzed on a case-by-case basis. Standards for analysis of releases to ground water are currently being developed by the American Nuclear Society and will be published by the American National Standards Institute.

(81) Vance, J. N., and Tosetti, R. J., Bechtel Power Corporation, "Is the Appendix I Cost-Benefit Analysis Worth the Effort?", presented at the annual American Nuclear Society Meeting, Toronto, Canada, June 1976.

This paper examines the size of the effort associated with performing the Appendix I cost-benefit analysis required by the NRC staff and suggests an alternative method for complying with the Appendix I requirements. The alternative method is a simplified approach which separates the site-specific and the non-site-specific parameters. The site-specific parameters include meteorology, population and production distributions. The non-site-specific parameters include the radiological source terms, the dose conversion factors for each pathway, the cost of the treatment equipment and the release point. Nomographs are presented which facilitate performance of the cost-benefit analysis.

(82) Wilson, R., Ontario Hydro, Toronto, Ontario, "Man-rem, Economics and Risk in the Nuclear Power Industry", Nuclear News pp. 28-30, February 1972.

Ontario Hydro experience in nuclear power production has led to an increasing awareness of the importance of man-rem consumption as a parameter in power station construction and operation. There are two aspects of station man-rem consumption that must be considered, and these are worker safety and economics. It might appear that these two concerns are opposed and that efforts to reduce man-rem consumption would mean an increase in the ultimate cost of power, but this is not so, and indeed on future large multi-unit stations the opposite might well hold.

(83) Wilson, R., (and others), Ontario Hydro, Toronto, Ontario, "Man-rem Expenditures and Management in Ontario Hydro Nuclear Power Stations", Ontario Hydro Health Physics Department, HPD-75-1, July 1975.

Operation of the CANDU stations over the past 12 years resulted in situations where man-rem consumption exceeded that available from station staff. The historical annual dose consumption for each station is presented and the breakdown of annual dose over the past three year period by major work groups show operators and mechanical maintenance groups receive the highest fractions of station dose although no individual worker exceeded the dose limit. Modification work was undertaken to eliminate alloys with high percentage of cobalt such as stellite pump bearing sleeves. New methods of decontamination were instituted and local shielding was applied to identified major radiation sources. Training was provided in basic health physics to designers and a man-rem accounting process oriented to tasks was instituted to identify doses associated with routine small jobs. Design targets for dose limits were developed and the economic worth of a man-rem is discussed. Various approaches for reducing exposures were considered and tabulated in descending order of effectiveness.

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