DRAFT

ENVIRONMENTAL STATEMENT

ENVIRONMENTAL RADIATION PROTECTION REQUIREMENTS FOR NORMAL OPERATIONS OF ACTIVITIES IN THE URANIUM FUEL CYCLE

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Radiation Programs

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ENVIRONMENTAL STATEMENT

FOR A

PROPOSED RULEMAKING ACTION

CONCERNING

ENVIRONMENTAL RADIATION PROTECTION REQUIREMENTS FOR NORMAL OPERATIONS OF ACTIVITIES IN THE URANIUM FUEL CYCLE

Environmental Protection Agency
Region V
Chicago

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RADIATION PROGRAMS

MAY 1975

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Prepared by

OFFICE OF RADIATION PROGRAMS

Approved by

Roger Strelow

Assistant Administrator for Air and Waste Management

MAY 12, 1975

SUMMARY

(x) Draft
( ) Final Environmental Statement

Environmental Protection Agency
Office of Radiation Programs

1. The proposed action is administrative.

2. 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.

3. Summary of environmental impact and adverse effects.

   a. The proposed standards would limit irreversible contamination of the local, national and global environment due to releases of radioactive krypton-85 (half-life 10.7 years), iodine-129 (half-life 17 million years), and alpha-emitting transuranics (half-lives 18 years to 2 million years). The total reduction in potential health impact attributable to operations through the year 2000 is estimated to be in excess of 1000 cases of cancer, leukemia, and serious genetic effects in human populations.

   b. Maximum annual radiation doses to individual members of the public resulting from fuel cycle operations would be limited to 25 millirems to the whole body and all other organs except thyroid, which would be limited to 75 millirems. Current Federal Radiation Protection Guides for maximum annual dose to

individual members of the public are 500 millirems to the whole body and 1500 millirems to the thyroid from all sources of exposure except those due to medical use and natural background. However, most fuel cycle operations are now conducted well within these guides, and the principal impact of the proposed individual dose limits will be limited to the relatively small populations in the vicinity of mills, conversion, and fabrication facilities.

c. There are no anticipated adverse environmental effects of the proposed standards.

4. The following alternatives were considered.

a. No standards.

b. Revision of Federal Radiation Guides for maximum annual exposure of members of the public.

c. Standards for fuel reprocessing facilities only.

d. Standards without a variance for unusual operating situations, and incorportating standards for annual population dose to limit environmental burdens of long-lived radionuclides.

e. The proposed standards.

f. Standards based on a lower level of cost-effectiveness than those proposed.

g. Standards based on use of "best available" effluent controls.

5. The following Federal agencies have been asked to comment on this Draft Environmental Statement.

Department of Commerce
Department of Health, Education, and Welfare
Department of Interior
Department of Transportation
Energy Research and Development Administration
Federal Energy Administration
Nuclear Regulatory Commission

6. This draft environmental statement was made available to the public, the Council on Environmental Quality, and the other specified agencies on _____, 1975; single copies are available from the Director, Criteria and Standards Division (AW-560), Office of Radiation Programs, U.S. Environmental Protection Agency, 401 M Street, S.W., Washington, D.C. 20460.

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I. INTRODUCTION

Within the last few years, it has become clear that the national effort to develop a commercially viable technology to generate electricity using nuclear energy has been successful, and that the generation of electrical power by this means will play an essential and major role in meeting national power needs during the next several decades. However, this extensive projected use of nuclear power has led to widespread public concern over the hazards to health posed by the radioactive materials associated with nuclear power generation. Unlike fossil-fueled power generation, which uses fuels known to man from prehistoric times, the fissioning of nuclear fuel is a very recently discovered phenomenon and man is just beginning to learn how to assess the full implications of its exploitation. Paradoxically it is also true, however, that we know more about the implications for health of radioactive materials than of the pollutants released by the burning of traditional fossil fuels. This knowledge facilitates the process of assessing the implications of using nuclear energy for the generation of electrical power. This is particularly true for planned releases of radioactive materials; the assessment of accidental releases is a much more difficult task which is heavily dependent upon our limited capability to predict the probabilities of accidents. As part of the process of developing these proposed standards, the Agency has made a

comprehensive assessment of planned releases of radioactive materials associated with nuclear power generation, so as to assure the best available basis for judgments of what the potential effects on public health and the environment are, what can be done to minimize these effects through the issuance of environmental radiation standards, and the costs and tradeoffs involved.

The Environmental Protection Agency was vested with the responsibility for establishing environmental radiation standards through the transfer of authorities to the Agency from the Atomic Energy Commission (AEC) and the former Federal Radiation Council by the President's Reorganization Plan No. 3 of 1970. The Agency's role is complimentary to the responsibilities recently transferred from the AEC to the Nuclear Regulatory Commission (NRC), which are focused on the detailed regulation of individual facilities within the standards established by EPA, whereas the Agency must address public health and environmental concerns associated with the fuel cycle taken as a whole. The proposed standards recognize the complementary nature of the roles of the two agencies, and, in particular, are cognizant of the findings of the former AEC and the NRC with respect to the practicability of various types of effluent control and of timetables for their implementation.

This statement summarizes the data base and judgments upon which these 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 alternative courses of action on public health, the environment, the industry and upon government. It should be recognized that past growth of the nuclear power industry has been conducted so that radioactive environmental contamination is minimal at the present time. Because of this situation an unusual opportunity, as well as a challenge, exists to manage future growth in the use of nuclear energy in a preventive rather than in a remedial context, a situation that is the ultimate aim of all environmental protection. Within such a context, the tradeoffs between potential health risks or environmental quality and the costs of control can be made most easily and with the maximum effectiveness.

In the United States the early development of technology for the nuclear generation of electric power has focused around the light-water-cooled nuclear reactor. For this reason the proposed standards and this statement will consider only the use of enriched uranium-235 as fuel for the generation of electricity. There are, in all, three fuels available to commercial nuclear power. These are uranium-235, uranium-233, and plutonium-239. The first of these materials occurs naturally and the last two are produced as by-products in uranium-fueled reactors from the naturally-occurring isotopes, thorium-232 and uranium-238, respectively. Although substantial quantities of plutonium-239 are produced by light-water-cooled reactors, large-scale production requires the development of a commercial breeder reactor. The liquid metal fast breeder, which would make possible the extensive production and utilization of plutonium fuel,

is now under intensive development, but is not expected to be commercially available before the late 1980's, at the earliest. However, some commercial use of recycled plutonium in light-water-cooled reactors is proposed for the near future. The third fuel, uranium-233 derived from naturally occurring thorium, will be used by a new reactor type now also under active development, the high temperature gas-cooled reactor, which is expected to be available for substantial commercial use by the end of this decade.

It has been projected that well over 300,000 megawatts of nuclear electric generating capacity based on the use of uranium fuel will exist within the next twenty years. This increase will require a parallel growth in a number of other activities that must exist to support uranium-fueled nuclear reactors. All of these activities together, including the reactor itself, comprise the uranium fuel cycle, which is conveniently separable into three parts. The first consists of the series of operations extending from the time uranium ore leaves the mine through fabrication of enriched uranium into fuel elements. This is followed by a part consisting only of the power reactor itself, in which the fuel is fissioned to produce electric power. The final part consists of fuel reprocessing plants, where the fuel elements are mechanically and chemically broken down to isolate the large quantities of high-level radioactive wastes produced during fission for permanent storage and to recover substantial quantities of unused uranium and reactor-produced plutonium for future reuse.

In the uranium fuel cycle these three parts have fundamentally different characteristics with respect to radioactive effluents. The first involves only naturally occurring radioactive materials which are, nevertheless, made available to the biosphere as the direct result of man's activity. The control technologies appropriate to these materials, specifically uranium and its associated daughter products, are common to most components of this part of the cycle. By means of fission and activation the reactor creates large additional quantities of radioactive materials. Although these are largely contained by fuel cladding, some small releases of these materials do occur. However, in spite of their relatively low levels, reactor effluents are important because these facilities are the most numerous component of the fuel cycle and are often located close to large population centers. And finally, although fuel reprocessing plants are few in number, they represent the largest single potential source of environmental contamination in the fuel cycle, since it is at this point that the fuel cladding is destroyed and all remaining fission and activation products become available for potential release.

The environmental effects of planned releases of radioactive effluents from the components of this cycle have been analyzed in detail by the EPA in a three-part technical report covering fuel supply facilities, light water reactors, and fuel reprocessing. This technical analysis assessed the potential health effects associated with each of the various types of planned releases of radioactivity from each of the

various operations of the fuel cycle and the effectiveness and costs of the controls available to reduce such effluents. In addition to this analysis, there is also available considerable additional information on planned releases from these facilities. This includes the generic findings of the AEC (now the NRC) concerning the practicability of effluent controls in connection with their proposed rulemaking action for light-water-cooled reactors, extensive findings of the utilities and the AEC as reflected by recent environmental statements for a variety of individual fuel cycle facilities, and finally, the results of environmental surveys conducted by the utilities, the States, the AEC, and EPA at operating facilities.

These standards deal with planned releases only, although it is recognized that the potential hazard from accidents could be substantial. However, since the coupling between controls for planned effluents and the potential for accidents is minimal, we have concluded that these two important issues can be addressed separately. In addition to the safety issue, there are two other aspects of nuclear power production that are not addressed by these standards. These are the disposal of radioactive waste and the decommissioning of facilities. These issues are currently under study and EPA expects to make recommendations in these areas in the future. In any case, the implications of the controls required by this rulemaking for radioactive wastes and for decommissioning represent minor perturbations on existing requirements for waste management for the fuel cycle.

II. THE PROPOSED ACTION

The Environmental Protection Agency proposes radiation standards for normal operations of the uranium fuel cycle in order to achieve two principle objectives: 1) to assure protection of members of the public against radiation doses resulting from fuel cycle operations, and 2) to limit the environmental burden of long-lived radioactive materials that may accumulate as a result of the production of electrical energy, so as to limit their long-term impact on both current and future populations. These objectives are proposed to be achieved by standards which would limit: 1) the annual dose equivalent to the whole body or any internal organ, except the thyroid, to 25 millirems, and the annual dose equivalent to the thyroid to 75 millirems; and 2) the quantities of krypton-85, iodine-129, and plutonium and other alpha-emitting transuranic elements with half lives greater than one year released to the environment per gigawatt-year of power produced by the entire fuel cycle to 50,000 curies, 5 millicuries, and 0.5 millicuries, respectively. The proposed rule is contained in the appendix.

Standards in the first category are designed to address doses due to short-lived fission-produced materials and naturally occurring materials,

while those in the second specifically address long-lived radioactive materials. The standards for environmental burdens of specific long-lived radionuclides are expressed in terms of the quantity of electricity produced in order that society will be assured that the risk which is associated with any long-term environmental burden is incurred only in return for a beneficial product: electrical power. The standard permits up to the specified amounts of these radionuclides to be released at any time or location and at any rate that will not exceed the individual dose limitations. The standards proposed apply to all operations within the fuel cycle, including milling, conversion, enrichment, fuel fabrication, light-water-cooled reactors, fuel reprocessing, and transportation of radioactive materials in connection with any of these operations. A variance is proposed to permit temporary operation in the presence of unusual operating conditions so as to assure the orderly delivery of power.

The importance of the nuclear power industry to future energy supply and the future public health and environmental implications of continued operation of this industry at currently required levels of effluent control combine to provide a major incentive for the establishment of these environmental radiation standards.

The nuclear power industry is projected to grow from its present proportion of approximately 4 percent of total electric power capacity to over 60 percent by the year 2000 (an absolute growth of about 20

gigawatts to 1200 gigawatts) (1). It is estimated that the capital investment in current dollars associated with this growth will increase from 3 to 600 billion dollars, and that the value of electric power produced annually will grow from about 3 to over 200 billion dollars during this same period (2).

The President's Energy Message of 1971 reinforced this trend to nuclear power by endorsing the early development of a commercial breeder reactor (3). While that decision does not directly bear on this rulemaking, it does make clear that a national commitment has been made for major future growth of nuclear power, an industry that is now in the early stages of significant commercial utilization. It is equally clear that national needs for electric power cannot be met without a large increase in the fraction of electric power produced by nuclear energy, given the present lack of availability of alternative sources, at least within the next few decades (4).

The development of a large nuclear power industry has, however, the potential for leading to unnecessary exposure of the public to radioactive materials and to irreversible contamination of the environment by persistant radionuclides (5). It is important, therefore, to establish the environmental radiation standards within which this growth will take place.

The principal impact of radioactive effluents on the biosphere is the induction of deleterious health effects in man. Comparable levels of impact undoubtedly exist in other biota, but there is no present evidence that there is any biological species whose sensitivity is sufficiently high to warrant a greater level of protection than that adequate for man.

Health effects induced in man by exposure to radiation fall into two broad categories - somatic and genetic. The principal somatic effects include leukemias; thyroid, lung, breast, bone, and a variety of other cancers; and, possibly, the impairment of growth and development, as well as non-specific life shortening. It appears clear that sensitivity varies with age, the embryo and young children being particularly sensitive. The range of possible genetic effects encompasses virtually every aspect of man's physical and mental well-being. The major exceptions are infectious diseases and accidents, but even here inherited susceptibilities also play a role (6).

The impact of radioactive effluents can be considered from three different perspectives. The first of these is the maximum radiation dose to individuals. This measure has been the one traditionally used for limiting the impact of radiation, and existing radiation standards are all related to limits on radiation doses to individuals (7). It is of interest to note that the origin of existing radiation limits for the general population, at least for somatic consequences, has been through taking a somewhat arbitrary fraction (usually 1/10) of the dose limits

established for radiation workers exposed under controlled occupational conditions (8). The current Federal Guides for limiting radiation exposure of members of the general public are 500 mrem/yr to the whole body of individuals and 5 rems in 30 years to the gonads. As an operational procedure, it is recommended that a limit of 170 mrem/yr to the whole body be applied to suitable samples of the population to assure that the first of these limits is satisfied for any individual. This procedure automatically assures that the second limit will also be satisfied (9).

A second perspective is provided by summing the individual annual radiation doses to each of the members of a population to obtain a measure of the total annual population impact. This summation may be made directly on doses, rather than on potential health effects, because it is the consensus of current scientific opinion that it is prudent to assume a proportional relationship between radiation doses due to environmental levels of radiation and their effects on health for the purpose of establishing standards to protect public health. Although this impact is usually expressed on an annual basis, it may also be assessed for longer periods, which leads to consideration of a third aspect of the complete assessment of the environmental impact of radioactive effluents - the buildup and persistence of long-lived radionuclides.

Much of the radioactivity released from nuclear facilities is short-lived and is essentially removed from the environment by radioactive decay in less than one year. However, a few radioactive materials have greater persistence and decay with half-lives ranging from decades to millions of years. These materials may deliver doses to populations throughout this period as they migrate through the biosphere. The Agency has characterized the sum of these doses as the "Environmental Dose Commitment" (5). It is calculated for a specific release at a specific time and is obtained by summing the doses to populations delivered by that release in each of the years following release to the environment until the material has either decayed to innocuous levels, been permanently removed from the biosphere, or for a specified period of time, in which case it is necessary to specify that only a partial dose commitment has been calculated. For the purpose of the analyses made for these standards, environmental dose commitments were calculated for a maximum period of 100 years. There are two other dose commitment concepts in common use. The first is the dose committed to an individual by intake of internal emitters. This dose commitment is directly incorporated into the sum of doses to individuals comprising the environmental dose commitment. The second is the UNSCEAR dose commitment, which is defined as the infinite time integral of the average dose in a population due to a specific source of exposure. This concept is not, in general, simply relatable to the environmental dose commitment, but in the limiting case of a population of constant size is

equal to the environmental dose commitment divided by the (constant) number of individuals in the population.

In recent years, it has become increasingly clear that the current Federal Radiation Protection Guide (500 mrem/yr to individuals, usually interpreted as an average of 170 mrem/yr to members of critical populations) for limiting radiation exposure of the public is unnecessarily high. The National Academy of Sciences, in its recent report to the Agency on the effects of environmental levels of radiation exposure (6), expressed what may be regarded as a consensus of informed scientific opinion when it said:

> There is reason to expect that over the next few decades the dose commitment for all man-made sources of radiation except medical should not exceed more than a few millirems average annual dose. [And further,] ...it appears that [societal] needs can be met with far lower...risk than permitted by the current Radiation Protection Guide. To that extent, the current Guide is unnecessarily high.

The potential impact on health caused by effluents from an expanding nuclear power industry, if it were to operate at the levels permitted by the current Federal Radiation Protection Guides, would be large. Current guides do not, in addition, directly address either the second or the third perspective of radiation exposure described above. However, the guides are accompanied by the advice that exposures should be kept as far below the guides for exposure of individuals as "practicable," and major portions of the industry now operate at approximately one-tenth of the

level permitted by the current guides. This was accomplished in large part through the implementation of this concept by the former AEC through the licensing of individual facilities.

However, attention to individual exposure alone leads to inadequate control of releases of long-lived radioactive materials, which may give rise to substantial long-term impacts on populations while contributing only small increases to annual individual exposures. On the other hand, the reduction of individual dose alone, if carried out without consideration of the associated population dose and the economic factors associated with the controls that reduce it, can also lead to the use of unreasonably restrictive control of short-lived radioactive materials that achieves negligible improvement in public health protection for unreasonably large investments in control technology. Reduction of exposure of individuals to as low as "practicable" levels is therefore not, by itself, an adequate basis for radiation standards.

Most present regulations for the nuclear industry are applied as individual licensing conditions for specific facilities. The AEC based these regulations on standards derived from the recommendations of a variety of external advisory groups, such as the International Commission of Radiation Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP) or, in recent years, on the guidance provided by the former Federal Radiation Council (FRC). These groups have traditionally focused primarily upon the objective of limiting risk

to the individual, although consideration of genetic consequences to entire populations has provided the basis for some general guidance on upper limits for exposure of entire populations. There has, however, been no external source of standards or guidance for radioactive materials from a specifically environmental point of view, such as, for example, from the point of view of limiting the long-term environmental buildup of radionuclides, until the President's Reorganization Plan No. 3 created EPA and charged it with that responsibility.

In summary, present radiation protection guidance, as it applies to the nuclear power industry, requires expansion to satisfy the needs of the times. Specifically:

a) The consideration of exposures on an annual basis must be expanded to include the long-term impact of the release of long-lived radionuclides to the environment.
b) The Radiation Protection Guide for annual dose to individuals is unnecessarily high for use by the industry.
c) Application of the concept "as low as practicable" must include explicit consideration of both total population exposure and the costs of effluent controls.

The proposed action reflects these three considerations in order to insure that the anticipated major expansion of nuclear power takes place with assurance of adequate radiation protection of public health and the environment.

III. THE STATUTORY BASIS FOR ENVIRONMENTAL RADIATION STANDARDS

These standards are proposed under authority of the Atomic Energy Act of 1954, as amended, transferred to the Environmental Protection Agency from the Atomic Energy Commission by the President's Reorganization Plan No. 3 (October, 1970). That plan provided for the transfer of environmental standards functions from AEC to EPA:

> ...to the extent that such functions of the Commission consist of establishing generally applicable environmental standards for the protection of the general environment from radioactive material. As used herein, standards mean limits on radiation exposures or levels, or concentrations or quantities of radioactive material, in the general environment outside the boundaries of locations under the control of persons possessing or using radioactive material.

This authority is distinct from and in addition to the authority to "...advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance to Federal agencies in the formulation of radiation standards..." which was also transferred to EPA from the former Federal Radiation Council by the same reorganization plan. That authority, while it is broad in scope, is most appropriately applied to the issuance of general radiation guidance to Federal agencies

and for the use of the States, however, and not to the setting of specific environmental radiation standards.

Two points are relevant to EPA's authority to set environmental radiation standards. First, although EPA is not limited to specific criteria for setting such standards (e.g., requirements for "best practicable" or "best available" technology, or for effluent levels having "no health effects"), EPA is constrained to set standards which apply only outside the boundaries of facilities producing radioactive effluents. The required environmental protection can be provided within this constraint. By the same token, this authority may not be used by EPA to set limits on the amount of radiation exposure inside these boundaries, consequently occupational exposures of workers inside the boundary remain the responsibility of the AEC (now the NRC), operating under existing Federal Radiation Protection Guides for occupational exposure.

Secondly, EPA can only set standards; the authority to regulate specific facilities was not transferred by Reorganization Plan No. 3 (10). Application and enforcement of these standards against specific facilities is the responsibility of the NRC. The division of responsibilities between EPA and AEC (whose regulatory responsibilities are now carried out by NRC) for carrying out these objectives was addressed specifically by the President's message transmitting Reorganization Plan No. 3 to the Congress as follows:

Environmental radiation standards programs. The Atomic Energy Commission is now responsible for establishing environmental radiation standards and emission limits for radioactivity. Those standards have been based largely on broad guidelines recommended by the Federal Radiation Council. The Atomic Energy Commission's authority to set standards for the protection of the general environment from radioactive material would be transferred to the Environmental Protection Agency. The functions of the Federal Radiation Council would also be transferred. AEC would retain responsibility for the implementation and enforcement of radiation standards through its licensing authority.

This division of responsibility is not expected to interfere with effective administration and achievement of these proposed environmental standards. (See Chapter VII, Section D.)

IV. RATIONALE FOR THE DERIVATION OF ENVIRONMENTAL RADIATION STANDARDS

Two objectives are of prime importance in considering the choice of methodology to be used to derive environmental radiation standards for a major activity such as the uranium fuel cycle. The first is that an assessment of the potential impact on public health be made that reflects an up-to-date consensus of currently available knowledge and that as complete an assessment of this impact be made as possible. The second is that in addition to public health impact, the cost and effectiveness of measures available to reduce or eliminate radioactive effluents to the environment be carefully considered. It would be irresponsible to set standards that impose unnecessary health risks on the public (unnecessary in the sense that exposures permitted by the standards can be avoided at a small or reasonable cost to the industry), and it would be equally irresponsible to set standards that impose unreasonable costs on the industry (unreasonable in the sense that control costs imposed by the standards provide little or no health benefit to the public).

Projections of health effects made in the technical analyses for this rulemaking have been based on recommendations resulting from the recently completed study of the effects of low levels of ionizing

radiation by the National Academy of Sciences-National Research Council's Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR Committee) (6). This Committee, which consisted of a broad cross-section of prominent members of the U.S. scientific community knowledgeable in the various disciplines appropriate to a review of existing scientific knowledge in this area, has provided EPA with the most exhaustive analysis of risk estimates that has been made to date. Their conclusions include, among others, the recommendations that it is prudent to use a linear, non-threshold, dose-rate-independent model for establishing standards to limit health effects from environmental levels of radiation, and that numerical standards for the nuclear power industry should be established on the basis of an analysis of the cost-effectiveness of reducing these effects.

Other authorities have suggested, usually on the basis of the same data, that estimates of health effects based on the first of the above recommendations may be either too high or too low. Those supporting the first view argue that (a) risk coefficients have been derived from data obtained at much higher doses and may, therefore, not properly reflect any non-linearity that may be present at low doses and (b) that repair mechanisms may operate at low dose rates to reduce the impact of such exposures. Those supporting the second view argue that (a) some data indicate that low doses may be more efficient in producing health effects than higher doses, (b) the effect of genetic mutations on overall ill-health is much greater than is commonly assumed, or (c) certain

population subgroups have a predisposition to radiation-induced cancer and are, therefore, at greater risk than most studies have indicated.

The NAS Committee examined all of these views in some detail and concluded that while each of these arguments may have validity under various assumptions or for various specific situations, the weight of currently available scientific evidence strongly supports the continued use of a linear non-threshold model for standards-setting. EPA agrees that this conclusion is the prudent one for use in deriving radiation standards to protect public health (11). We also recognize that rather large uncertainties remain for describing the actual situation, an uncertainty which is presently beyond scientific resolution.

The health assessments made for deriving these standards depart in two significant respects from practice common in the past for assessing the significance of radiation exposures. The first of these is the use of the concept of environmental dose commitment described earlier to assess the impact of environmental releases. Previous assessments have usually been limited to the calculation of radiation doses to individuals in local populations incurred immediately following the release of an effluent. For short-lived radionuclides this will usually suffice, but when long-lived materials are involved this practice can lead to large underestimates of the total impact of an environmental release. The underlying assumption justifying such a practice has been that individual doses to other than local populations and at times after the "first pass"

of an effluent are so small as to be indistinguishable from those due to natural background radiation and are therefore ignorable. This point of view is not considered acceptable because it not only neglects the implications of the non-threshold linear hypothesis for radiation effects, but also the point that the radiation doses involved are avoidable man-made doses, not doses due to natural radioactivity.

The second departure from usual practice in the past has been the use of explicit estimates of potential health effects rather than radiation dose as the endpoint to be minimized. In carrying out these assessments the results of the exhaustive review and analysis of available scientific observations on the relationship between radiation dose at low levels and health effects completed recently for the Agency by the BEIR Committee were extremely useful. It is perhaps obvious, in retrospect, that the proper focus for determination of the appropriate level for a standard should be its public health impact, but in the past minimization of dose has served as a useful surrogate for this impact because of uncertainties about the magnitude of the relationship between dose and effect. Assessments similar to those made for this statement have also appeared in some recent AEC Environmental Statements for generic programs, such as those for the proposed liquid-metal fast breeder reactor program and for plutonium recycle in light-water-cooled reactors.

The health impact analysis thus considers the total impact of releases of radioactive materials to the environment by including radiation doses committed to local, regional, national, and worldwide populations, as well as doses committed due to the long-term persistence of some of these materials in the environment following their release. The analysis served to identify which processes and effluents from the fuel cycle represent the major components of risk to populations, and leads to a clearer view of the need to control long-lived materials, as well as of the futility of excessive control measures for very short-lived radioactive materials.

In order to make a determination of the degree of effluent control that can reasonably be required by standards, an analysis of the cost-effectiveness of risk reduction was carried out. The consideration of the cost-effectiveness of all (or, in some instances, a representative sampling) of the alternative procedures available for risk reduction within the fuel cycle reveals where and at what level effluent control will achieve the most return for the effort and expense involved. Such an assessment of the costs and efficiencies of various forms and levels of effluent control requires that judgments be made of the availability, efficiency, and dependability of a wide variety of technological systems, and that for each of these capital and operating costs be determined over the expected life of the system. Cost data were reduced to present worth values for use in these cost-effectiveness considerations.

Finally, although the first consideration involved in developing these standards was reduction of the total potential health impact of radioactive effluents on large populations, doses to individuals must also be examined, since a few situations exist where individual exposure to short-lived radionuclides, such as the radioiodines, can occur at unreasonably high levels even after cost-effective control of population impact has been achieved. Although the risk to any given individual is quite small for doses below a few hundred millirems, EPA believes that such doses should also be minimized, especially when the individual at risk is not the direct recipient of the benefits of the activity producing them. In these cases, the approach to setting standards for maximum individual dose was to weigh the cost-effectiveness of individual dose reduction and the cost of control relative to total capital cost, in order to arrive at a judgment whether or not it was possible, at reasonable cost, to reduce these few individual exposures to the same general levels that are achievable for large populations for other sources of environmental radiation exposure from the uranium fuel cycle.

Within the context of the methodology outlined above, radioactive effluents to the environment from the nuclear power industry can be considered from three points of view:

1) the potential public health impact attributable to each effluent stream of radioactive materials from each type of facility in the fuel cycle;

2) the combined potential public health impact of the various components of the fuel cycle required to support the production of a given quantity of electrical power; and

3) the integrated potential public health impact of the entire fuel cycle due to the projected future growth of the industry over some period of time, such as through the year 2000.

The first of these is useful for assessing the effectiveness of the control of particular effluent streams from specific types of facilities. It provides the basic data from which judgments concerning the latter two perspectives flow. The second viewpoint, which provides an assessment of the total impact of the industry for each unit of the beneficial end-product (electrical power) as a function of the level of effluent control, provides the information required for assessing the potential public health impact of standards for the fuel cycle taken as a whole. Finally, although each of these perspectives assists in forming judgments as to the appropriate level of control and the public health impact associated with a unit of output from the fuel cycle, only the third provides an assessment of the potential public health impact of the entire industry. The magnitude of this future impact, which could be either considerable or relatively small, depending upon the level of effluent control implied by the proposed standards, provides an important part of the basis for EPA's conclusion that environmental standards defining acceptable limits on the radiological impact of the industry are clearly required.

The standards-setting method described in the preceding paragraphs may perhaps be best characterized as a process of cost-effective health risk minimization which is here applied to the broad class of related activities constituting the uranium fuel cycle. This method offers, we believe, the most rational approach to choosing standards to limit the impact of non-threshold pollutants from an industry encompassing a wide variety of operations which combine to produce a single output.

There are, of course, a variety of alternatives to this approach to setting environmental radiation standards. These encompass the use of health considerations alone instead of considering both health risk and costs, selective instead of comprehensive coverage of the industry, use of best available technology, and, finally, the option of substituting the use of EPA influence on AEC (now NRC) regulatory practice for the setting of standards. These alternative approaches were considered by the Agency and are discussed in Chapter VII along with some quantitative alternatives to the proposed standards that also consider both health risk and control costs.

V. TECHNICAL CONSIDERATIONS FOR THE PROPOSED STANDARDS

The sequence of operations occurring before and after the fissioning of fuel at the power reactor is shown schematically in Figure 1. Natural uranium ore (which contains 0.7 percent uranium-235) is first mined and then milled to produce a concentrate called "yellowcake" containing about 85 percent of uranium oxide. A conversion step then purifies and converts this uranium oxide to uranium hexafloride, the chemical form in which uranium is supplied to enrichment plants. At the enrichment plant the isotopic concentration of uranium-235 in the uranium is increased to the design specification of the power reactor (usually 2 to 4 percent) by a differential gaseous diffusion process. The greatest portion of the feed uranium hexaflouride becomes a plant tail depleted in uranium-235 content and is stored in gas cylinders. At the fuel fabrication plant the enriched uranium hexaflouride is converted into uranium oxide pellets, which are then loaded into thin zircalloy or stainless-steel tubing and finally fabricated into individual fuel element bundles. These bundles are used to fuel the reactor. After burnup in the reactor, the spent fuel is chemically reprocessed to remove radioactive waste products and to reclaim fissile material (mainly plutonium and unused uranium) for reuse. All of these operations depend upon the

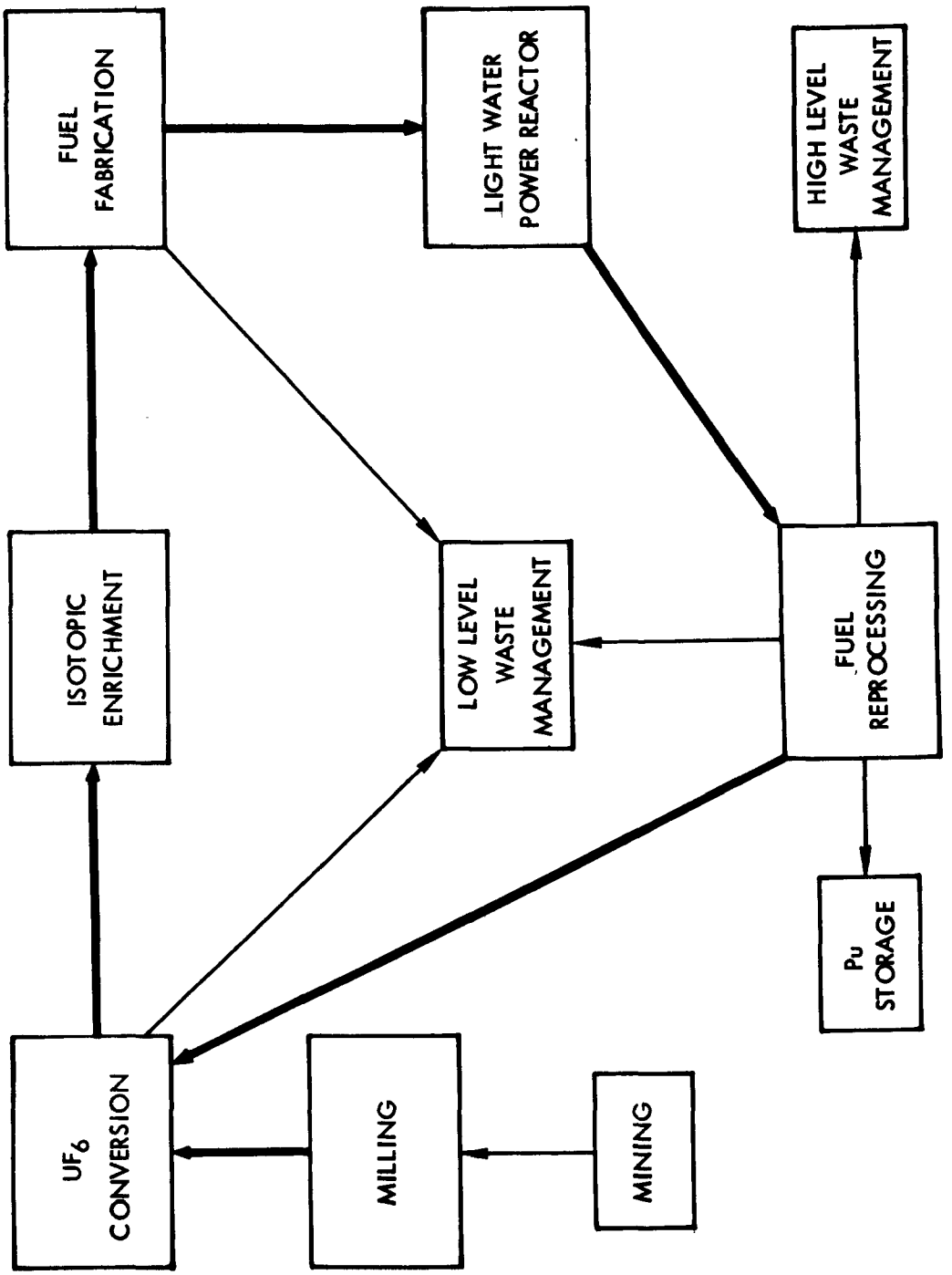


Figure 1. URANIUM FUEL CYCLE FACILITY RELATIONSHIPS

transportation of a variety of materials, many of which pose the hazard of radiation exposure.

Table 1 shows basic parameters that are representative of typical facilities for each of these fuel cycle operations (12). The values which relate these operations to the number of gigawatts of power production supported can be used as the basis for an assessment of the environmental impact of the fuel cycle as a whole. A projection of the magnitude of fuel cycle operations required to support reactors through the year 2000 is shown in Figure 2 (13). Currently existing capacity is expected to be sufficient to accommodate the requirements of the fuel cycle up to about the year 1980.

The environmental impacts due to radioactive materials associated with the various operations comprising the uranium fuel cycle fall into four major categories. These are: 1) doses to populations and to individuals due to naturally-occurring radioactive materials prior to fission in the reactor; 2) doses to populations and individuals from short-lived fission and activation products; 3) doses to populations from long-lived fission products and transuranic elements; and 4) gamma and neutron radiation from fuel cycle sites and transported radioactive materials, which may produce doses to a few individuals close to facilities, and to large numbers of people at low levels of exposure along shipping routes.

TABLE 1

CHARACTERISTICS OF
MODEL FUEL CYCLE FACILITIES

Operation (note 1)	Fuel Cycle Plant Annual Capacity		Number of Model LWR's Supported by Facility
	Range	Model	
Uranium Mill ($MT\ U_3O_8$)	500-1100**	1140	5.3
UF_6 Production (MT U)	5000-10,000	5000	28
Isotopic Enrichment (swu)	6000-17,000	10,500*	90
UO_2 Fuel Fabrication (MT U)	300-1000	900	26
Light-Water-Cooled Reactor (GW(e) capacity)	0.04-1.3	1	1
Spent Fuel Reprocessing (MT U)	300-1500	1500	43

* Current operating level of industry and assumed model plant capacity
** Characteristic of about 70% of current facilities

1) The units which characterize each type of operation are abreviated as follows: Metric Tons = MT, separative work units = swu, and gigawatts (electric) = GW(e).

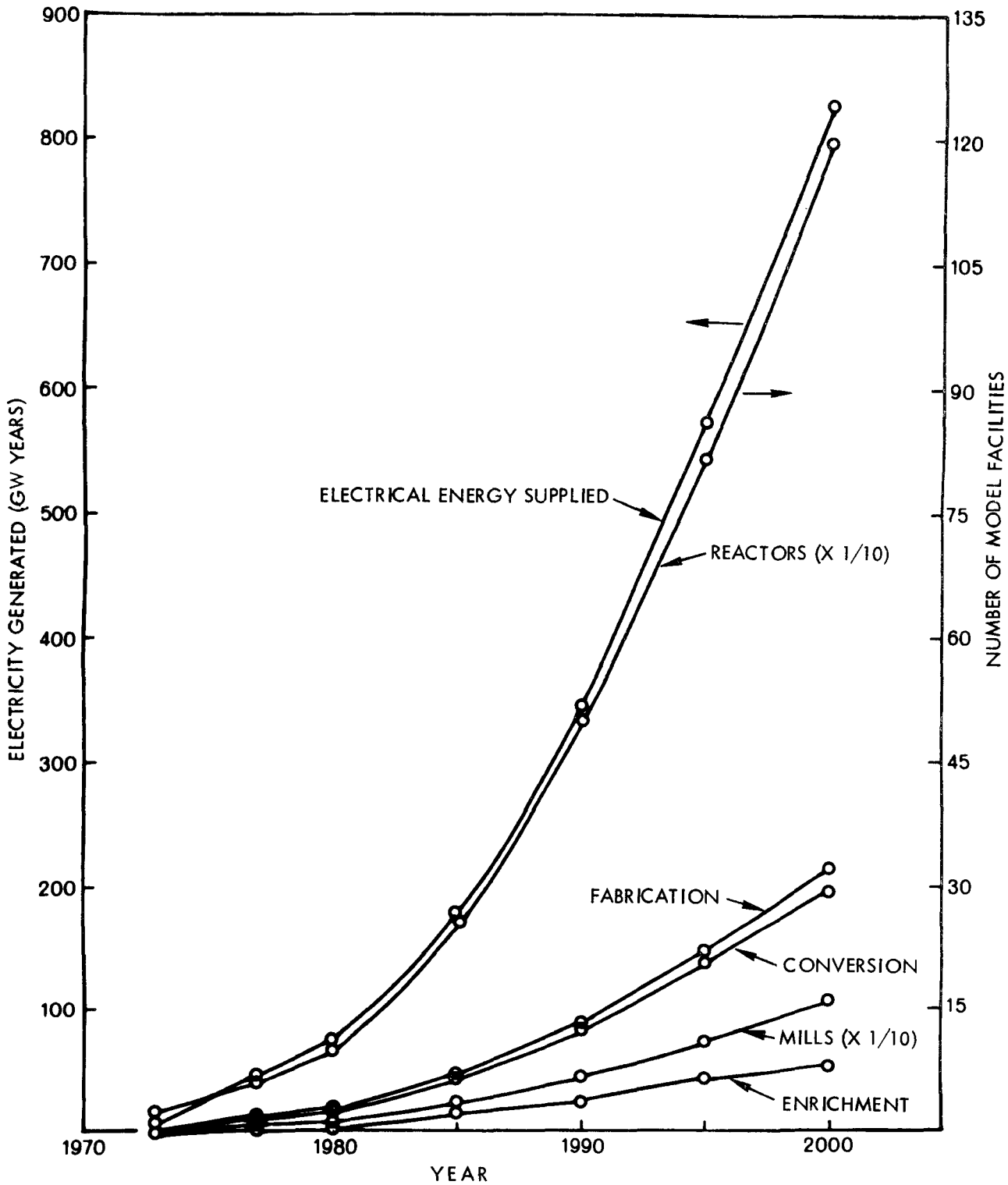


Figure 2. PROJECTED NUCLEAR FUEL CYCLE FACILITY NEEDS

Standards to limit the above four categories of individual and population dose can be expressed using three major kinds of units of measure: 1) limits on annual doses to the whole body or to specific organs of individuals (millirems/year); 2) limits on annual population dose or environmental dose commitment (person-rems/year or person-rems, respectively); and 3) limits on the total discharge of long-lived materials to the environment per unit of output from the fuel cycle (curies/gigawatt-year). Limits on the impact on individuals through each of the above categories of exposure are most easily expressed directly as limits on annual dose (millirems/year). Control of population impacts, both from long- and short-lived materials, can be achieved directly through application of either of the latter two kinds of units of measure. However, although the best measure of the population impact of long-lived materials is environmental dose commitment (person-rems), standards expressed in person-rems would be extremely difficult to enforce because of the many pathways and wide choice of models for transport through the biosphere that are available. The best approach for long-lived materials is to limit the total quantity of such materials introduced into the environment by first calculating environmental dose commitment and health effects and then deciding what limits on the directly measurable quantity (the quantity released to the environment measured in curies) best achieve the level of protection indicated. Furthermore, analysis of dose distributions indicates that the population impact of short-lived materials is quite adequately limited by a limit on individual exposure, and that a separate limit for the impact of these

materials on populations expressed in person-rems/year is an unnecessary redundancy. Thus, standards for the fuel cycle expressed in just two kinds of units of measure (millirems/year and curies/gigawatt-year) are adequate to limit both the total population impact of fuel cycle operations and, at the same time, maximum individual risk.

Table 2 summarizes the principal types of radioactive effluents from the fuel cycle and the associated target organs of greatest concern. The degrees of environmental protection available to minimize the public health impact of these as well as less important effluents may be assessed using three complimentary sources of information: 1) projections based upon modeling of source terms, the capabilities of effluent control, and environmental pathways, 2) measurements of the actual performance of existing facilities, and projections based upon these measurements for improved levels of effluent control, and 3) the performance anticipated by the industry and the Atomic Energy Commission as reflected by recently filed environmental statements for a variety of facilities.

The most complete set of information is that derived from model-based projections. For this reason, the principal criteria for judgments about acceptably low levels of environmental impact are based upon this data base. The rationale for the choice of these criteria is described in Section A below, which also summarizes the results of these projections. Sections B and C present data from environmental statements

Table 2. Principal Radioactive Effluents from the Uranium Fuel Cycle and the Associated Critical Organs

Effluent	Principal Critical Organ(s)
Noble gases	Whole body
Radioiodine	Thyroid
Tritium	Whole body
Carbon-14	Whole body
Cesium and other metals in liquids	Whole body, G.I. tract
Plutonium and other transuranics	Lung
Uranium and daughter products	Lung, bone
Gamma and neutron radiation	Whole body

and field measurements for specific facilities, respectively. These data in some instances confirm the conclusions drawn from models, and in others point out areas where modifying judgments are appropriate. The final section describes the conclusions reached by the Agency for the proposed standards.

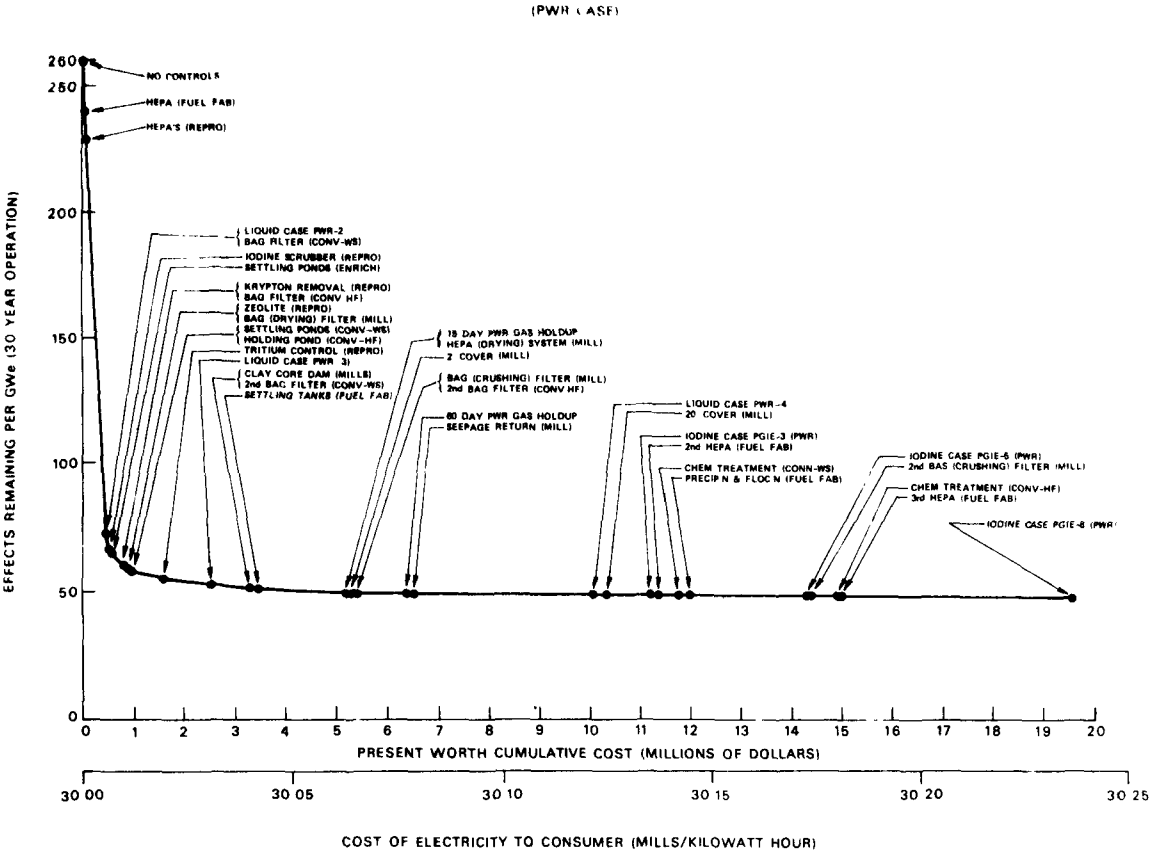
A. MODEL PROJECTIONS OF FUEL CYCLE ENVIRONMENTAL IMPACTS

There are several elements to the development of a projection of the potential health impact of radioactive effluents. The first is a determination of effluent source terms as a function of the level of effluent control. Next, the assumed radionuclide effluents are followed using semiempirical models over as wide an area and for as long a period as they may expose human populations. Human doses are then calculated from the radionuclide concentrations given by these models for air, water, and foodstuffs. For each radionuclide this involves modeling of the penetration of the radiation through body tissues, rates of ingestion and excretion, and partition among and metabolism in the various organs of the body. Finally, after doses to various critical organs have been determined, the probabilities of incurring somatic and genetic health effects attributable to these doses are estimated.

These projections have been carried out and are described in detail for each of the major effluent streams from the various activities

comprising the fuel cycle in the EPA reports entitled "Environmental Analysis of the Uranium Fuel Cycle" (13). The results of this analysis include both the reduction in potential health impact and the costs of a large variety of measures that can be instituted within the fuel cycle to reduce its environmental impact. These have been summarized in Figures 3a and 3b for the entire fuel cycle by using the normalizing factors shown in Table 1 for the typical model facilities described in detail in reference 13. Figure 3a displays the reduction in potential health effects achieved as a function of cumulative incremental control system costs to the entire fuel cycle for the case of a typical pressurized water reactor, for a representative variety of control options on each component of the cycle. The costs of control have been normalized to one gigawatt of electric power output and were applied in the order of decreasing cost-effectiveness of health effects reduction for the fuel cycle, taken as a whole. A similar curve can be constructed for the fuel cycle for the case of a typical boiling water reactor, and is shown in Figure 3b. A detailed discussion of the various control options selected for display on these figures, as well as of alternatives not shown, will be found in reference 13. The examples shown are typical, however, and provide a good representation of the options available for effluent reduction.

Table 3 shows, for the major categories of radiological impact, the projected doses to maximum exposed individuals and the quantities of long-lived radionuclides achievable at the levels of effluent control



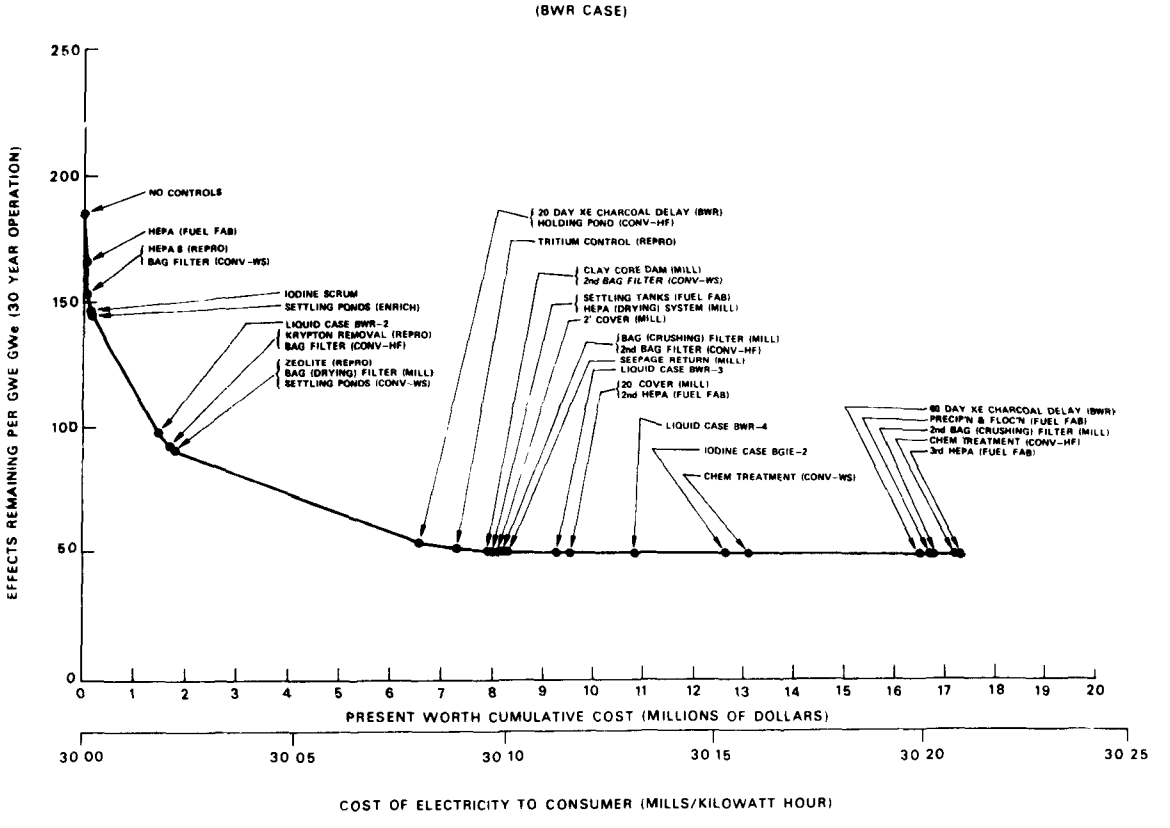


FIGURE 3. RISK REDUCTION VS. COST FOR THE URANIUM FUEL CYCLE

Table 3. Dose and Quantity Levels Implied by Model Projections

	Level†	Source	Control††	Limiting Factor
A. Maximum Annual Individual Doses (mrem/yr).				
1. Whole body				
a. Noble gases	<1	PWR	1B-15	C/E
	1-5	BWR	2-20	C/E
	<1	FR	Note 1	C/E
b. Tritium	3	FR	None	Not available
c. Carbon-14	<1	FR	Note 1	C/E
d. Cesium, etc.	<1	PWR	PWR-3	C/E
	<1	BWR	BWR-3	C/E
	3	FR	Note 2	C/E
2. Lung				
a. Plutonium, etc.	1	FR	HEPA	C/E
b. Uranium, etc.	11	Mill	Filter	C/E
	10	Fab	HEPA	Recovery of uranium
3. Thyroid-radioiodine*	2-9	PWR	PGIE-3,0-5	Maximum individual
	1-8	BWR	BGIE-2,0-5	Maximum individual
	15	FR	Note 3	C/E
4. Bone - Uranium, etc.	13	Mill	Clay core	C/E
B. Maximum Quantities Released to the Environment, Per Gigawatt-Year of Electric Power (Curies).				
1. Tritium	30,000	FR	None	Not available
2. Carbon-14	~20	LWR	Note 1	C/E
3. Krypton-85	4000	FR	Note 1	C/E
4. Iodine-129	<0.002	FR	Note 3	C/E
5. Plutonium, etc.**	<0.0003	FR	HEPA	C/E

† All doses are rounded to the nearest number of millirems/year at the location of maximum dose outside the facility boundary.

†† System designations are those used in reference 13; the levels at LWR's are for 2 units.

* At the nearest farm in the case of elemental release of iodine, and at the nearest residence in the case of organic releases; dose ranges shown encompass that for 100% release of either form.

** Defined as alpha-emitting transuranics of half-life greater than 1 year.

Note 1 Assumes Krypton retention via any of several alternative methods of equivalent cost. Such control is assumed to permit the retention of the approximately 60% of carbon-14 produced by the fuel cycle that is released by fuel reprocessing at negligible additional cost. The balance shown is released at the reactor.

Note 2 In addition to tritium whole body exposures at fuel reprocessing, cesium-137, ruthenium-106 and iodine-129 may combine to yield comparable whole body doses. The dose shown is that remaining in the presence of cost-effective levels for control of other major effluents (particularly transuranics and iodine).

Note 3 Assumes iodine control is available with a removal efficiency of 99.9% for both iodine-131 and iodine-129. Although some uncertainty exists concerning the performance of immediately available systems, systems presently under active development should achieve such efficiencies and become available prior to expansion of the fuel reprocessing industry to more than one or two facilities following the year 1980.

consistent with such considerations as acceptable levels of cost-effectiveness of risk reduction, equitable distribution of radiological impact, or existing use of technology by industry as the result of non-radiological considerations. The criteria used for judging the acceptability of levels of cost-effectiveness of risk reduction are discussed later in this section. The second and third columns indicate the type of facility at which each major impact occurs and the level of control (described in reference 13) which has been assumed, respectively. The final column indicates which of the above limiting considerations was controlling for each category of exposure.

The results shown in Table 3 indicate that at these levels of control of environmental releases the attainable range of maximum annual whole body dose to an individual at the boundaries of representative reactor sites (for the case of combined exposure to air and water pathways) is 0-2 mrem/yr for pressurized water reactors and 1-6 mrem/yr for boiling water reactors. Three major types of sites (river, lake, and seacoast) are included in the projections which yield these dose ranges. Adding a large (1500 metric ton per year) fuel reprocessing facility to either the PWR or the BWR case increases these maximum doses to 6-10 mrem/yr and to 7-14 mrem/yr, respectively. There are no other types of facilities in the fuel cycle which produce whole body doses of significance in comparison to these types of facilities.

It should be noted that the cases considered in this analysis assume two one gigawatt(electric) power reactors on each site. Larger numbers of reactors would require larger sites in order to achieve these doses at the boundary, or, alternatively, a greater degree of effluent control. It is anticipated that sites used for multiple reactor installations will, in practice, be larger than those for single or twin reactor installations, and that in those instances where this is not the case the economies associated with the use of smaller sites and multiple installation of reactors will readily accommodate the somewhat higher costs of improved effluent control required to maintain the above dose levels. An additional factor influencing the maximum doses at sites with large numbers of reactors is the small likelihood that all of the limiting fuel failure and leakage parameters assumed in order to model the effluent source terms will be realized by all of the reactors on a site simultaneously.

Maximum potential annual doses to the lung and to bone from the fuel cycle occur at mills and fuel fabrication facilities. These doses result from the release of dust containing natural or enriched uranium. At fuel fabrication facilities current releases are restricted to levels corresponding to maximum lung doses of approximately 10 mrem/yr, due to the incentive provided by the recovery of valuable enriched uranium. Cost-effective levels of dose reduction at mills and other facilities associated with the supply of uranium fuel to reactors lead to comparable or lower doses to the lung, as well as to bone.

Thyroid doses due to environmental releases of short-lived radioiodines from the fuel cycle are particularly difficult to model due to uncertainties in the magnitudes and effective release heights of source terms and the chemical form in which iodine is released, as well as complicated environmental pathways, which, in addition to direct inhalation, typically involve airborne transport of iodine to vegetation (the extent of which is extremely sensitive to rainfall), immediate or delayed uptake by cows, and final ingestion by humans in milk. Doses calculated from milk ingestion are subject to additional uncertainties due to dilution resulting from milk pooling and the relatively rapid decay of radioiodine (half-life of iodine-131 = 8.1 days). Because of all of these uncertainties, model calculations of thyroid dose are anticipated to be markedly more conservative than those for most other effluents - i.e., actual doses are expected to be considerably lower than calculated doses. The model calculations project maximum individual thyroid doses of 1-9 mrem/yr from typical reactor sites at the locations of either permanent residents or at nearest farms.

The radioiodine situation at fuel reprocessing plants is even more uncertain than at reactors, because of lack of experience with many of the control methods for iodine appropriate to these plants. In addition to the variety of control methods currently available, a number of more advanced methods are now in final stages of development. Currently available systems provide cost-effective control of iodine emissions with anticipated overall decontamination factors of 1000 (13). Since no fuel

reprocessing facility is expected to become operational until 1978, and only two or three prior to 1983, it is important to also consider more advanced systems that are expected to become available during that time period. These include iodine evolution at the dissolution stage of reprocessing, iodox systems, and mercuric nitrate scrubbers (14). These systems should achieve decontamination factors in excess of 10,000, and are not anticipated to represent a major increase in the cost of fuel reprocessing. Comprehensive development programs for all of these systems have been underway for a number of years at Oak Ridge National Laboratory, and most are in final stages of pilot scale demonstration, having completed laboratory scale testing. The majority of these systems are anticipated to be competitive in cost with current systems. It thus appears reasonable to assume that within the next few years overall plant decontamination factors of at least 1000 can be readily achieved. On this basis, the calculated maximum thyroid dose from a fuel reprocessing facility would not exceed 15 mrem/yr.

The second part of Table 3 reflects the capabilities of cost-effective control techniques for long-lived radionuclides, where they are available. It should be noted that although tritium control is not yet available, the volox process now under active development for fuel reprocessing for the LMFBR program would also provide effective control of the largest source of tritium from the uranium fuel cycle. This development program is not expected to be completed for more than a decade, however (15).

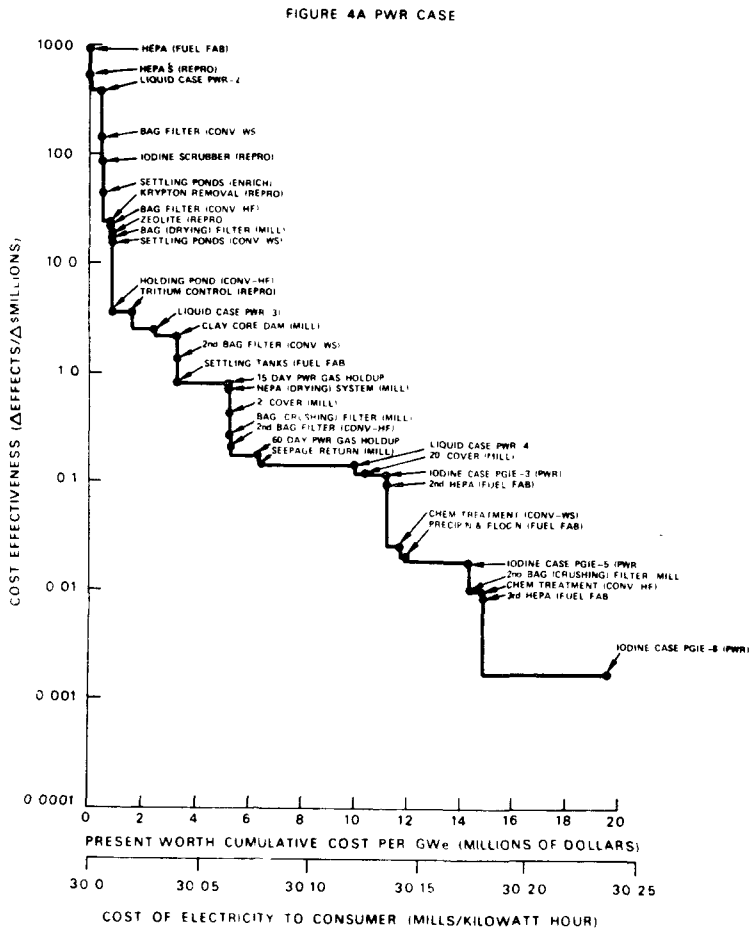
Carbon-14 has only recently been recognized as an effluent of potentially large impact from the fuel cycle (16), and control methods have not yet been extensively investigated. However, retention of krypton-85 by cryogenic means at fuel reprocessing (one of the principle control options for this radionuclide) may permit, at negligible additional cost, the simultaneous removal of carbon-14 as carbon dioxide.

Specific control options for krypton-85, iodine-129, and plutonium and other long-lived transuranics are discussed in reference 13. The comments above concerning retention of short-lived radioiodines at fuel reprocessing also apply to iodine-129. Controls for plutonium and other transuranics are well established technology; those for krypton-85 and iodine-129 are either developed (but not yet in commercial use) or demonstrated in the laboratory and in the final stages of development for commercial use.

We return now to a discussion of the choice of criteria for acceptable levels of risk reduction. The display of the options available for reducing the environmental impact of the fuel cycle shown in Figure 3 can be examined from several points of view. If a certain number of health effects were presumed justified in order to obtain the generation of a given quantity of electricity, then this curve would allow a judgment to be made as to which controls should be used in order to meet that criterion at the lowest cost. If, on the other hand, a determination had been made that the total cost of control should not

exceed a fixed amount, the curve can be used to make a determination of the maximum amount of health effects reduction possible. However, such judgments are not available for either of these simple constraints with regard to the generation of electricity. A judgment of the appropriate level of environmental control must instead consider a variety of issues. These include such considerations as: a) the limiting rate up to which society is willing to incur costs to prevent deleterious effects on health, b) the availability of improved control technology not yet in use, as well as present patterns of use of control technology, installed for the reduction of radioactive effluents, in order to recover valuable materials, or for other reasons, and c) the distribution of potential health effects, i.e., may a few individuals incur relatively larger risks so that others may receive the benefit of an industry's operation.

If the data in the cost versus health effect curves in Figure 3 are plotted as differential curves, as shown in Figure 4, a display of the rate of aversion of health effects per unit cost versus cumulative cost is obtained. An examination of these curves in conjunction with Figure 3 shows that near a cumulative present worth cost of about three million dollars per gigawatt of power capacity for the entire fuel cycle for the PWR case (about eight million dollars for the BWR case), a breakpoint occurs between efficient and inefficient control options. At this point the rate of reducing potential health effects is roughly one per half-million dollars. In the region beyond this point, the differential curve continues to descend rapidly to very low rates of cost-effectiveness



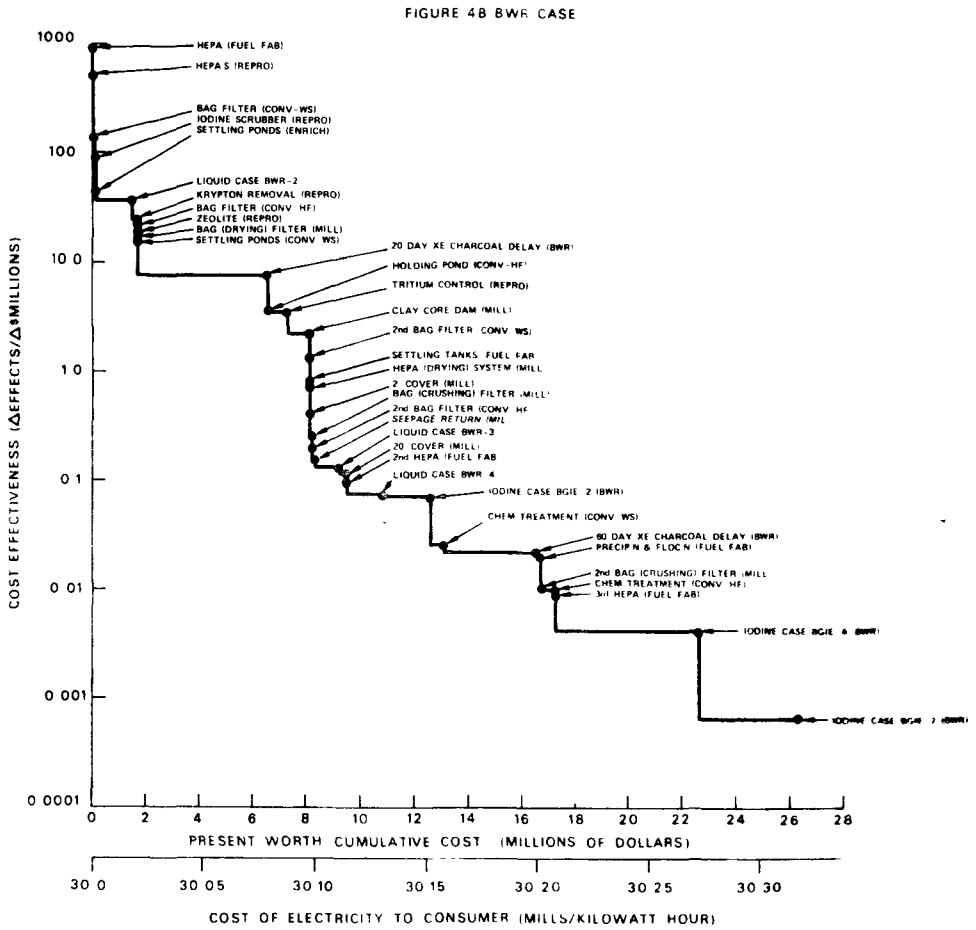


FIGURE 4. COST EFFECTIVENESS OF RISK REDUCTION FOR THE URANIUM FUEL CYCLE

(note that the vertical scale is logarithmic, not linear), and an insignificant further reduction in health effects is obtainable for additional control expenditures.

If the sole criterion for choosing an acceptable level of potential health impact was that expenditures to achieve health effects reduction stop at such a breakpoint, then no more cost should be incurred beyond about three or eight million dollars per gigawatt of fuel cycle power generating capacity (depending upon whether the power reactor is a PWR or BWR, respectively), no matter how many potential effects were remaining at that level. At this point resources are being committed at the rate of about one half million dollars for each health effect averted. Since the majority of these potential health effects are serious in nature, involving loss of life or severe disability, this could be taken as implying acceptance of that rate as limiting for preventing the loss of human life due to the impact of effluents from uranium fuel cycle operations.

It is extremely difficult to estimate what limiting value society actually places on expenditures to prevent loss of human life, because so many intangible factors must be evaluated (17). This task becomes especially difficult when one is faced with the question of preventing the loss of life; the task is less difficult, but no more exact, when considering the choice of appropriate compensation for a specific loss that has already occurred. Leaving aside the moral implications of

assigning a monetary value to compensation for such a specific loss and considering only the experience we can draw upon for what society has been willing to spend to prevent future losses, one can distinguish several characteristics. The amount depends heavily upon whether the risk of incurring the effect is imposed voluntarily or involuntarily (the latter case carrying a much greater willingness to spend) and how far into the future it is anticipated to occur. The amount also depends upon who is supplying it and upon how the burden of payment is distributed. In addition, the historical trend is for steadily increasing amounts, and there is no reason to believe that this trend will not continue.

Most current estimates of the acceptable limiting rate of investment for the prevention of future loss of life appear to fall at or below an upper limit of one-quarter to one-half million dollars (18), just below the value, noted above, at which the cost-effectiveness of health effects reduction for the fuel cycle reaches a point of rapidly diminishing return. This range of estimates of the acceptable limiting value for prevention of future loss of life corresponds to a minimum cost-effectiveness of risk reduction of two to four effects per million dollars. Returning to the curves in Figure 4 displaying cost-effectiveness of risk reduction, it can be seen that most of the systems which lie above or within this range of cost-effectiveness (with the important exceptions of krypton and tritium control) have already been developed and are either available for immediate application or are already being applied by the industry in response to a variety of factors

that are not as well defined, perhaps, as the explicit health effect and cost considerations developed here, but are present nonetheless. It seems reasonable, therefore, that levels of environmental protection achievable by systems of cost-effectiveness greater than this range of values should be required, and that levels of protection that can only be achieved using systems of lower cost-effectiveness should not be required unless other extenuating circumstances exist. Such circumstances may be that they are currently already included in facility designs for a purpose not related to radiation control, or that their use may be indicated in rare instances to bring about the reduction of excessive doses to specific individuals in the general environment, that is, to ameliorate extreme maldistribution of impact within the population.

B. RESULTS FROM ENVIRONMENTAL ASSESSMENTS UNDER NEPA

For the past three years, an extensive program has been carried out by the utilities, manufacturers, and the AEC in order to assess the expected performance characteristics of nuclear power facilities, for each of which the AEC (now the NRC) is required to file an Environmental Statement under the provisions of the National Environmental Policy Act of 1969. By the end of 1974, Environmental Statements had been submitted for 152 reactors at 82 different sites. These analyses provide unusually detailed descriptions of the impact of facilities at specific sites. For

each site such details as the local meteorology, topography, population distribution, water usage patterns, and land usage patterns (including the locations of nearby permanent residences, vegetable and dairy farms, and recreational facilities) are considered with respect to each pollutant released to the environment. The sample of statements available encompasses every important power consuming region of the United States and every significant geographical situation. Individually and collectively, these assessments represent the most comprehensive analysis ever performed of the potential impact of an industry upon the environment.

Tables 4, 5, and 6 summarize the results of these analyses for radioactive releases from pressurized water reactors, boiling water reactors, and other fuel cycle facilities, respectively. The results for reactors are listed in order of the most recently filed Environmental Statement for each site. In cases where more than one statement has been filed the most recent has been used. The statements are all final unless otherwise indicated. For each reactor site the maximum whole body doses due to gaseous releases, liquid releases, and gamma radiation from the site, as well as the maximum thyroid dose to a child's thyroid (calculated at the nearest pasture) are shown. In the case of other fuel cycle facilities, the maximum whole body, thyroid, lung, and/or bone doses are shown, as is appropriate for the particular type of facility considered.

TABLE 4. Environmental Impacts of Pressurized Water Reactors

Facility (No. of Units)	EIS (Date)	Exposure (mrem/yr)			
		Gaseous	Liquid (Whole-body)	Site Gamma*	Iodine (Thyroid)
WPPSS (2)	12/74 (draft)	<1	2	<1	3
Farley (2)	12/74	<1	<1	N.R.	<1
Seabrook (2)	12/74	<1	<1	<1	12
South Texas (2)	11/74	<1	<1	<1	<1
Greenwood (2)	11/74	<1	1	<1	2
Callaway (2)	10/74 (draft)	<1	<1	<1	4
Pilgrim (2)[a]	9/74	<1	<1	<1	3
Braidwood (2)	7/74	1	2	<1	8
Byron (1)	7/74	<1	2	<1	9
Commanche Peak (2)	6/74	<1	1	<1	5
Bellefonte (2)	6/74	<1	<1	<1	<1
Fulton (2)[f]	5/74 (draft)	1	<1	<1	<1
St. Lucie (2)	5/74	<1	<1	<1	4
Surry 3 & 4 (2)	5/74	<1	<1	<1	1
Vogtle (4)	3/74	<1	<1	<1	4
S. Harris (4)	3/74	<1	12[b]	<1	15[c]
Millstone (3)[a]	2/74	<1	<1	<1	10
Sequoyah (2)	2/74	2	<1	<1	<1
R. E. Ginna (1)	12/73	<1	<1	<1	<1
Catawba (2)	12/73	<1	1	<1	15
Indian Point (3)	10/73 (draft)	2	<1	<1	6
Haddam Neck (1)	10/73	<1	2	<1	5
Trojan (1)	8/73	<1	<1	N.R.	<1
D. C. Cook (2)	8/73	<1	<1	<1	3
Beaver Valley (2)	7/73	<1	<1	N.R.	2
Diablo Canyon (2)	5/73	<1	<1	N.R.	<1
Crystal River (1)	5/73	<1	<1	<1	2
Prairie Island (2)	5/73	<1	<1	N.R.	2
H. B. Robinson (1)	4/73 (draft)	<1	2	<1	2
North Anna (4)	4/73	<1	1	<1	<1
Calvert Cliffs (2)	4/73	<1	<1	<1	3
Salem (2)	4/73	<1	<1	<1	4
Waterford (1)	3/73	<1	4	N.R.	5

TABLE 4. Environmental Impacts of Pressurized Water Reactors (cont.)

Facility (No. of Units)	EIS (Date)	Exposure (mrem/yr)			
		Gaseous	Liquid (Whole-body)	Site Gamma*	Iodine (Thyroid)
San Onofre (3)	3/73	<1	<1	<1	<1
Davis-Besse (1)	3/73	<1	3	<1	1
Rancho Seco (1)	3/73	<1	3	N.R.	1
Arkansas (2)	2/73	<1	<1	N.R.	4
Forked River (1)	2/73	<1	1	<1	<1
V. Summer (1)	1/73	<1	5[b)]	N.R.	8
Three Mile Island (2)	12/72	<1	<1	<1	5[d)]
Zion (2)	12/72	1	<1	N.R.	3
Kewannee (1)	12/72	<1	1	N.R.	4
Watts Bar (2)	11/72	2	<1	<1	3
McGuire (2)	10/72	<1	<1	<1	<10
Fort Calhoun (1)	8/72	<1	<1	N.R.	10
Maine Yankee (1)	7/72	<1	<1	N.R.	<1
Turkey Point (2)	7/72	<1	<1	<1	<1
Surry 1 & 2 (2)	6/72	<1	<1	<1	48[e)]
Palisades (1)	6/72	<1	3	N.R.	1
Point Beach (2)	5/72	1	<1	N.R.	5
Midland (2)	3/72	4	<1	N.R.	<1
Oconee (3)	3/72	1	<1	N.R	5

N.R. = Not Reported.

*500 hours unshielded occupancy of boundary per year.

a) One BWR and two PWR units.

b) Assumes public access to cooling water discharge canal and consumption of 18 kg of fish and mollusks raised in discharge per year.

c) Monitoring and appropriate operational practices will be required by the AEC to maintain this dose level, however, the AEC considers the dose calculated without use of such measures (28 mrem/yr) very conservative (i.e., the actual dose will be lower).

d) The dose calculated in the EIS (18.5 mrem/yr) will be reduced to this level by changes in control capability required of the applicant by the AEC.

e) 98% of the release is from the condenser air ejector and steam generator blowdown, and can be eliminated through simple modifications of existing control equipment.

f) Two HTGR units.

TABLE 5. Environmental Impacts of Boiling Water Reactors

Facility (No. of Units)	EIS (Date)	Exposure (mrem/yr) Gaseous	Liquid (Whole-body)	Site Gamma*	Iodine (Thyroid)
Hartsville (4)	12/74 (draft)	<1	<1	<1	9
Oyster Creek (1)	12/74	<1	<1	<1	9
Allen's Creek (1)	11/74	<1	<1	<1	<1
Clinton (1)	10/74	<1	<1	<1	<1
Pilgrim (2)[c]	9/74	<1	<1	<1	3
River Bend (2)	9/74	<1	<1	<1	22[a,b]
Douglas Point (2)	5/74 (draft)	<1	<1	1	6
Perry (2)	4/74	<1	<1	<1	24[a,b]
Hope Creek (2)	2/74	<1	1	3	1
Millstone (3)[c]	2/74	<1	<1	1	10
Nine Mile Point (2)[d]	1/74	<1	<1	12	<1
Brunswick (2)	1/74	<1	<1	<1	28[e]
Limerick (2)	11/73	1	<1	<5	<1
Dresden (3)	11/73	<1[f]	<1	<1	7
Grand Gulf (2)	8/73	2	4	<1	3
Susquehanna (2)	6/73	4	<1	<1	<10
Peach Bottom (2)[g]	4/73	8	<1	<1	480[h]
Fitzpatrick (2)	3/73	3	<1	3	11
Duane Arnold (1)	3/73	1	<1	<1	7
LaSalle (2)	2/73	<1	<1	<1	9
Bailly (1)	2/73	1	4	25	<1
Cooper (1)[i]	2/73	5	4	N.R.	5
Hanford No. Two (1)	12/72	3	<1	<1	3
Monticello (1)	11/72	1	<1	N.R.	29[b]
Hatch (2)	10/72	1	<1	<1	17[a,b]
Zimmer (1)	9/72	<1	<1	<1	9
Shoreham (1)	9/72	2	<1	N.R.	<1
Brown's Ferry (3)	9/72	2	<1	<1	<1
Quad Cities (2)	9/72	4	<1	N.R.	2
Vermont Yankee (1)	7/72	<1	<1	N.R.	7
Fermi Unit Two (1)	7/72	2	<1	N.R.	<28[j]

(Footnotes next page)

TABLE 5. Environmental Impacts of Boiling Water Reactors (cont.)

FOOTNOTES

N.R. = Not Reported.

*500 hours unshielded occupancy of boundary per year.

a) The AEC has required installation of additional equipment to maintain doses to less than 15 mrem/yr in its comments on the EIS.

b) At least three-fourths of the projected dose is due to turbine building exhaust, which is untreated.

c) One BWR and one PWR unit.

d) Includes the contribution from Fitzpatrick. The site gamma dose assumes 100 hours in a boat at point of nearest approach per year. The figures shown are after scheduled 1975 augment of unit one gaseous effluent control.

e) The AEC also calculates a dose of 43 mrem/yr through the goat-milk pathway; more than half of the dose is due to turbine building effluent, applicant is evaluating improved systems.

f) The dose of 22 mrem/yr in Table 5.3 of the EIS for unit one will be reduced by a factor of 100 by a scheduled augment committed by the applicant (see p.11-40 of the EIS).

g) Plus one 40 MW(e) HTGR.

h) Applicant calculates a maximum dose of 0.45 mrem/yr. AEC will require applicant to reduce iodine dose to "as low as practicable" levels (see summary comments on EIS).

i) EIS lists calculated doses of up to 10 mrem/yr (whole-body) and of 95 mrem/yr (infant thyroid), but applicant has committed to install additional control equipment to insure no greater than 5 mrem/yr for both pathways.

j) Assumes a hypothetical cow grazing at the site boundary. Distance to the nearest pasture was not determined in this early EIS.

TABLE 6. Environmental Impacts of Other Fuel Cycle Facilities

Facility (Type)	EIS (Date)	Exposure (mrem/yr)			
		Whole-body	Thyroid	Lung	Bone
Humeca (mill)	12/72 (draft)	--	--	11	42[a)]
Highland (mill)	3/73	--	--	3-12	0-1
Shirley Basin (mill)	12/74	--	--	6	11
Sequoyah (conversion)	4/74 (draft)	--	--	3	<1
Barnwell (conversion)	4/74 (draft)	--	--	<1	1
Exxon Nuclear (fabrication)	6/74	--	--	<1	N.R.
Midwest[b)] (reprocessing)	12/72	1	1	N.R.	2
Barnwell (reprocessing)	4/74	4	6	4	7

N.R. = Not Reported.

a) This early draft EIS contains insufficient information to assess this dose in detail, but it is at least an order of magnitude greater than that from other current comparable facilities.

b) This facility is not now expected to become operational in the forseeable future. A cow is occasionally pastured 1.5 mi. north of the site; the maximum estimated annual dose to a child's thyroid from milk supplied by such a cow is 7.4 mrem.

Table 4 demonstrates that for over 90 percent of the 52 sites containing PWR's, maximum whole body doses from gaseous releases no greater than 1 mrem/yr are anticipated. For three, maximum doses of 2 mrem/yr and for one, 4 mrem/yr are expected. Maximum doses due to liquid effluents display a similar pattern; the handful of doses shown that are significantly greater than 1 mrem/yr are calculated for the highly unlikely situation of individuals postulated to derive a major portion of their annual animal protein diet from fish grown directly in the undiluted effluent from the site. (Such situations, although perhaps theoretically possible, have not been observed, are not anticipated to actually occur, and could be avoided, if necessary, by restricting fishing at effluent discharge outlets.) Similarly, no individual is estimated to receive a dose as great as 1 mrem/yr due to gamma radiation from the combined impact of all facilities at any site. Finally, 90 percent of sites anticipate doses to a child's thyroid due to ingestion of milk at the nearest farm no greater than 10 mrem/yr. The single facility exceeding 15 mrem/yr could control 98 percent of its projected releases through simple modifications of the handling of untreated air ejector and steam generator blowdown effluents (19).

Table 5 demonstrates that 80 percent of the 31 sites containing BWR's anticipate maximum whole body doses from gaseous releases no greater than 2 mrem/yr, and that all but one will not exceed 5 mrem/yr. That site (Peach Bottom) predicts 8 mrem/yr at its nearest boundary for fulltime year-round unsheltered occupancy. The actual dose at the

nearest residence would be significantly lower. Doses from liquid effluents are smaller, with 90 percent estimating 1 mrem/yr or less and no site exceeding 4 mrem/yr.

Doses due to gamma radiation originating onsite can be significant at BWR sites because of the circulation of activation-produced nitrogen-16 through the turbines in this reactor design. Careful design of shielding and turbine location relative to the site boundary and topographical features is required. In spite of this, only two BWR sites project boundary doses greater than 5 mrem/yr to individuals. In one of these cases (Nine Mile Point) the dose can be reduced by restricting boating near the discharge canal; in the other (Bailly) the dose is to steel workers, not permanent residents, on an adjacent site, and appears to be unnecessarily high.

Of all the effluents from power reactors, iodine releases from BWR's represent the greatest potential source of maximum exposure to individuals. Although 70 percent of sites have projected maximum thyroid doses at the nearest farm of less than 10 mrem/yr, five estimate doses between 20 and 30 mrem/yr, and one projects doses an order of magnitude greater. The principal potential source contributing to all potential doses that are greater than 10 mrem/yr is iodine released from the turbine building vent (20). Treatment of this source term is possible, but is made more difficult by the large volume of air released from the turbine building. Selective treatment of the largest sources in the

turbine building is possible, however, at reasonable cost, and is incorporated in a number of recent designs (21). The need for such treatment must be weighed, nonetheless, in the light of the results of field measurements of potential doses to the thyroid discussed below in Section C.

Table 6 summarizes the available information on doses to the public in the general environment due to operation of fuel cycle facilities other than reactors. It is far less extensive than that available for reactors, but represents the projected impact of facilities typical of modern practice. Significant, but relatively small doses are projected to the lung and bone at mills and fuel reprocessing, as well as to the thyroid at fuel reprocessing. The single instance of a projected dose significantly exceeding 10 mrem/yr is for a facility not projecting use of cost-effective levels of particulate control (22).

C. FIELD MEASUREMENTS OF ENVIRONMENTAL IMPACT

The oldest commercial power reactor, Dresden I, commenced operation over fifteen years ago, in October 1959. By the end of 1972, there were 26 commercial power reactors in operation at 22 different sites, and in 1973, ten more reactors commenced operation. These utilities submit to the AEC (now the NRC) reports of actual releases on at least a semi-annual basis. These are reviewed for accuracy and published annually.

In addition, EPA and its predecessor organizations have conducted detailed surveillance programs at selected facilities. These studies have consistently confirmed the accuracy of reported effluents of noble gases and liquids and the potential doses associated with these, but appear to reveal significantly lower potential thyroid doses than would be expected from reported releases using commonly employed modeling techniques and parameters for environmental pathways.

Table 7 shows calculated maximum doses at the site boundary for the reported releases of noble gases from all operating facilities for the years 1972 and 1973 (23). In all cases, actual releases were less than those assumed for the model-based calculations discussed in Sections A and B above. Figure 5, which is taken from a recent EPA report (24), shows the distribution of these releases for all BWR's commencing operation within the past decade as well as that assumed for the model calculations of the preceding sections. A similar figure is not available for PWR's due to their extremely low levels of reported releases. It can be seen from the figure that the average facility experiences releases a factor of 3 lower than the model assumptions, and that all facilities were at least 35 percent lower.

The doses shown in Table 7 are expected, on the basis of field experience, to fairly accurately represent actual doses that would be received by a hypothetical individual located at the site boundary in the prevailing wind direction, year-round, and unshielded by any structure.

TABLE 7. Calculated Doses from Noble Gas Releases at Operating Plants (1972-73)

Facility (Site)	Start Up	Net Site Capacity [GW(e)]	Annual Output (% of Capacity)		Fence Dose (mrem/yr)		Fence Dose @ 0.8 Cap. (mrem/yr)		Fence Dose w/Retrofit (mrem/yr)		D.F.†
PWR's			1972	1973	1972	1973	1972	1973	1972	1973	
Yankee Rowe	8/60	0.18	40	68	<1	<1	<1	<1	N.A.	N.A.	N.A.
Indian Point 1 & 2	8/62,5/73	1.14	16	24	<1	<1	*	<1	"	"	"
San Onofre 1	6/67	0.43	74	60	<1	<1	<1	<1	"	"	"
Haddam Neck	7/67	0.58	85	46	<1	<1	<1	<1	"	"	"
R. E. Ginna	11/69	0.47	57	87	<1	<1	<1	<1	"	"	"
Point Beach 1 & 2	11/70,5/72	0.99	70	67	<1	<1	<1	<1	"	"	"
H. B. Robinson	9/70	0.70	72	82	<1	<1	<1	<1	"	"	"
Palisades	5/71	0.70	32	41	<1	<1	<1	<1	"	"	"
Surry 1 & 2	7/72,3/73	1.58	6	65	<1	<1	*	<1	--	"	"
Turkey Point 3 & 4	10/72,6/73	1.39	--	62	--	<1	--	<1	--	"	"
Maine Yankee	10/72	0.79	7	58	<1	<1	*	<1	--	"	"
Oconee 1	4/73	0.88	--	47	--	<1	--	<1	--	"	"
Zion 1	6/73	1.05	--	22	--	<1	--	<1	--	"	"
Ft. Calhoun	8/73	0.46	--	42	--	<1	--	<1	--	"	"

N.A. = Not Applicable.

*Not projected, due to the low fraction of capacity utilized.

TABLE 7. Calculated Doses from Noble Gas Releases at Operating Plants (1972-73) (cont.)

Facility (Site)	Start Up	Net Site Capacity [GW(e)]	Annual Output (% of Capacity)		Fence Dose (mrem/yr)		Fence Dose @ 0.8 Cap. (mrem/yr)		Fence Dose w/Retrofit (mrem/yr)		D.F.†
BWR's			1972	1973	1972	1973	1972	1973	1972	1973	
Dresden 1	10/59	0.20	65	33	13	12	16	29	<1	<1	180
Big Rock Point	9/62	0.08	57	68	5	5	8	5	<1	<1	40††
Humbolt Bay	2/63	0.07	62	77	67	54	87	56	2	1	40††
LaCrosse	7/67	0.05	60	46	<1	3	1	4	<1	<1	100
Oyster Creek	5/69	0.64	78	64	37	35	47	44	1	1	40
Nine Mile Point	9/69	0.63	59	68	11	21	15	25	<1	<1	75
Dresden 2 & 3	1/70,1/71	1.62	57	64	2	6	3	7	<1	<1	40
Millstone 1	10/70	0.65	55	34	8	1	12	2	2	<1	8
Monticello	12/70	0.55	75	68	30	33	32	39	<1	1	40
Quad Cities 1 & 2	10/71,4/72	1.60	28	73	1	7	3	8	<1	<1	16
Vermont Yankee	3/72	0.51	10	44	3	16	25	29	1	1	>20
Pilgrim 1	6/72	0.66	15	71	1	3	1	4	<1	<1	>40

† Decontamination factor of system augment committed by facility. No D.F.'s are listed for PWR's, since all existing facilities project releases of <1 mrem/yr.

†† No commitment for retrofit made. A minimum augment has been assumed (recombiner plus 1 day holdup) beyond 20 minute holdup and release via the existing stack.

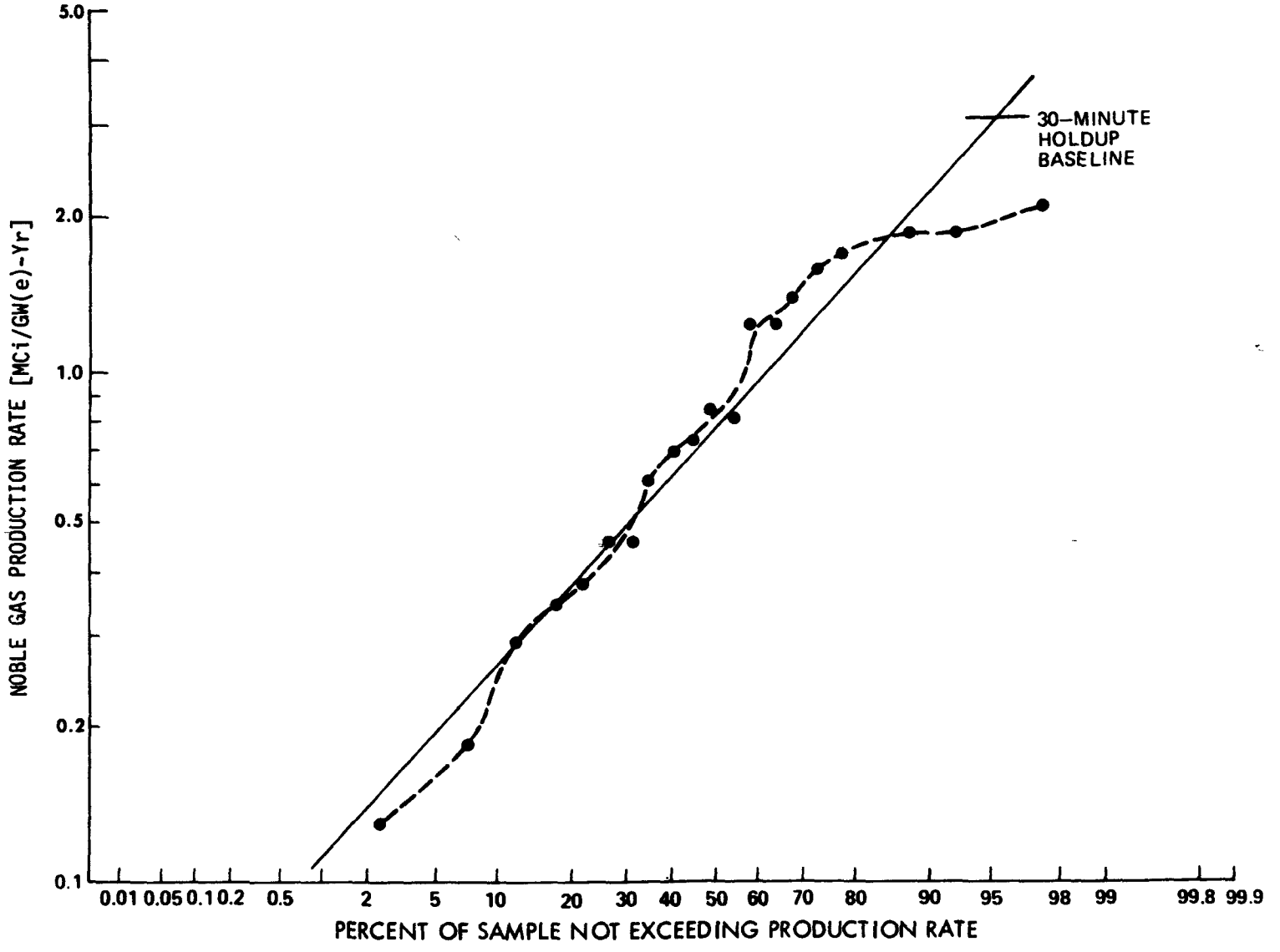


Figure 5. Distribution of noble gas releases in 1971-73 for boiling water reactors that commenced operation after 1968. The solid line is a fitted log normal distribution.

Actual maximum doses to real individuals would, of course, be substantially lower. These doses have also been calculated for an assumed year of full operation (taken to be 80 percent of rated capacity, on the average, on an annual basis) at the level of effluent control in effect during 1972 and 1973. Finally, on the basis of the retrofits of these facilities presently committed (all will be completed within the next year, except for the two small old BWR's indicated as not yet committed), the doses that would have been observed in these years if the retrofits had been in place are shown. The data indicate that all PWR's currently produce maximum potential fence post doses of less than 1 mrem/yr and that all BWR's with currently committed (or assumed minimum) retrofits would deliver fence post doses of 2 mrem/yr or less. These results appear to confirm the model projections of the two preceding sections.

Liquid pathway releases from these facilities result in much smaller potential doses than do noble gas releases. Detailed studies of several specific facilities have revealed no actual dose to any individual from this pathway as great as 1 mrem/yr (25).

Studies of iodine pathways and potential thyroid doses have been conducted jointly by EPA and AEC over the past two years at the Dresden, Monticello, Oyster Creek, and Quad Cities sites (26). In both years, although atmospheric fallout from bomb testing has prevented the accumulation of definative long-term measurements, the available results

present a consistent picture of iodine concentrations in milk at least an order of magnitude less than that projected by models for the milk pathway currently used for environmental analyses. The difficulty appears to arise from inadequate assumptions regarding the input parameters for the airborne transport of iodine, although this is by no means definitively established and such other factors as the influence of wash-out, chemical form of the iodine, and pasture retention factors are also in question. Regardless of the exact cause of the discrepancy, the measurements at these facilities are consistent, and there is no known data in contradiction. The data for Monticello, Dresden, and Quad Cities are the most complete, and at pastures near each of these sites the concentrations of radioiodine in milk that were observed would lead to maximum thyroid doses to infants of a few tenths of a mrem/yr per curie of iodine-131 released annually to the environment from the site.

The results of these studies were used to project the expected maximum doses to a child's thyroid at the nearest pasture at all but 2 of the 12 BWR sites reporting releases in 1972 and 1973. (The locations of pastures and meteorological characteristics for two small, atypical BWR's, Humbolt Bay and Big Rock Point, were not available.) These projections were obtained by normalizing the meteorological characteristics for the nearest pasture and the actual releases of each facility to the same quantities for Monticello and Quad Cities, and projecting the resulting doses for operation of each facility at 80 percent of full capacity. The results indicate that, based on actual

releases reported in 1972 and 1973 by these operating facilities and the field measurements conducted in those years at the two facilities studied in detail, no facility had projected maximum potential thyroid doses to an infant as great as 1 mrem/yr, in either year, for assumed average annual operation at 80 percent of full rated capacity.

Field measurements at other fuel cycle facilities are very sparse. In 1968 DHEW completed a study at a fuel reprocessing facility (27); this facility is not now in operation and is not representative of the performance of current technology. The study indicated maximum potential individual whole body doses of up to several hundred mrem/yr and comparable maximum organ doses to the bone were possible at that time due to ingestion of deer (which had access to or graze) and fish raised in the plant effluent.

D. THE PROPOSED STANDARDS

Acceptable maximum levels of public exposure and environmental contamination by long-lived radioactive materials due to environmental releases from the operations comprising the fuel cycle were determined by considering the cost-effectiveness of the reduction of total population impact, the acceptability of the resulting maximum individual exposures, and the potential for environmental contamination by long-lived radioactive materials. The standards were chosen to limit the quantity

discharged or the maximum individual annual dose rate depending upon whether the radioactive materials concerned were long-lived or short-lived, respectively. Table 8 summarizes the numerical values of the standards proposed for the uranium fuel cycle on these bases.

The proposed standard for maximum annual whole body dose to any individual limits the combined external and internal dose due to short-lived gaseous and liquid effluents as well as to exposure to gamma radiation originating from all operations of the fuel cycle to 25 mrem/yr. Such a value is easily satisfied by levels of control that are cost-effective for the risk reduction achieved; is achieved by all sites for which Environmental Statements have been filed; and, on the basis of operating experience at existing sites, can be readily achieved in practice. The combined impact of a fuel reprocessing facility, when added to that at any reactor site, is such that the standard would continue to be met by levels of control that are cost-effective at all such sites. This case of mixed types of facilities on a single site is judged to represent the worst case reasonably anticipatable.

The appropriate level for a standard limiting the maximum annual thyroid dose of individuals is not easy to determine. On the basis of existing field measurements a value much less than that proposed would appear to be appropriate. However, the level of control assumed necessary by the AEC in recent licensing actions on the basis of model projections is somewhat greater than that justified on the basis of cost-

Table 8. The Proposed Standards for Normal Operations of the Uranium Fuel Cycle

A. Individual Dose Limits

1. Whole body	25 millirems/year
2. Thyroid	75 millirems/year
3. Other organs*	25 millirems/year

B. Limits for Long-Lived Radionuclides

1. Krypton-85	50,000 curies/gigawatt-year
2. Iodine-129	5 millicuries/gigawatt-year
3. Transuranics**	0.5 millicuries/gigawatt-year

C. Variances

At the discretion of the regulatory agency (licensor) for temporary and unusual operating circumstances to insure orderly delivery of electrical power.

D. Effective Dates

1. Two years, except
2. 1983 for krypton-85 and iodine-129.

* any human organ except the dermis, epidermis, or cornea.
** limited to alpha-emitters with half-lives greater than one year.

effectiveness of risk reduction to the entire population alone. This is because a small number of individuals are potentially subject to relatively high doses. If actual doses are, indeed, as low as those indicated by the limited existing number of field measurements, the degree of control assumed necessary may be unwarranted. For this reason, the proposed standard is not based upon the evidence of field measurements, except to the degree that they indicate that the very high doses projected in a few instances are unrealistic. The standard has been chosen, instead, so as to reflect a level of biological risk comparable, to the extent that current capability for risk estimation permits, with that represented by the standard for whole body dose.

Doses to other organs are readily maintained within 25 mrem/yr using economical readily available controls for limiting environmental releases. These doses arise principally from exposure of lung and bone as a result of airborne effluents from fuel supply and reprocessing facilities. The single example of a projected value in excess of this limit in environmental assessments by the industry (bone dose at a mill) represents an unnecessarily high environmental impact that can and should be reduced. As in the case for whole body dose, cost-effective levels of control are available and can be readily achieved in practice.

The proposed standards for long-lived materials fall into two categories: those which can be achieved using currently available methods for control of environmental releases, and those that require use of

methods that have been demonstrated on a laboratory or larger scale, but have not yet achieved routine use. In the former case, exemplified by the standard for plutonium and other transuranics, the standard limits the environmental burden to a level consistent with that reasonably achievable using the best available control methods. In the latter case, that of the proposed standards for krypton-85 and iodine-129, the limiting levels of environmental burdens specified are not those achievable by best available performance, but instead by minimum performance reasonably anticipated from these new systems. As experience is gained concerning the ability of the industry to limit fuel cycle releases of these materials to the environment the Agency will consider the appropriateness of more stringent levels for maximum environmental burdens of these persistent radionuclides.

Similarly, as knowledge becomes available concerning the capability of technology to limit environmental releases of tritium and carbon-14, the appropriate levels of environmental burdens of these radionuclides will be carefully considered by the Agency. However, the knowledge base now available is inadequate for such a determination, and no standards are presently proposed for these radionuclides.

The proposed standards are designed to govern regulation of the industry under normal operation, and therefore a variance is provided, to be exercised by the regulatory agency, to accommodate unusual and temporary conditions of facility operations which deviate from such

planned normal operation. This provision is important because the standards, although they can easily be satisfied with a wide margin at most facilities, are not intended to provide for operational flexibility under unusual operating situations. Unusual conditions have not been addressed by these considerations, which are intended to define currently acceptable levels of normal operation only, and not acceptable levels of unusual operation. It is anticipated that such unusual operation will occur, at some facilities more often than at others, and that every effort will be made to minimize such operation by the regulatory agency.

The proposed standards for maximum doses to individuals were derived through consideration of the doses arising from effluents released from single sites. However, since large numbers of sites are projected for single geographical regions in several parts of the country, the possibility of additive doses exceeding the maximum limits for individuals due to the combined effect of effluents from many sites must also be considered. This problem may be conceptualized as having two components. The first is the possibility that two sites may be sufficiently close to each other that the maximum dose to an individual from one is appreciably increased by the other. The second is the possibility that the combined effect of all of a large number of sites in a particular geographical region may give rise to a general increase in dose levels of significance compared to the maximum dose from any single site.

Because of the importance of specific meteorological and geographical parameters, the first possibility is best considered on the basis of real cases. The largest potential contribution to individual dose is via airborne releases. Since doses due to such releases generally fall off to less than 10 percent within 10 to 20 kilometers of site boundaries, only sites separated by less than 20 km were considered. There are presently only 3 pairs of such sites projected through the year 1985. These were each examined using meteorological parameters characteristic of these sites. The maximum increases in maximum doses are shown in Table 9. In no case is the increase as great as 20 percent. Given the margin of flexibility available in the capability of effluent control systems, this modest overlap of doses is not judged to pose any difficulty with respect to compliance with the proposed standard.

The second possibility, that of a general increase due to the impact of large numbers of facilities in a region, has been extensively examined in a recent AEC study of the implications of projected future nuclear facilities in the upper Mississippi river basin (28). This study, which was carried out, among other objectives, to assist EPA in evaluating the environmental aspects of expanded use of nuclear power, analyzes the potential combined impact of approximately 350 reactor facilities and 9 fuel reprocessing facilities projected for this river basin in the year 2000. The study divided the region into 300 areas. The analysis shows that in none of these 300 areas does the projected average dose to individuals exceed 1.2 mrem/yr. The average for the entire region is

TABLE 9

Potential Incremental Doses Due to Overlap of Exposures to Airborne Effluents at Closest Presently Projected Nuclear Facility Sites

Site Designations	Distance Between Sites (km)	Maximum Dose†
Peach Bottom - Fulton	2.4	1.20
Point Beach - Kewaunee	7.0	1.06
Hope Creek, Salem - †† Summit	14.5	<1.04

† Expressed as the ratio of the maximum dose for the two sites together to the maximum dose in the absence of the second site. In each case the maximum dose due to overlap occurs at or near the point where the maximum dose due to a single site would occur.

†† Hope Creek and Salem facilities share a common site.

less than 0.2 mrem/yr. It should be noted that these are average, rather than maximum, doses, so that these results do not specify the maximum doses projected in each subarea, but rather the sum of the general impact of the many sites outside each area plus the average local impact of any single sites within the area. A substantial portion of even these small doses must necessarily arise from these average local contributions. The analysis included a detailed treatment of all pathways, including air, water, and foodstuffs. Well over 90 percent of all doses result from pathways involving airborne transport of effluents. It is concluded that any general increase in radiation doses from regional contributions will be small compared to the maximum individual dose to which the proposed standard applies.

VI. ANTICIPATED IMPACT OF THE PROPOSED ACTION

The proposed environmental radiation standards for the uranium fuel cycle are anticipated to have impacts on long-term contamination of the environment, on public health, and on the economic cost of producing electrical energy. The impact of the proposed standards has been assessed relative to that associated with current standards under which the nuclear industry has evolved up to the present time. Since the proposed standards are more restrictive than current standards their environmental and public health impacts will logically be positive and not adverse in nature. On the other hand, achievement of improved levels of protection of public health and the environment will require controls that will result in increased costs which must be reflected in energy prices. Standards could also have implications for Federal and State agencies charged with the responsibility of regulating the industry (or operating facilities that are part of the fuel cycle), on the distribution of pollutants between the various environmental media, for the number of uranium fuel cycle facilities that can be operated at single or contiguous sites, and even on the mix of nuclear and non-nuclear fuels used for the production of electricity. These real and potential impacts are considered in turn in the following sections.

A. ENVIRONMENTAL IMPACT

The environmental impact of fuel cycle operations has been considered from the point of view of long-term irreversible commitments of radioactive pollutants to the planet's terrestrial, atmospheric, and aquatic environments. In the next section, the public health implication of these commitments, as well as that of short-lived materials, is considered. However, that consideration of public health impact is limited to potential health effects initiated by exposure to these materials during the first 100 years following their introduction to the environment, and cannot, because of our inadequate understanding of their long-term behavior, comprehend their full potential impact. Effects on other life forms have not been assessed, since they are not expected to be significant at levels adequate for protection of human populations.

Environmental burdens of tritium, carbon-14, krypton-85, iodine-129, and plutonium and other transuranics were examined for projected normal releases over the next 50 years from the U.S. nuclear power industry operating under existing standards and regulations (5). The results of these analyses are shown in Figures 6-10. For those radionuclides now released without any restriction, the levels that could be achieved with and without the proposed standards are shown. In cases where releases of these materials are currently limited, projections for each of several levels of control are shown.

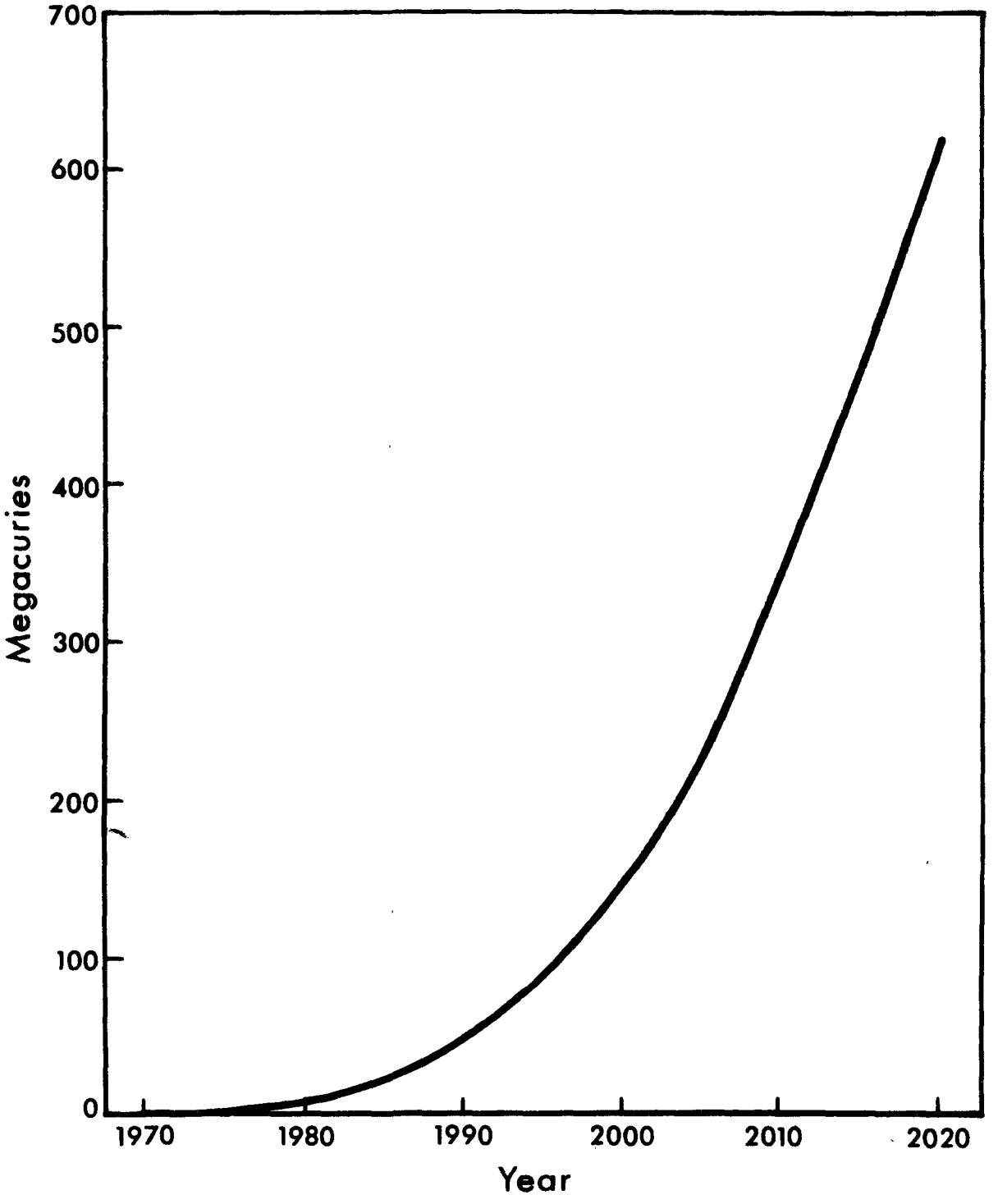


Figure 6. Projected Environmental Burden of Tritium from the United States Nuclear Power Industry.

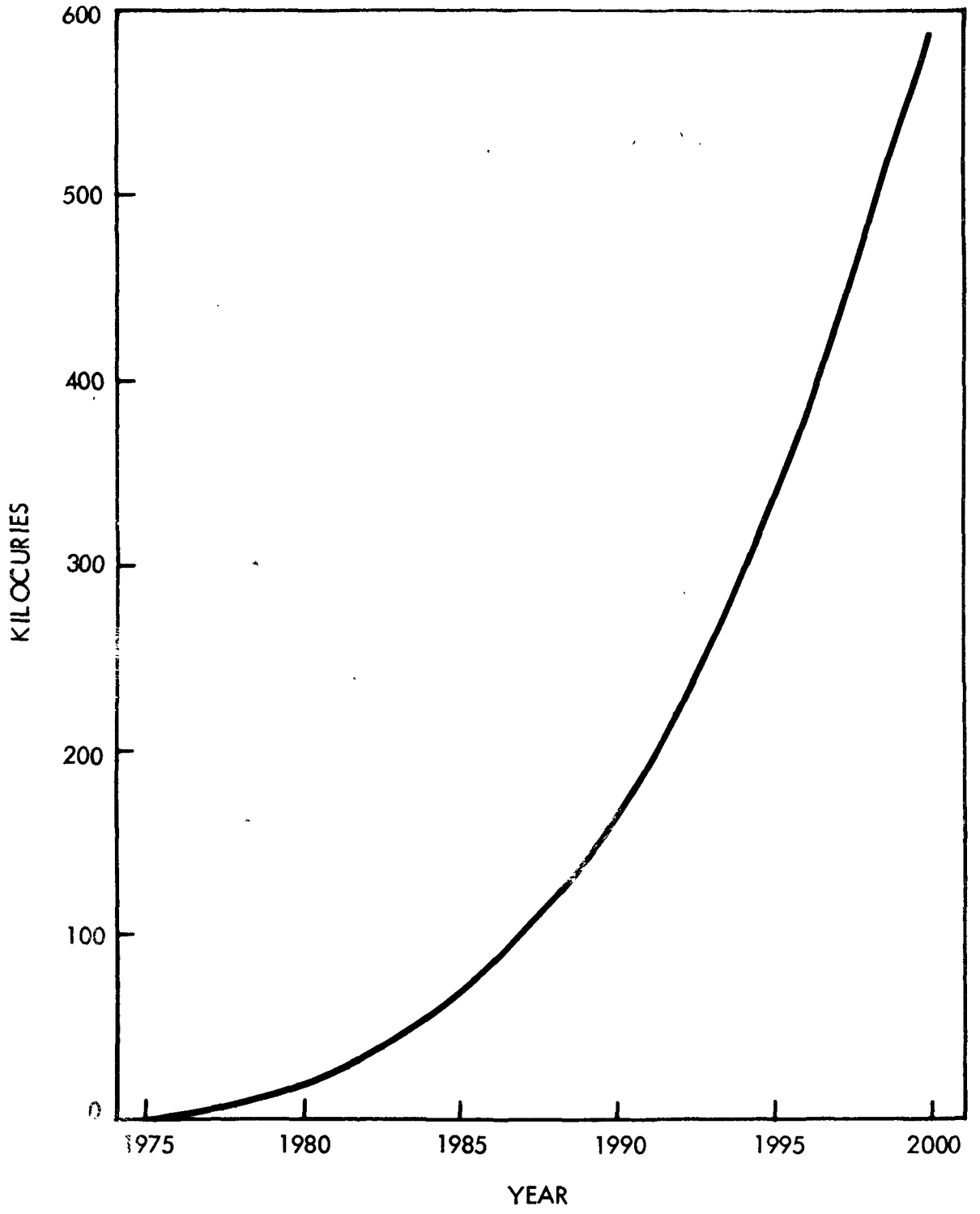


Figure 7. Projected environmental burden of carbon-14 from the United States nuclear power industry.

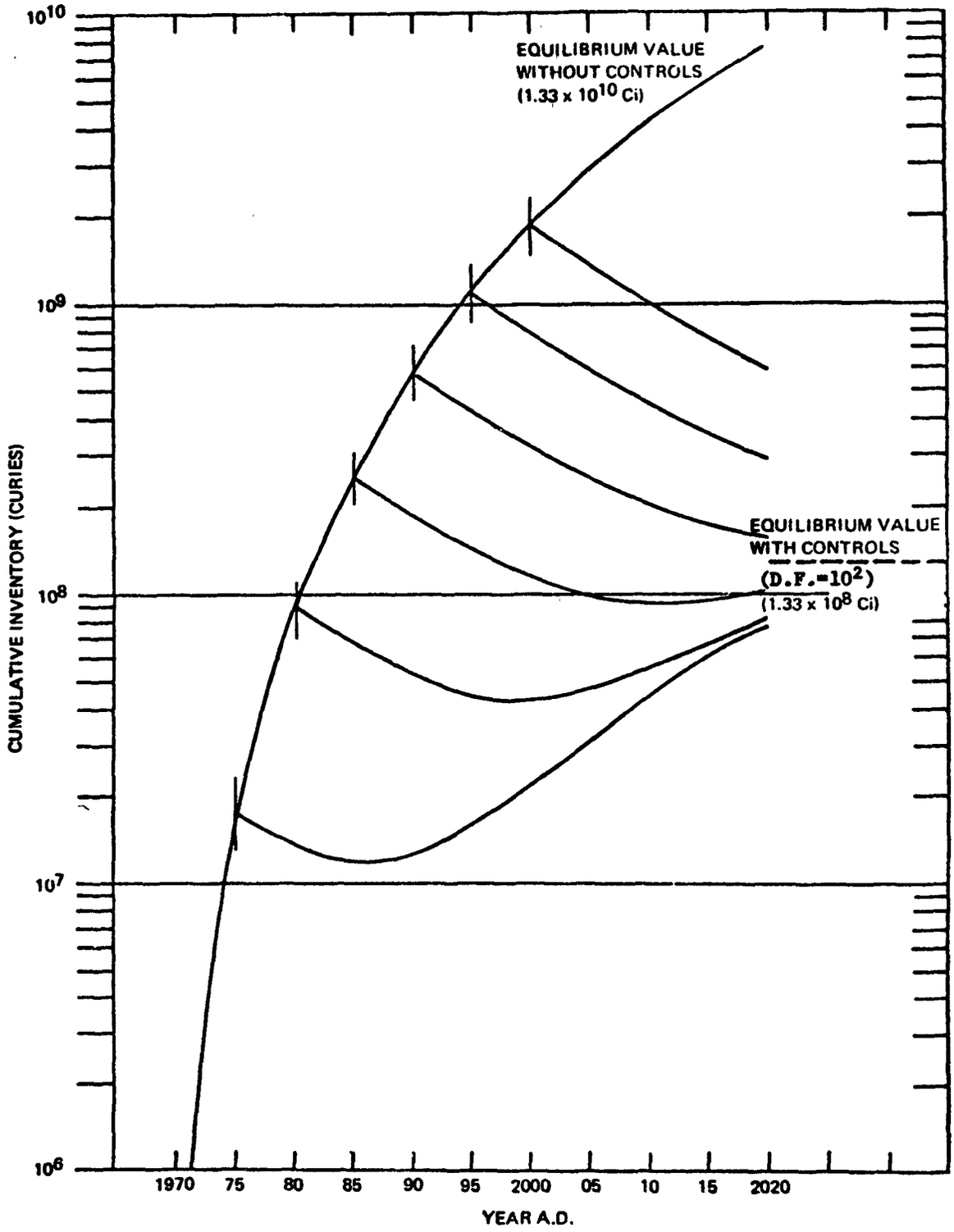


FIGURE 8. PROJECTED ENVIRONMENTAL BURDENS OF KRYPTON-85 FROM THE UNITED STATES NUCLEAR POWER INDUSTRY FOR CONTROL INITIATED IN VARIOUS YEARS. THE EQUILIBRIUM VALUES ARE THOSE FOR MAXIMUM POWER PRODUCTION EQUAL TO THAT PROJECTED FOR THE YEAR 2020.

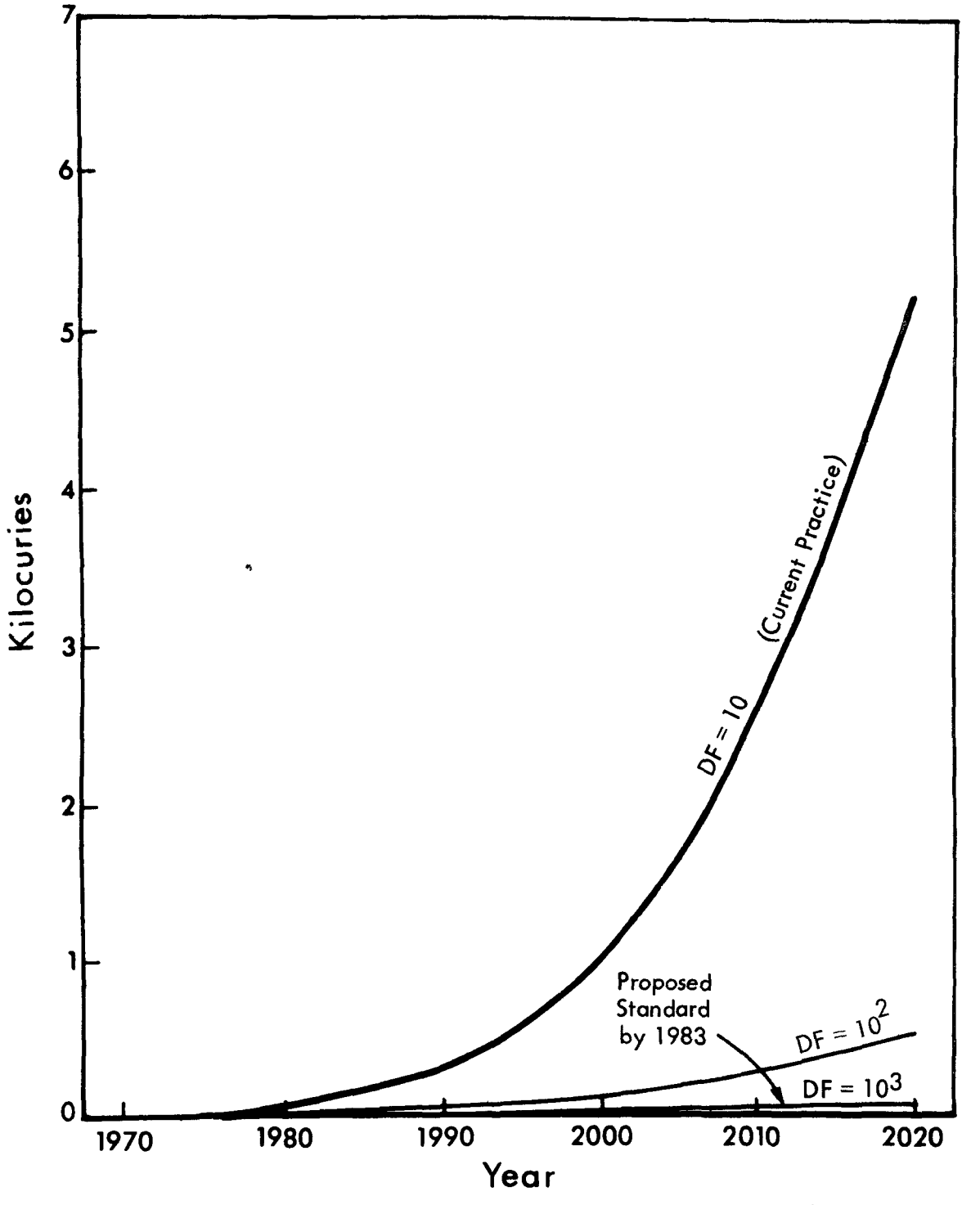


Figure 9. Projected Environmental Burdens of Iodine-129 from the United States Nuclear Power Industry at various levels of control

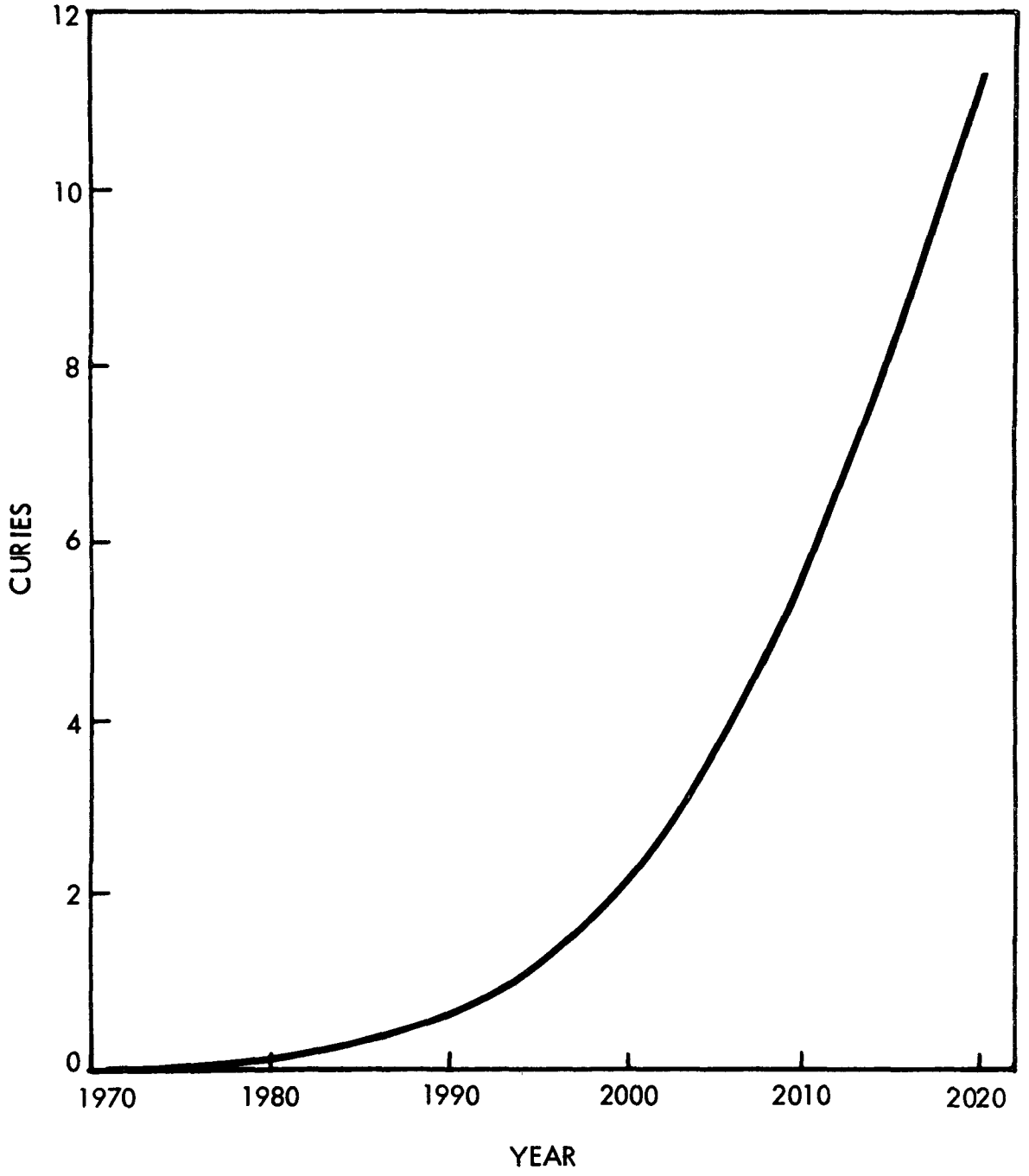


Figure 10. Projected environmental burden of alpha-emitting transuranics with half-lives greater than one year, from the United States nuclear power industry, assuming release of 10^{-9} of inventory and operation with uranium fuel only.

These projections demonstrate several significant characteristics. In all cases, existing environmental burdens due to nuclear power operations are small, and in all cases rapid increases are anticipated in the near future at current levels of control. The public health significance of these increased burdens, as assessed in the next section of this Statement for the first 100 years following release, is significant for all of these radionuclides and is particularly large for tritium, carbon-14, and krypton-85. The total significance of environmental burdens of carbon-14, iodine-129, and the long-lived transuranics, which have half-lives of 5700 years, 17 million years and from 18 to 380,000 years, respectively, cannot be quantitatively assessed, but must be assumed to be considerably greater than that anticipated during the first 100 years alone. The potential future impact of the release of krypton-85, especially if other releases around the world are added to these estimates, is strongly dependent not only upon the level of nuclear power production, but also upon the year in which controls to limit releases of this radionuclide are implemented (29). As Figure 8 demonstrates, implementation of controls with a decontamination factor (D.F.) of 100 in the early 1980's would insure that the environmental burden never exceeds the equilibrium burden, with such controls, associated with any power production level projected over the next 50 years. Although the proposed standard only requires a D.F. of 10, it is expected that use of the controls needed to satisfy this requirement will result in an actual performance approaching that shown in Figure 8. The proposed standards would limit projected environmental

burdens of iodine-129 to 1 percent of that currently projected (30), and would also require continuation of presently used best practicable control of releases of transuranics.

The admonition of the National Environmental Policy Act that "...it is the continuing responsibility of the Federal Government use all practicable means..to the end that the Nation may...fulfill the responsibilities of each generation as trustee of the environment for succeeding generations..." is particularly germane to consideration of these long-term environmental pollutants. At currently projected levels of fuel cycle operations it is clear that the potential for future radiation effects is substantial in the absence of standards to limit environmental burdens of these materials. This goal is not satisfied by these standards for releases of tritium and carbon-14 only because control technologies for these materials are not yet commercially available.

B. HEALTH IMPACT

The anticipated impact of these standards on the potential for effects on public health is shown in Table 10. These estimates of potential health effects are limited to cancers (including leukemia), and serious genetic effects (these include congenital abnormalities leading to serious disability, and increases in diseases that are specifically

Table 10. Potential Health Effects Attributable to Operation of the Nuclear Fuel Cycle Through the Year 2000 at Various Environmental Radiation Protection Levels.†

Type of Radioactive Material	Federal Radiation Guides	Current AEC Practice††	EPA Generally Applicable Stds.††
1. Short-lived materials	34,000	170	160
2. Long-lived materials†††			
a) Controllable (^{85}Kr, ^{129}I, ^{239}Pu, etc)	1040	1040	20
b) Tritium	440	440	440*
c) Carbon-14	12,000	12,000	12,000**

† These projections are based upon the linear non-threshold assumption, which, at the current level of understanding of radiation effects in man, warrants use for determining public policy on radiation protection. It should be recognized, however, that these projections are not scientific estimates, but judgments based upon scientific data obtained under different conditions of exposure than those associated with nuclear fuel cycle operations. Health effects shown are limited to total cancers, including leukemias, and serious genetic diseases (see text). The entries are the predicted number of health effects attributable to releases from the U.S. nuclear industry by the year 2000. The projections assume that approximately 8300 GW(e)-yr of electric power will be produced by nuclear reactors in this period, based on AEC case B projections (WASH-1139(74)). It is also assumed that all nuclear fuel cycles will operate at the same level of impact as the uranium fuel cycle.

†† Assumes implementation of Appendix I as proposed in the Concluding Statement of the Regulatory Staff, February 20, 1974.

††† Effects are projected for the first 100 years following release only.

* The majority of this impact can be eliminated through implementation of the voloxidation process at fuel reprocessing, if current development efforts continue and are successful.

** About 60% of this impact may be eliminated as a by-product of the retention of krypton-85 at fuel reprocessing, however, knowledge concerning control of this source of health impact is currently limited.

genetic, such as certain forms of mental defects, dwarfism, diabetes, schizophrenia, epilepsy, and anemia). The genetically-related component of diseases such as heart diseases, ulcers, and cancer as well as more general increases in the level of ill-health are omitted from estimates of genetic effects, as are effects on growth, development and life span, because of the wide range of uncertainty in existing estimates of their importance, coupled with a judgment that their total impact is probably not greater than that of those health effects that have been quantitatively considered. To the extent that other somatic and genetic effects are important, the present estimates of the impact of radioactive effluents on health are not conservative, although such effects are expected to be reduced by improved levels of effluent control in the same proportion as are those that have been quantified. In most instances, the numerical estimates of health effects were derived using the results of EPA's model projections of fuel cycle operations and health risk estimates from the recent National Academy of Sciences' report on this subject (6).

The Table 10 entries in the column labeled "Federal Radiation Guides" were derived assuming use of the minimum level of effluent control required to assure a dose to individuals at site boundaries no greater than 170 mrem/yr. They do not represent the physically unrealizable assumption of 170 mrem/yr/individual to entire local or national populations. While these entries are representative of the levels of operation that are permitted by the current Federal Radiation

Guides (as reflected by the NRC's effluent standards in 10CFR20), it should be recognized that current operations are conducted so as to maintain maximum doses well below these permitted levels. The proposed standards will have the effect of removing the possibility that these unnecessarily high levels of dose could ever be legally incurred by any normal fuel cycle operations. The second column shows the reduction in potential effects that has been achieved through application by the AEC of the Federal Radiation Guidance that annual doses to individuals be kept "as low as practicable." The entries reflect the levels of potential impact that could result from the guidance for design and operation of light-water-cooled reactors proposed by the AEC as Appendix I to 10CFR50, if it is promulgated by NRC as proposed (31). The final column shows the estimated levels of effects if the industry were to operate under the proposed standards. The small reduction shown in the final column for short-lived materials occurs only as a result of reductions in dose from components of the cycle other than reactors, since it is assumed that the proposed standards will be implemented at reactors by proposed Appendix I.

The proposed standards would result in a reduction of approximately 1000 potential health effects due to releases of long-lived materials to the environment through the year 2000. The principal residual impact of the fuel cycle would then be that attributable to carbon-14 and tritium, and control of a substantial fraction of this impact may be achievable through inexpensive modification of systems that are installed to meet

the requirements of the proposed standard for krypton. In any case, the Agency will closely follow the development of knowledge concerning control of these materials. Figure 11 shows the projected growth of the potential health impact of these materials through the year 2000. The projections are for assumed operation of the industry using uranium fuel only.

C. ECONOMIC IMPACT

The economic impact of the costs imposed by these standards should be considered from two viewpoints; first, is the cost reasonable for the protection received, and second, will the costs have any impact upon the ability of industry to supply needed power. The cost-effectiveness of the risk reduction achieved by the proposed standards was given careful consideration. Most of the reduction in potential health effects required by these standards comes as a result of the reduction of releases of long-lived materials. This reduction is achieved at a cost of considerably less than $100,000 per effect (30), a rate of spending for public health protection considerably less than that already in effect in the industry for other types of radioactive effluent control. This is the case because the proposed standards impose increased control requirements principally on effluents that can deliver doses to very large populations over long periods of time, instead of in areas where

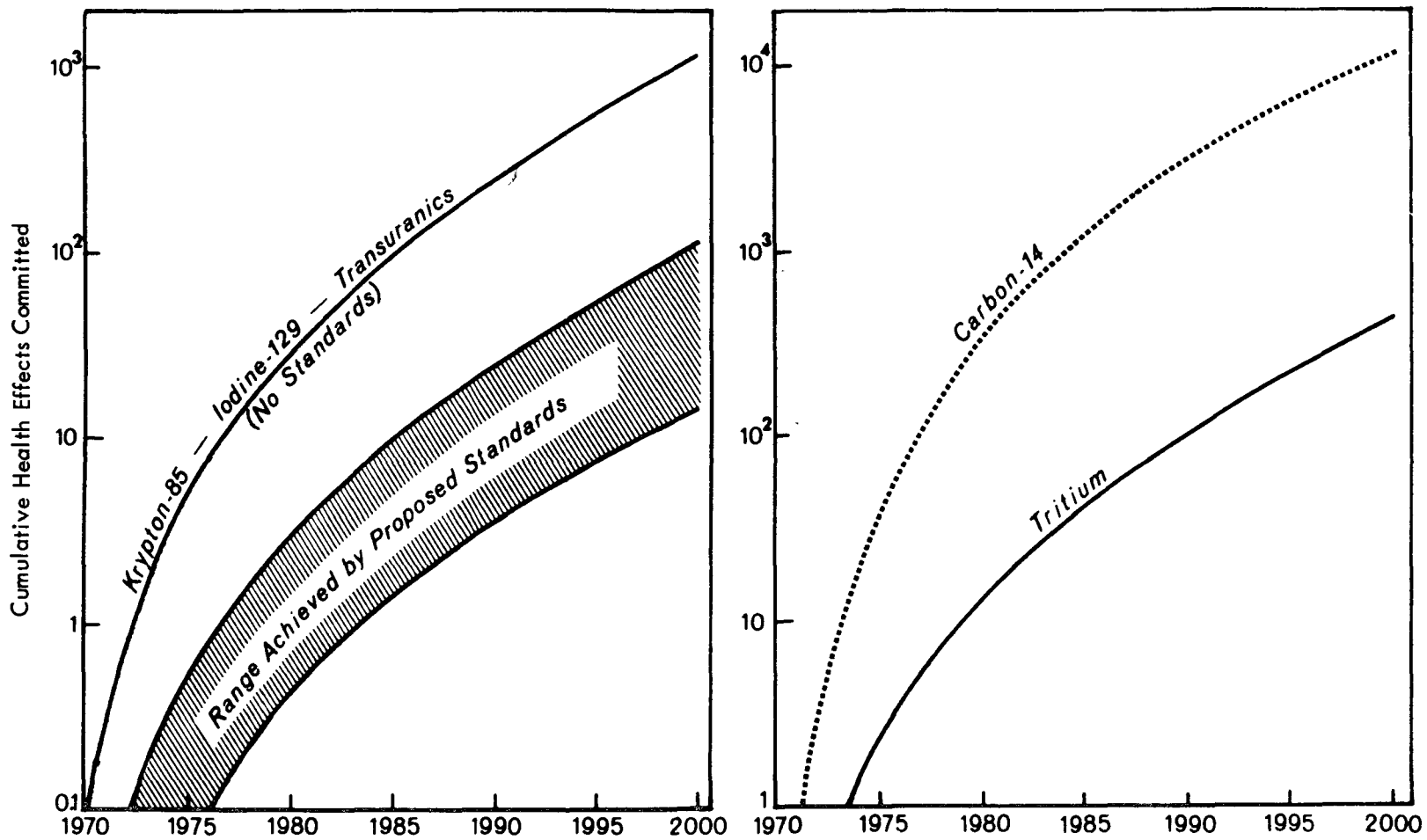


Figure 11. Projected health effects attributable to releases of long-lived radionuclides. Health effects are projected for 100 years following release only, and the exclusive use of uranium fuel is assumed.

short-term doses to only relatively few individuals near facilities can occur.

The capital cost of a new one GW(e) reactor was estimated in 1972 to be on the order of 450 million dollars. Current estimates are considerably higher, and values of over 700 million dollars are now projected (33). The additional capital costs, beyond those incurred by practice employed in industrial operations prior to the proposal of Appendix I by the AEC, for control equipment required to meet the standards are estimated to be approximately 1.5 to 2.8 million dollars (1972 base) at a PWR and 6.2 to 7.6 million dollars at a BWR, for a 1 GW(e) facility. The range of values reflects the range of iodine control required at different sites. There are currently approximately 45 reactors in operation, 60 under construction, 105 ordered, and 21 more planned for construction during the next 10 years. The cost of controls to meet the proposed standards is less than one percent of the capitol cost of pressurized water reactor and one to one and one-half percent of the capitol cost of a boiling water water reactor. The increased annual operating cost associated with these additional controls would be less than 1 percent for a PWR and perhaps as much as 5 percent for a BWR. The higher costs for BWR's are a reflection of a simpler basic design which produces, however, a considerably larger volume of effluents that must be treated. It should be particularly noted that these increased costs for reactors would be required, independently of these EPA standards, if Appendix I is issued by NRC as currently proposed. Since this increase

has already been anticipated by industry in its current designs and the NRC is currently informally implementing Appendix I in its license specifications, the proposed EPA standards would not, in any real sense, cause any increased expenditures at reactors.

The principal economic impact of the proposed standards is that they would require up to a 5 percent increase in the capital costs of a fuel reprocessing plant and about a 1 percent increase in its annual operating costs, principally to remove krypton-85. The impact on the balance of other components of the fuel cycle is anticipated to be smaller. The capital cost of controls to meet the proposed standards at a fuel reprocessing facility is estimated as approximately 7 million dollars, or 0.2 million dollars per gigawatt(electric) of fuel cycle capacity served. The combined cost of controls at all other fuel supply and handling facilities is estimated to be approximately 0.3 million dollars per gigawatt(electric) of fuel cycle capacity served. Since fuel cycle costs not directly associated with the power reactor represent less that 20 percent of the total cost of power (34), the impact of these increased fuel supply and reprocessing costs on the cost of power is anticipated to be considerably less than 1 percent. This cost, even when added to increases in capital and operating costs for controls on the reactor required by proposed Appendix I, is calculated to result in an overall impact of these standards on the cost of power that is still less than one percent of its total cost at the busbar from a PWR, and less than two percent from a BWR. Incremental costs to consumers will be a factor of

two to four less than even these small increments, due to the presence of large unaffected fixed costs for power transmission and distribution. It is concluded that the combined economic impact of these proposed standards and proposed Appendix I will be small, and cannot realistically be anticipated to have any impact on the ability of the industry to supply electrical power.

D. ADMINISTRATIVE IMPACT

The Federal agency principally affected by these standards will be the Nuclear Regulatory Commission (NRC), which has the responsibility to insure adherence to EPA's environmental standards in its regulation of the individual facilities comprising the commercial nuclear power industry. The Energy Research and Development Administration (ERDA) will be affected to the extent that the uranium enrichment facilities operated by ERDA supply the commercial nuclear power industry and additional development and/or demonstration of effluent controls for krypton-85 and iodine-129 is carried out by ERDA laboratories. The Department of Transportation will also be affected to the extent that its regulations concern shipments of spent fuel assemblies and high-level radioactive wastes.

It is unlikely that issuance of these environmental standards will cause any delay due to the need for changes in licensing regulations. In

the case of reactors, the AEC has proposed new design and operating guidance (Appendix I to 10CFR50) which, almost four years after it was first proposed, has not yet been issued. This guidance could, with certain minor modifications, be issued immediately as regulatory implementation of these standards for reactors by NRC. The AEC announced, when it proposed Appendix I to 10CFR50, that it would make any changes in that proposed guidance that would be required to conform to EPA standards. Since the standards proposed here for reactors do not require substantial modification of proposed Appendix I, there should be no impact on NRC's regulatory process that differs materially from that already proposed by the AEC.

The standards should also facilitate the preparation and review of Environmental Statements for individual facilities by providing a clear statement of environmental radiation requirements from the agency responsible for determining these requirements. They are not anticipated to require substantial additional analysis in such Statements due to their applicability to the total dose from all facilities in any particular region, because such impacts are, in general, extremely small in comparison to the proposed standards.

In the case of other components of the fuel cycle, the current regulatory situation is one of uncertainty and potential change. These facilities have generally operated within the numerical limits prescribed in 10CFR20 (which contains a detailed statement of the implications,

isotope by isotope, of the current Federal Radiation Guides for maximum exposure of individuals) with no codification of numerical guidance for these activities of the lowest practical effluent levels. In May 1974, the AEC announced that it was undertaking rulemakings to determine "as low as practicable" design and operating conditions for several of these components of the cycle (35). Issuance of the proposed standards by EPA should help to expedite issuance of this "as low as practicable" guidance by NRC. To the extent that any environmental statement is required of the NRC for new regulations implementing EPA standards, that process should also be considerably simplified and shortened by the existence of these environmental standards, compared to the lengthy procedures now followed for developing regulations governing environmental releases from the industry. It should be noted that those parts of the proposed standards which impose significant new requirements have been phased in time so as to permit orderly regulatory implementation with adequate lead times for their integration into plant design and construction schedules.

ERDA is directly affected through requirements of these standards at its uranium enrichment facilities. No substantial impact is anticipated, however, since these facilities now operate well within the proposed standard according to published AEC data. In addition, any further development work required on control systems for krypton-85 and iodine-129 will probably be carried out by ERDA at the Oak Ridge National Laboratory (and possibly other facilities), as a continuation of activities previously underway under the auspices of AEC.

In addition to the NRC regulation discussed above, certain facilities in the uranium fuel cycle (some mills and conversion plants) are now regulated by States under agreements with the NRC. This is also not anticipated to lead to any difficulty, since such "Agreement States" must, under terms of the authorizing statute for these agreements, conform to NRC regulations, which in turn must implement EPA standards.

It is anticipated that any necessary modification of procedures and regulations for transport of radioactive materials associated with operations of the fuel cycle (especially spent fuel and high-level waste shipments) will be carried out jointly by NRC and DOT, which share the responsibility of insuring adherence to radiation protection requirements in this area. Such modifications are anticipated to consist principally of measures to insure that such materials do not remain for substantial periods of time at locations where members of the public may accumulate substantial doses.

E. INTERMEDIA EFFECTS

The proposed standards encompass pollutants discharged via both air and water pathways. They also imply commitments of land use for the storage of both the high and low level wastes collected by control systems. In general, choice of the release pathway that involves the minimum environmental impact is unambiguous; the only major exception is

for release of tritium. And in general, the waste disposal implications of the standards are most serious for long-lived radioactive wastes. However, the incremental amounts of these wastes are very small for the controls required by these standards, compared to the already existing quantities produced by nuclear power facilities, i.e., those that do not result from effluent control choices.

There is no presently available control mechanism for tritium; the possibility of future control at fuel reprocessing facilities (the principal source of tritium releases) has been discussed in a number of investigations (36). For the present, the alternatives available for reducing population exposure are limited to dispersal via air-versus-water. A portion of the population dose delivered when tritium is dispered to air occurs over the long term and on a worldwide basis. This worldwide portion of the dose is the same when tritium is dispersed via water. The balance of the dose is delivered promptly to the U.S. population, and, if delivered via air, is relatively independent of the characteristics of the effluent site and approximately three times larger than the worldwide population dose. If delivered via water, the population dose is extremely site dependent, ranging from negligible to approximately ten times larger than the worldwide component of population dose. The important variable is whether or not the receiving waters are used for public drinking water supplies. An additional complication is the possibility of additional contamination by other radionuclides if water is the dispersal route. Although the proposed standards do not

address the issue of the most expeditious choice of release pathway for tritium, it is recommended that the discharge pathway delivering minimum dose be determined by the regulatory agency and required on a site-by-site basis.

Disposal of radioactive effluents through dilution and dispersal in air or water has, in the past, been a common method for satisfying radiation protection requirements, which have been commonly expressed as maximum permissible concentrations in air and water. The alternative is that contemplated by these standards: collection of these materials through the use of effluent control systems at the source followed by retention of long-lived materials in a land burial site or in an engineered storage facility. The environmental question is which alternative, over the long term, presents the least environmental hazard. The answer in the case of materials having half-lives less than about 100 years is unequivocally in favor of storage, since this route reduces the probability of future human exposure to a small value. In the case of longer-lived materials storage is also the preferred route. However, the possibility exists that future releases of stored materials may take place, with attendant human exposure, and the magnitude of this possibility is not well-defined. These waste management issues are not addressed by this rulemaking. It is simply assumed that waste management represents an improvement over disposal, with high probability of success in the short term, and with reasonable prospects for success over the long term. Although this issue is basic to the environmental viability

of nuclear power, it has been treated as separable from the question of reasonable levels of planned effluents because the wastes generated by effluent control systems represent a miniscule addition to the total waste management problems of the industry.

The issues associated with the decommissioning of facilities are ultimately again those of waste management. The incremental problems to decommissioning represented by a few additional effluent control systems are a small perturbation on the already-existing decommissioning burden of these facilties as a whole.

F. IMPACT ON MULTIPLE SITING, "NUCLEAR PARKS," AND ENERGY MIX

Uranium fuel cycle facilities in a particular geographical area could consist of a large number of plants (of the same or mixed types) on multiple sites in the same general area so that the potential for overlapping doses to members of the general public exists. The Agency has investigated the likelihood of such overlapping doses from multiple sites (Section V-D). The potential for the proposed standards to be exceeded (or more precisely to require significantly increased control in order to be met) by overlapping doses from multiple sites was found to be very small because of the very special physical siting conditions that would have to exist. Such situations are not expected to occur with any significant frequency nor with any significant impact.

A somewhat similar question arises in connection with the proposed nuclear park concept (37). The Agency has examined the possibility that "nuclear parks" may exist in the near future, with a dozen or more nuclear generating facilities and an associated fuel reprocessing facility located on a single site. The nuclear park concept is not considered likely to be implemented during the next decade or so (38), and in view of the need to accumulate operating experience for the new large facilities now under construction and the Agency's intent to review these standards at reasonable intervals in the future, it is considered premature and unnecessary to predicate these standards on conjectures regarding siting configurations beyond the next decade. Changes in these standards to accommodate such considerations should be deferred until they are needed and can be justified by experience.

The proposed standard was also examined with respect to the possibility that it might influence the mix between the use of nuclear and non-nuclear fuels for the production of electrical power. The ease with which the proposed standards can be met, both technically and economically, leads to the ready conclusion that these standards could not have any such influence.

VII. ALTERNATIVES TO THE PROPOSED ACTION

In the course of developing these proposed standards, the Agency has considered a variety of alternative courses of action. These fall into two broad categories. The first encompasses what may be characterized as administrative alternatives, and includes modification of existing Federal Radiation Protection Guidance for Federal agencies, issuance of generally applicable environmental standards for the fuel cycle as a whole (the recommended course of action) or for specific classes of activities within the fuel cycle separately, and, finally, the alternative of no standards. The second category encompasses different levels of generally applicable environmental standards for the entire fuel cycle, and includes standards with and without variances for abnormal situations and at various levels of cost-effectiveness of risk reduction, including the extreme case of applying best available technology, without regard to the degree of risk reduction obtained. Each of these alternatives are discussed below, beginning with those characterized above as administrative.

Existing Federal Radiation Protection Guides for annual radiation exposure of members of the general public apply independently of the

source of exposure. These general guides could have been revised downward, or a portion of the existing guides could have been apportioned to the nuclear power industry as representing an acceptable level of health risk for the benefit of receiving electrical power. The development of such revised or apportioned general guides need not depend upon a detailed analysis of the capabilities of effluent control technology, since only a judgment of what level of exposure will result in either a negligible or an acceptable level of health effects is required. Such a judgment requires either a) the demonstrated existence of a threshold for all significant radiation effects (which can be attained by the industry), or b) public acceptance of some level of dose as representing a "negligible" or "acceptable" risk. However, the recent NAS-NRC review of somatic and genetic effects of radiation again rejected use of a threshold assumption for setting radiation standards, and there is neither a publicly accepted level of negligible or acceptable risk, nor any realistic prospect for obtaining agreement on a value for such a general concept. Finally, when considering the risk to health of nuclear power in relation to its benefit, it is clearly not acceptable to permit a health risk equal to that benefit; what is required is to maximize the residual benefit by minimizing the associated risk to health. However, since they cannot reflect the detailed control capabilities of different kinds of sources, guides based on health alone cannot minimize annual environmental radiation exposures; they can only provide a ceiling on the permissible level of pollution. Also, it is not clear how to modify or apportion existing guides so as to prevent environmental buildup of long-

lived materials. The Agency concluded that this alternative could not provide adequate environmental protection.

The fuel reprocessing industry represents the largest single potential source of radioactive effluents from the uranium fuel cycle. The Agency could have proposed effluent standards based on cost-effective risk reduction for this portion of the industry alone, as a first step, and issued standards for other components of the fuel cycle subsequently. Such a course would provide for satisfactory protection of the environment, especially from long-lived radioactive effluents, and it would involve a much shorter initial analysis than is required to set comprehensive radiation protection standards for the entire fuel cycle. However, such standards a) would not be nearly as responsive to legitimate public concerns about radiation from the industry as are comprehensive standards, and b) could infringe upon the licensing responsibilities of the NRC for individual facilities (10). Finally, adoption of this alternative would represent an inefficient use of governmental resources. As many as six separate rulemakings eventually would be required to complete the establishment of comprehensive standards for the industry. This alternative was not adopted because it is inefficient, is in potential conflict with a reasonable division of EPA's responsibilities for environmental standards-setting and NRC's regulation of specific facilities, and would not adequately respond to public concerns about the environmental implications of planned radioactive releases from nuclear power.

EPA could also choose to issue no standards and instead exert its influence to reduce environmental releases by publishing technical analyses of the environmental impact and control capabilities of the various components of the fuel cycle. This alternative would require the least immediate effort and would not result in the possibility of substantial environmental degradation during the next few years. However, the opportunity to establish needed precedents for control of environmental radiation from nuclear power through issuance of formal Federal standards for protection against environmental degradation by long-lived radioactive materials would not be exercised. Of even greater importance, the Agency would be failing to carry out its basic responsibility under Reorganization Plan No. 3 to set environmental radiation standards to insure adequate protection of public health.

In summary, the environmental inadequacies of a revised Federal guide for individual exposure, the need for definitive EPA standards to control the environmental implications of the entire nuclear power industry, and the efficient use of Agency resources argue conclusively for the administrative alternative adopted. This alternative permits a balanced consideration of the reduction of deleterious health effects which takes into account the costs and capabilities of controls, and which limits the quantity of long-lived radioactive materials released by the industry so as to minimize irreversible environmental contamination. It thus best satisfies all environmental concerns and is at the same time most responsive to the Nation's energy priorities.

The Agency has, in addition, considered three major quantitative alternatives to the proposed action. The first alternative incorporates standards with higher limits on individual dose that would apply to any operating situation (not just to normal operations) and utilizes annual population dose rather than quantity of long-lived radionuclides per gigawatt-year as the unit of measure for standards to limit the accumulation of these radionuclides in the environment. It is substantially the alternative proposed by the AEC in their memorandum to the President (October 19, 1973) concerning the division of responsibilities between AEC and EPA (39), and for which numerical values were advanced in subsequent discussions between the two agencies. The second alternative is similar to that proposed, but is somewhat more restrictive. It represents the lowest levels that can be justified on the basis of reasonable levels of cost-effectiveness of risk reduction, and requires the implementation of restrictions on the release of long-lived radionuclides on a shorter timetable than that proposed. The final alternative considered is for substantially lower limits on both individual dose and quantities of long-lived radionuclides in the environment than those proposed by this rulemaking action. These limits represent the lowest ambient environmental levels achievable by the fuel cycle using the most effective technology available for effluent control, regardless of the associated cost-effectiveness of risk reduction. The types of control technology required to achieve the levels contemplated by each of these alternatives are limited to those either currently available and used by NRC licensees or those in advanced stages of

development, in which case sufficient lead time is provided by the standard for any further development and safety evaluation required prior to their use by licensees. Detailed analyses of control costs and the associated levels of environmental and public health impacts of these various levels of control are provided in references 13 and 40.

Alternative A: Replace the entire proposed Subpart B by:

> a) The annual dose equivalent to a member of the public from radiation or radioactive materials released to the environment from the entire uranium fuel cycle shall not exceed 50 millirems to the whole body, 150 millirems to the thyroid, and 150 millirems to any other organ; and b) the total annual population whole body dose from radiation or radioactive materials released to the environment from the entire uranium fuel cycle shall not exceed 1 person-rem per megawatt of electric capacity.

The first part of this alternative provides considerably higher upper limits of dose than those provided by the proposed action for normal operations and, unlike the standards in the proposed action, these are intended to be interpreted as shutdown values beyond which any fuel cycle facility causing the standard to be exceeded would be required to suspend operations. For this reason no variance is provided. Justification of this limit must therefore result not from a determination of what constitutes an acceptable level of normal operation with respect to environmental impact, but rather from a determination of an unacceptable level of population risk, or an unsafe level of

operation. Such a determination is not possible, in general, because knowledge of the particular conditions associated with each case of potential or actual operation above such a limit is required. Nor is it clear, with respect to safety, that EPA rather than NRC bears the primary responsibility for such a determination.

The environmental benefit to be derived from establishment of standards at these levels would be negligible, since the potential for actual operation of any facilities above such limits is already vanishingly small. There appears to be no known instance of a reactor having ever delivered such doses to any actual individual in the general environment, even with the relatively unsophisticated levels of effluent control in effect over a decade ago (41).

With respect to the second part of this alternative, the current annual population whole body dose to the world's population is approximately 0.13 person-rems per megawatt of electric power produced, or approximately 0.1 person-rems per megawatt of capacity, at present actual operating levels of U.S. fuel cycle facilities. These values are achieved <u>without</u> any limitation on environmental releases of long-lived radionuclides, such as krypton-85 or tritium. Thus, a standard of 1 person-rem per MW(e) would have no impact whatsoever on either population exposures due to short-lived radionuclides or on local or worldwide environmental buildup of long-lived radionuclides.

If this alternative were modified so as to apply to the environmental dose commitment, rather than to the annual population dose, the value proposed would still have absolutely no effect on releases of long-lived materials, since the environmental dose commitment per GW(e) of capacity, assuming release of all tritium and krypton, is currently approximately 0.3 person-rems. (The above assessments do not include the impact of carbon-14, since the limits proposed also did not.)

The economic costs associated with this alternative are only slightly smaller than those for the proposed standard. It is assumed that Appendix I would still be implemented for control of normal releases, since the standards for individual exposure apply to abnormal, not normal, releases under this alternative. Some cost saving would result from the absence of any requirement to control releases of long-lived radionuclides; this is estimated to amount to approximately 0.2 million dollars per gigawatt of fuel cycle capacity. An additional reduction of capitol cost of up 0.3 million dollars per gigawatt of fuel cycle capacity could result under this alternative from failure to upgrade fuel supply facilities to "as low as practicable" levels of control similar to those that would be required at reactors by Appendix I.

The principal environmental and health impacts of this alternative would be that environmental burdens of the long-lived radionuclides krypton-85 and iodine-129 would be increased by one or two orders of

magnitude and an increase of approximately 1,000 health effects (attributable to releases over the next 25 years) over that associated with the proposed standards due to lack of control of these long-lived radionuclides would occur. The administrative impact would be decreased by lack of a requirement to develop controls for these materials, and increased by failure to provide standards to assist the development of design and operating guidance and to facilitate the preparation of Environmental Statements for facilities in the fuel cycle other than reactors.

This alternative is environmentally and administratively unacceptable: it would provide negligible environmental benefit, would encourage rather than restrict the continued accumulation of irreversible environmental burdens of long-lived radioactive pollutants, and would inject the EPA into an area which is the primary responsibility of the NRC--the determination of the safety of levels of abnormal operation.

Alternative B: Modify Subpart B of the proposed rule by making the following substitutions:

whole body dose	15	mrem/yr
thyroid dose	45	mrem/yr
other organ doses	15	mrem/yr
krypton-85	25,000	curies
iodine-129	5	millicuries
transuranics	0.5	millicuries

The variance provision would remain in its proposed form; the effective date for implementation of the standards for krypton-85 and iodine-129 would be 1980.

This alternative could be satisfied by all presently proposed sites for which Environmental Statements have been submitted, with two possible exceptions with respect to the control of iodine emissions. It is also considered quite likely that krypton-85 and iodine-129 control capability can easily be available by the proposed date. The weakness of this alternative is that it would not achieve a significantly greater level of health protection and would at the same time sacrifice flexibility for dealing with the possibility of an unusual site. The earlier effective date for krypton-85 and iodine-129 is not expected to significantly reduce environmental burdens of these materials, since only one or two fuel reprocessing facilities are scheduled to go into operation prior to 1983, and it is anticipated that these will install such systems ahead of schedule for required demonstration and shakedown runs prior to the effective date of the proposed standards in any case.

It is estimated that this alternative would require approximately 0.6 M$/GW(e) in capital costs beyond those required to meet the proposed standards, principally due to increased requirements for iodine control at reactors, and for particulate control at milling operations. No significant improvement in environmental or health impact is anticipated.

A significant increase in administrative impact is anticipated, due to the increased difficulty of assuring compliance.

It is concluded that this more restrictive alternative does not offer any significant advantage over the proposed action.

Alternative C: Modify Subpart B of the proposed rule by making the following substitutions:

whole body dose	5	mrem/yr
thyroid dose	15	mrem/yr
other organ doses	5	mrem/yr
krypton-85	5000	curies
iodine-129	1	millicurie
transuranics	0.1	millicuries

The balance of the proposed rule is not altered, including the variance provision.

This alternative would require the incursion of substantial additional costs for minor improvements in the levels of health protection and of environmental burdens of long-lived radionuclides. The reduction in health effects due to short-lived effluents over that provided by the proposed action would occur primarily at reactors, which contribute 90 percent of the residual impact under the proposed action as shown in Table 10; this improvement would be achieved at a cost

approaching one billion dollars per potential health effect removed, a clearly unreasonable burden upon society.

The use of the most effective technology available at all fuel cycle facilities is estimated to cost up to 22 million dollars per gigawatt(electric) of fuel cycle capacity. Up to an estimated total of 160 health effects could be avoided through the year 2000 by installation of such controls at reactors due to reduction of short-lived effluents. The decrease in health impact obtainable through improvement of controls over long-lived materials is not possible to estimate, given the present state of knowledge of performance capability of controls for these materials, but in any case would be less than that for short-lived effluents. The improvement in control achieved for long-lived materials is not easy to estimate since greater uncertainty is not associated with how much control (i.e., how much cost) will be needed to satisfy the requirements of the proposed action, but with what level of effectiveness can be achieved by any of a number of control alternatives of approximately equivalent cost when these systems are placed into operation at commerical facilities. This alternative would impose a large administrative burden on NRC in order to insure compliance with standards set at such low levels.

It is concluded that this alternative, which could impose severe hardships and expense on utilities at some sites while achieving only a small improvement in public health at great cost, would place

unreasonable burdens on industry, and therefore on society in general, for insufficient beneficial return.

Table 11 summarizes the differences between these three alternatives and the proposed standards, particularly with respect to health effects, control costs, and control of long-lived radioactive environmental contamination. The table demonstrates that the total reduction in potential health impact of the proposed standards over alternative A is achieved at a present worth cost on the order of a hundred-thousand dollars per health effect, while that of alternatives B and C over the proposed standards each requires costs of several tens of millions of dollars per health effect. Figure 12 is a reproduction of Figure 3, showing the risk reduction-versus-costs (per gigawatt of electric power capacity for the fuel cycle) for the various controls required to satisfy these alternatives to the proposed action.

TABLE 11. Comparison of the Proposed Standards and Alternative Levels of Control of Environmental Releases

Action	Health Effects/GW(e)*†	Control Cost/GW(e)**	Long-lived Radionuclides Limited (Year)	Variance
Alternative "A"	4.7	6.7 M$	None	No††
Proposed Standards	0.92	7.2 M$	^{85}Kr, ^{129}I, Transuranics (1983)	Yes
Alternative "B"	0.88	9.8 M$	^{85}Kr, ^{129}I, Transuranics (1980)†††	Yes
Alternative "C"	0.32	21 M$	^{85}Kr, ^{129}I, Transuranics (1983)	Yes

*For thirty years operation of typical facilities over the years 1970-2000. See Note 1, Table 10.

**Present worth, including capital and operating costs for 30 years plant life. See Reference 13.

†Excludes carbon-14 and tritium, which are not addressed by any of these alternatives. These two isotopes are estimated to contribute a potential 45 additional health effects, as a result of their 100-year environmental dose commitments, per GW(e) of fuel cycle capacity operated for 30 years.

††This alternative is intended as a limit on abnormal emission levels, beyond which shutdown would occur.

†††Earlier introduction of controls over long-lived materials under this alternative could result in the elimination of up to an additional 25 potential health effects, worldwide, due to the elimination of the 100-year environmental dose commitment of potential releases from the fuel cycle during 1980-82.

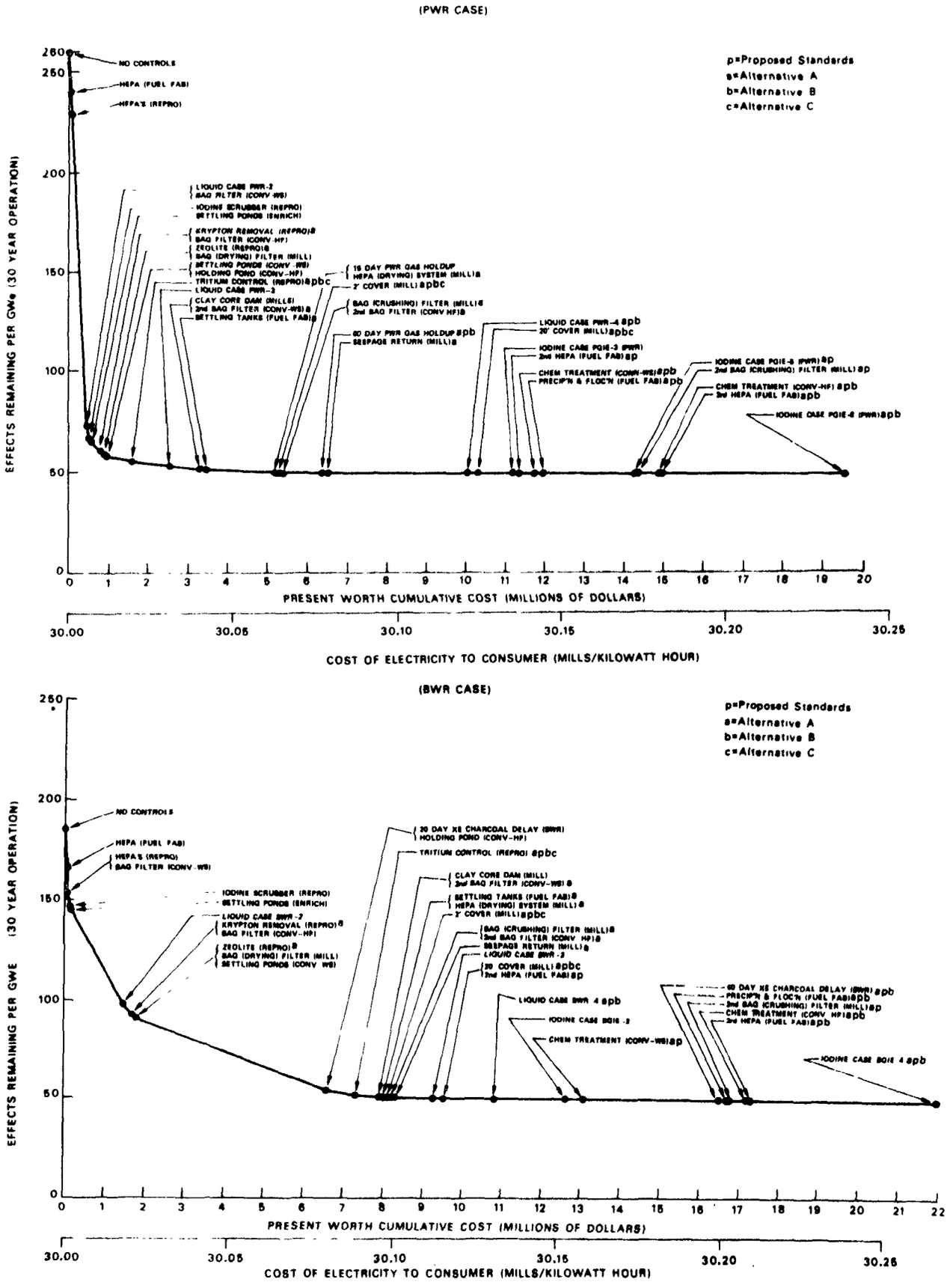


FIGURE 12 . RISK REDUCTION VS COST FOR THE ALTERNATIVES CONSIDERED. THE SYSTEMS NOT REQUIRED BY THE ALTERNATIVE LIMITS ARE INDICATED BY SYMBOL.

REFERENCES

1. Nuclear Power Growth, 1974-2000; WASH-1139(74), U.S. Atomic Energy Commission, February 1974.

2. Nuclear Power, Financial Consideration, Program Report, Vol.1, No.5, Atomic Industrial Forum, September 1973.

3. Message to the Congress from the President of the United States concerning energy policy, June 4, 1971.

4. The Nation's Energy Future, WASH-1281, U.S. Atomic Energy Commission, December 1973.

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

6. The Effects on Populations of Exposure to Low Levels of Ionizing Radiation, Report of the Advisory Committee on the Biological Effects of Ionizing Radiation, National Academy of Sciences - National Research Council, November 1972.

7. See, e.g., Recommendations of the International Commission on Radiological Protection, ICRP Publication 9, Pergamon, Oxford, 1959, and Basic Radiation Protection Criteria, Report No. 39, National Council on Radiation Protection and Measurements, Washington, 1971.

8. Taylor, L.C., The Origin and Significances of Radiation Dose Limits for the Population, WASH-1336, U.S. Atomic Energy Commission, August 1973.

9. Radiation Protection Guidance for Federal Agencies, Federal Radiation Council, Federal Register Document 60-4539, May 1960.

10. Memorandum to Russell E. Train, Administrator, Environmental Protection Agency, and Dixy Lee Ray, Chairman, U.S. Atomic Energy Commission, from Roy L. Ash, Director, Office of Management and Budget, December 7, 1973.

11. Policy Statement: Relationship Between Dose and Effect, Office of Radiation Programs, U.S. Environmental Protection Agency, March 3, 1975

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

13. Environmental Analysis of the Uranium Fuel Cycle, Part I - Fuel Supply, Part II - Nuclear Power Reactors, Part III - Fuel Reprocessing, EPA-520/9-73-003, U.S. Environmental Protection Agency, October and November 1973.

14. See, e.g., Unger, W.E., et al., Aqueous Fuel Reprocessing Quarterly Reports for the Periods Ending 12/31/72 (ORNL-TM-4141), 3/31/73 (ORNL-TM-4240), 6/30/73 (ORNL-TM-4301), 9/30/73 (ORNL-TM-4394), Oak Ridge National Laboratory; Groenier, W.S., An Engineering Evaluation of the Iodex Process: Removal of Iodine from Air Using a Nitric Acid Scrub in a Packed Column, ORNL-TM-4125, Oak Ridge National Laboratory, August 1973; and Yarbro, O.O.; Mailen, J.C.; and Groenier, W.S., Iodine Scrubbing from Off-gas with Concentrated Nitric Acid, presented at the 13th AEC Air Cleaning Conference, August 1974.

15. Voloxidation - Removal of Volatile Fission Products from Spent LMFBR Fuels, Goode, J.H., Ed., (ORNL-TM-3723), Oak Ridge National Laboratory, January 1973.

16. Magno, P.J.; Nelson, C.B.; and Ellett, W.H., A Consideration of the Significance of Carbon-14 Discharges from the Nuclear Power Industry, presented at the 13th AEC Air Cleaning Conference, August 1974.

17. See, e.g., Mishan, E.J., Evaluation of Life and Limb: A Theoretical Approach, Journal of Political Economy, 79, 687 (1971); Lederberg, J., Squaring the Infinite Circle: Radiobiology and the Value of Life, Bulletin of the Atomic Scientists, September 1971; Dunster, H.J., The Use of Cost Benefit Analysis in Radiological Protection, National Radiological Protection Board, Harwell, Didcot, Berks, England, September 1973; and Schelling, T.C., The Life You Save May be Your Own, in "Problems in Public Expenditure Analysis", Chase, S.B., Jr., Ed., Brookings, 1968.

18. See, e.g., Hedgram, A. and Lindell, B., P.Q.R. - A Special Way of Thinking?, National Institute of Radiation Protection, Stockholm, Sweden, June 1970; Sagan, L.A., Human Costs of Nuclear Power, Science 177, August 11, 1972; and Cohen, J.J., A Suggested Guideline for Low Dose Radiation Exposure to Populations Based on Benefit-Risk Analysis, presented at the 16th Annual Meeting of the Health Physics Society, New York, July 1971.

19. Of the 1.05 curies per year iodine-131 projected source term for Surry 1 and 2, 1.03 curies per year comes from the condenser air ejector and steam generator blowdown vent. These effluents could be treated through minor modification of the existing gaseous treatment system.

20. More than 75% of the source terms for the River Bend, Perry Island, Hatch, and Monticello sites are from the turbine building, more than 50% of the source term of the Brunswick site is from this source, and at Peach Bottom, although only 25% of the source term comes from this source, this release makes the largest contribution to maximum potential thyroid dose.

21. See, e.g., Mississippi Power & Light Co., Grand Gulf Nuclear Station Units 1 and 2, PSAR, AEC Docket Nos. 50-416 and 50-417.

22. The draft environmental statement for the Humeca Mill does not specify the control technology used. However, the information presented indicates that dust removal capability currently available and proposed for use at similar facilities are not proposed for air cleaning.

23. Calculations of Doses, Population Doses, and Potential Health Effects Due to Atmospheric Releases of Radionuclides from U.S. Nuclear Power Reactors in 1972, Office of Radiation Programs, U.S. Environmental Protection Agency, Radiation Data and Reports, 15, 477 (1974); and unpublished data, Office of Radiation Programs, U.S. Environmental Protection Agency.

24. Martin, J.A., Jr.; Nelson, C.B.; and Peterson, H.T., Jr., Trends in Population Radiation Exposure from Operating Boiling Water Reactor Gaseous Effluents, CONF-741018, Proceedings of the Eighth Midyear Topical Symposium of the Health Physics Society, October 1974.

25. Kahn, B., et al., Radiological Surveillance Studies at a Pressurized Water Nuclear Power Reactor, RD 71-1, U.S. Environmental Protection Agency, August 1971; Kahn, B., et al., Radiological Surveillance Studies at a Boiling Water Nuclear Power Reactor, U.S. Environmental Protection Agency, March 1970.

26. Detailed Measurement of Iodine-131 in Air, Vegetation, and Milk Around Three Operating Reactor Sites, Weirs, B.H.; Voilleque, P.E.; Keller, J.H.; Kahn, B.; Krieger, H.L.; Martin, A.; and Phillips, C.R., (IAEA/SM-180/44), presented at the Symposium on Environmental Surveillance Around Nuclear Installations, International Atomic Energy Agency, November 1973; and unpublished data, U.S. Environmental Protection Agency and U.S. Atomic Energy Commission.

27. Shleien, B., An Estimate of Radiation Doses Received by Individuals Living in the Vicinity of a Nuclear Fuel Reprocessing Plant in 1968, BRH/NERHL 70-1, U.S. Department of Health, Education, and Welfare, May 1970.

28. The Potential Radiological Implications of Nuclear Facilities in the Upper Mississippi River Basin in the Year 2000 (The Year 2000 Study), WASH-1209, U.S. Atomic Energy Commission, January 1973.

29. Effects of Control Technology on the Projected Krypton-85 Environmental Inventory, Oscarson, E.E., presented at the Noble Gases Symposium, Las Vegas, Nevada, September 1973; Considerations Regarding Timing of Krypton Control Implementation, Oscarson, E.E.; Ellett, W.H.; and Nelson, N.S., presented at the International Symposium on Radiation Protection, Aviemore, Scotland, June 1974; see also references 5, 13 (Part III), and 16.

30. Supplementary Testimony Regarding the State of Technology for and Practicability of Control and Retention of Iodine in a Nuclear Fuel Reprocessing Plant, Yarbro, O.A., Oak Ridge National Laboratory, at the Consolidated Environmental Hearing for Barnwell A.G.N.S. Construction and Operating License, Docket Nos. 50-332 and 50-332 OL, U.S. Atomic Energy Commission, Columbia, S.C., October 1974.

31. Concluding Statement of the 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, U.S. Atomic Energy Commission, February 1974.

32. Testimony Regarding Health Risks Resulting from the Release of Krypton-85 and Radioiodine from the Barnwell Nuclear Fuel Plant, Magno, P.J. and Nelson, N.S., U.S. Environmental Protection Agency, at the Consolidated Environmental Hearing for Barnwell A.G.N.S. Construction and Operating License, Docket Nos. 50-332 and 50-332 OL, U.S. Atomic Energy Commission, Columbia, S.C., October 1974.

33. Power Plant Capitol Costs: Current Trends and Sensitivity to Economic Parameters, WASH-1345, Division of Reactor Research and Development, U.S. Atomic Energy Commission, October 1974.

34. Benedict, M., Electric Power from Nuclear Fission, Proceedings of the National Academy of Sciences 68, 1923 (1971).

35. "As Low As Practicable" Guidelines for Light-Water-Reactor Fuel Cycle Facilities, Notice of Intent to Amend AEC Regulations (10CFR Parts 40, 50, and 70), Federal Register 39, 16902 (1974).

36. The Separation and Control of Tritium: State-of-the-Art Study, Pacific Northwest Laboratories, BMI, U.S. Environmental Protection Agency, April 1972; Midwest Fuel Recovery Plant, Applicant's Environmental Report, Suppl. 1, NED 14504-2, General Electric

Company, November 1971; Chemical Technology Annual Progress Report, ORNL-4794, Oak Ridge National Laboratory, October 1972; and ref. 15.

37. Weinberg, A.M. and Hammond, R.P., Global Effects of Increased Use of Energy, Bulletin of the Atomic Scientists 28, p.5, March 1972.

38. Evaluation of Nuclear Energy Centers, Division of Reactor Research and Development, U.S. Atomic Energy Commission, WASH-1288, January 1974.

39. AEC Position on Division of Responsibilities and Authorities Between the Atomic Energy Commission and the Environmental Protection Agency, memorandum to the President from Dixy Lee Ray, October 19, 1973.

40. Final Environmental Statement 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, WASH-1258 (3 volumes), U.S. Atomic Energy Commission, July 1973.

41. Blomeke, J.O. and Harrington, F.E., Management of Radioactive Wastes at Nuclear Power Stations, ORNL-4070, Oak Ridge National Laboratory, January 1968.

APPENDIX

ENVIRONMENTAL PROTECTION AGENCY

[40 CFR Part 190]

ENVIRONMENTAL RADIATION PROTECTION

FOR NUCLEAR POWER OPERATIONS

Notice of Proposed Rulemaking

Reorganization Plan No. 3, which became effective on December 2, 1970, transferred to the Administrator of the Environmental Protection Agency the functions of the former Atomic Energy Commission to establish "...generally applicable environmental standards for the protection of the general environment from radioactive material." The Plan defined these standards as "limits on radiation exposures or levels, or concentrations or quantities of radioactive material outside the boundaries of locations under the control of persons possessing or using radioactive material." On May 10, 1974, the Agency published an advance notice of its intent to propose standards under this authority for the uranium fuel cycle and invited public participation in the formulation of this proposed rule.

The Agency has reviewed and considered the comments received in response to that notice and proposes herein environmental radiation standards which would assure protection of the general public from unnecessary radiation exposures and radioactive materials in the general environment resulting from the normal operations of facilities comprising the uranium fuel cycle. Nuclear power generation based on recycled plutonium or on thorium is excluded from these standards because sufficient operating data and experience concerning fuel cycles utilizing these fuels are not yet available. Before any of these developing technologies becomes

of potential significance to public health the need for additional generally applicable standards will be considered.

The environmental radiation standards proposed in this notice supplement existing Federal Radiation Protection Guidance limiting maximum exposure of the general public [F.R. Docs. 60-4539 and 61-9402] by providing more explicit public health and environmental protection from potential effects of radioactive effluents from the uranium fuel cycle during normal operation. Numerically the proposed standards are below current Federal Radiation Protection Guides. The Agency is not, at this time, proposing revisions in existing Federal Radiation Protection Guidance for the general public because of its belief that a detailed examination of each major activity contributing to public radiation exposure is required before revision of this general guidance should be considered. Existing Federal Radiation Protection Guidance for workers in the fuel cycle is also not affected by these proposed standards. In addition, since these standards are proposed under authority derived from the Atomic Energy Act of 1954, as amended, they do not apply to radioactive materials and exposures in the general environment that are the result of effluents from mining operations because that Act does not provide authority over such effluents. Finally, since there are no planned releases from existing radioactive waste disposal sites and these sites primarily serve sources of waste other than uranium fuel cycle operations, these standards do not apply to such sites. The Agency has each of these areas of concern under continuing study.

It is the intent of the Agency to maintain a continuing review of the appropriateness of these environmental radiation standards and to formally review them at least every five years, and to revise them, if necessary, on the basis of information that develops in the interval.

INTERAGENCY RELATIONSHIPS. Reorganization Plan No. 3 transferred to the Environmental Protection Agency (EPA) the broad guidance responsibilities of the former Federal Radiation Council and also transferred from the former Atomic Energy Commission (AEC) the more explicit responsibility to establish generally applicable radiation standards for the environment. However, the responsibility for the implementation and enforcement of both this guidance and these standards lies, in most cases, in agencies other than EPA as a part of their normal regulatory functions. For nuclear power operations, this responsibility, which had been vested in the AEC, is now vested in the Nuclear Regulatory Commission (NRC), which will exercise the responsibility for implementation of these generally applicable standards through the issuance and enforcement of regulations, regulatory guides, licenses, and other requirements for individual facilities.

BASIC CONSIDERATIONS. The Agency has concluded that environmental radiation standards for nuclear power industry operations should include consideration of: 1) the total radiation dose to populations, 2) the maximum dose to individuals, 3) the risk of health effects attributable to these doses, including the future risks arising from the release of long-lived radionuclides to the environment, and 4) the effectiveness and costs of the technology available to mitigate these risks through effluent

control. The Agency also recognizes the findings of the recent study of the biological effects of low levels of ionizing radiation by the Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR Committee) of the National Academy of Sciences - National Research Council. Two of the principal conclusions of the BEIR Committee were: 1) that current societal needs appear to be achievable "...with far lower average exposure and lower genetic and somatic risk than permitted by the current Radiation Protection Guide. [Thus,] to this extent, the current Guide is unnecessarily high..." and 2) that "Guidance for the nuclear power industry should be established on the basis of cost-benefit analysis, particularly taking into account the total biological and environmental risks of the various options available and the cost-effectiveness of reducing these risks."

For the purpose of setting radiation protection standards the most prudent basis for relating radiation dose to its possible impact on public health continues to be to assume that a potential for health effects due to ionizing radiation exists at all levels of exposure and that at the low levels of exposure characteristic of environmental levels of radiation the number of these effects will be directly proportional to the dose of radiation received (a linear non-threshold dose-effect relationship). Even under these assumptions, the range of estimates of the health risks associated with a given level of exposure derived from existing scientific data is broad. It is recognized that sufficient data are not now available to either prove or disprove these assumptions, nor is there any reasonable

prospect of demonstrating their validity at the low levels of expected exposure with any high degree of certainty. However, the Agency believes that acceptance of the above prudent assumptions, even with the existence of large uncertainties, provides a sound basis for developing environmental radiation standards which provide reasonable protection of the public health and do so in a manner most meaningful for public understanding of the potential impact of the nuclear power industry. Standards developed on this basis are believed to also protect the overall ecosystem, since there is no evidence that there is any biological species sensitive enough to warrant a greater level of protection than that adequate for man.

Radiological protection of the public from nuclear power industry operations has been based to date on guidance which has had as its primary focus the general limitation of dose to the most exposed individual, rather than limitation of the total population dose from any specific type of activity. The proposed expanded development of the nuclear power industry requires, however, the use of a broader environmental perspective that more specifically considers the potential radiological impact on human populations of radioactive effluents from this industry, rather than just that on the most exposed individual. A number of long-lived radionuclides are now discharged from various fuel cycle operations which carry a potential for buildup of environmental levels and irreversible commitments for exposure of populations that may persist for tens, hundreds, or thousands of years. The extent of the cumulative population doses which may occur over the years following release of such radionuclides is related

to their radioactive decay times, the details of their dispersion through environmental media, the period over which they remain in the biosphere, and their exposure (both internal and external) of individuals in populations. The cumulative dose resulting from releases to the environment of such materials can be termed an "environmental dose commitment," and quantitatively expressed in terms of the number of person-rems of dose committed. The proposed standards are based, to the extent that present knowledge permits, on such projections of the migration of radioactive effluents through the biosphere and estimates of the sum of potential doses to present and future populations during that migration.

Since potential effects from radiation exposure are assumed to occur at any level of exposure, it is not possible to specify solely on a health basis an acceptable level of radiation exposure for either individuals or populations; it is necessary to balance the health risks associated with any level of exposure against the costs of achieving that level. In developing the proposed standards, EPA has carefully considered, in addition to potential health effects, the available information on the effectiveness and costs of various means of reducing radioactive effluents, and therefore potential health effects, from fuel cycle operations. This consideration has included the findings of the AEC and the NRC with respect to practicability of effluent controls, as well as EPA's own continuing cognizance of the development, operating experience, and costs of control technology. Such an examination made it possible to propose the standards at levels consistent with the capabilities of control technology and at a

cost judged by the Agency to be acceptable to society, as well as reasonable for the risk reduction achieved. Thus, the standards generally represent the lowest radiation levels at which the Agency has determined that the costs of control are justified by the reduction in health risk. The Agency has selected the cost-effectiveness approach as that best designed to strike a balance between the need to reduce health risks to the general population and the need for nuclear power. Such a balance is necessary in part because there is no sure way to guarantee absolute protection of public health from the effects of a non-threshold pollutant, such as radiation, other than by prohibiting outright any emissions. The Agency believes that such a course would not be in the best interests of society.

The total population impact associated with a particular level of effluent control is best assessed in terms of dose commitments to populations measured in person-rems, which are then converted into estimates of potential health impact. However, the environmental models used for deriving these assessments, while useful for making estimates of potential health impact, are not considered to be so well-defined as to allow standards for populations to be expressed directly in terms requiring their explicit use. The Agency believes that future changes and refinements in models, and thus in the person-rem assessments upon which these standards are based, will occur on a continuing basis. The standards are therefore not proposed directly in terms of person-rems, but future reviews of their adequacy will reflect any changes in model-based

assessments of population dose. Standards have also not been proposed directly in terms of person-rems because the regulatory implementation of such a requirement does not appear to be administratively feasible for the fuel cycle under existing widely varying geophysical and demographic conditions and for doses that may, in some instances, be delivered over indeterminately long periods of time. The proposed standards are expressed in terms of 1) limits on individual doses to members of the public and 2) on quantities of certain long-lived radioactive materials in the general environment. On the basis of its assessments of the health risks associated with projected annual population doses and environmental dose commitments, the Agency has concluded that these two types of standards are the most appropriate choice of criteria to provide effective limitation of the potential health impact on populations of short-lived and long-lived radioactive materials, respectively.

Even though adequate protection of populations considered as a whole may be assured by standards based upon the above consideration of health risks and control costs, it may not always be the case that adequate protection is assured on this basis to some individuals in these populations who reside close to the site boundaries of nuclear facilities, because of the distribution characteristics of certain effluents. Such a situation is possible in the case of thyroid doses due to releases of radioiodines from reactors and fuel reprocessing facilities. Although the risk from such doses to nearby individuals is quite small, it is inequitable to permit doses to specific individuals that may be

substantially higher than those to other members of the population from other radionuclides. Additional protection for these individuals should be provided when technology or other procedures are available for minimizing any additional potential risk at a reasonable cost. The standards proposed to limit doses to individuals reflect this additional requirement where it is appropriate to do so.

TECHNICAL CONSIDERATIONS. It is convenient to consider effects of radioactive materials introduced into the environment by the uranium fuel cycle in three categories. Prior to the occurrence of nuclear fission at the reactor only naturally occurring radioactive materials are present in fuel cycle operations. This first category of materials consists principally of uranium, thorium, radium, and radon with its daughter products. Radioactive materials introduced to the environment from facilities for milling, chemical conversion, isotopic enrichment, and fabrication of fuel from uranium which has not been recycled are limited to these naturally occurring radionuclides. As a result of the power-producing fission process at the reactor a large number of new radionuclides are created as fission or activation products. These may be introduced into the general environment principally by reactors or at fuel reprocessing and are conveniently categorized as either long-lived or short-lived fission and activation products, depending upon whether their half-lives are greater than or less than one year. Although naturally occurring radionuclides are of some concern, it is these fission and

activation products which are of greatest concern from the point of view of controlling radiation doses to the public due to nuclear power operations.

Standards are proposed for the fuel cycle in two major categories. The proposed standards would limit: 1) the annual dose equivalent to the whole body to 25 millirems, to the thyroid to 75 millirems, and to any other organ to 25 millirems; and 2) the quantities of krypton-85, iodine-129, and certain long-lived transuranic radionuclides released to the environment per gigawatt-year of power produced by the entire fuel cycle to 50,000 curies, 5 millicuries, and 0.5 millicuries, respectively. The first standards are designed to limit population and individual exposures near fuel cycle operations due to short-lived fission-produced materials and naturally occurring materials, and due to transportation of any radioactive materials, while the second specifically addresses potential population exposure and buildup of environmental burdens of long-lived materials.

The proposed standard for annual whole body dose to any individual limits the combined internal and external dose equivalent from gaseous and liquid effluents as well as exposure to gamma and neutron radiation originating from all operations of the fuel cycle to 25 millirems. Such a limit is readily satisfied at all sites for which fuel cycle facilities are presently projected through the year 1985 (including any potential overlap of doses from adjacent sites) by levels of control that are cost-effective for the reduction of potential risk achieved; is in accord with the capabilities of controls anticipated by the AEC for all sites for which Environmental Statements have been filed; and, on the basis of present

operating experience at existing sites, can be readily achieved in practice. The combined effect of any combinations of operations at the same location that are foreseeable for the next decade or so was also examined and is judged to be small, so that the proposed standards can readily be satisfied by use of levels of control that are similar to those required for single operations. It should be noted that this proposed standard for maximum whole body dose, which is higher than that proposed by the AEC as guidance for design objectives for light-water-cooled reactors, differs from those objectives in that it applies to the total dose received from the fuel cycle as a whole and from all pathways, including gamma radiation from onsite locations. It is also not a design objective, but a standard which limits doses to the public under conditions of actual normal operation.

The appropriate level for a standard limiting the maximum annual total dose to the thyroid of individuals is not easy to determine. A standard for maximum total thyroid dose based on considerations limited to the same criteria as for maximum whole body dose (cost-effectiveness of reduction of total population impact and achievability) would permit unacceptably high doses to individuals near some site boundaries. The proposed standard of 75 millirems per year to the thyroid has therefore been chosen to reflect a level of biological risk comparable, to the extent that current capability for risk estimation permits, to that represented by the standard for dose to the whole body. The effluent controls required to achieve this limit have been examined extensively by EPA, AEC, and the industry, particularly

in regard to the AEC's proposed Appendix I to 10 CFR 50 for light-water-cooled reactors, and, in the view of the Agency, this level of maximum annual individual dose to the thyroid can be achieved at reasonable effort and cost.

The principal potential doses to internal organs other than the thyroid are to the lung via inhalation of airborne particulates and to bone due to ingestion via water and other pathways of the naturally occurring materials processed in the several components of the fuel cycle required to convert uranium ore into reactor fuel. The impact on populations due to effluents from these operations is generally quite small (due to their predominately remote locations and lack of widespread dispersion), however, significant lung doses are possible to individuals near to these operations, particularly in the case of mills and conversion facilities. The use of well-established, efficient, and inexpensive technology for the retention and control of particulate effluents can readily achieve the levels of control required to meet the proposed standard of 25 millirems per year for limiting dose equivalent to the internal organs (other than thyroid) of individuals.

Environmental radiation exposures from transportation operations are due to direct radiation. Although average radiation doses to individuals in the general public from transportation activities are very small, situations in which individuals could receive higher doses may reasonably be postulated. It is recognized that exposures due to transportation of radioactive materials are difficult to assess and regulate because as

shipments move in general commerce between sites the exposed population is constantly changing. Transportation activities should be conducted with every effort made to maintain doses to individuals as low as reasonably achievable, consistent with technical and economic feasibility. In any case, the maximum dose to any member of the general public due to uranium fuel cycle operations, including those due to shipments of radioactive materials, should not exceed the proposed standard of 25 millirems per year to the whole body of an individual. The Agency will continue to examine potential exposures due to transportation of radioactive materials with a view to further action, if necessary.

Among the variety of long-lived radionuclides produced in the fuel cycle, tritium, carbon-14, krypton-85, iodine-129, plutonium, and certain other long-lived transuranic radionuclides are of particular significance as environmental pollutants. Environmental pathways of tritium, carbon-14, and krypton-85 are worldwide. Even though the balance of the above radionuclides may not rapidly become widely dispersed, they are significant because of their potential for extreme persistence in environmental pathways, possibly for thousands of years for plutonium and other transuranics, and for even longer periods for iodine-129.

Because of their high toxicity and long half-lives, the cumulative impact of releases of plutonium and other transuranics to the environment could be large. However, due to very large uncertainties concerning their environmental behavior over long periods of time, as well as a lack of definitive information concerning the relationship between exposure to

these materials and health effects, the limits of this potential impact cannot be more than roughly estimated. Therefore prudence dictates that the environmental burden of these materials be minimized to the lowest levels reasonably achievable. Similarly, although its toxicity is less than that of the alpha-emitting transuranics, in view of the extreme persistence of iodine-129 (half-life 17 million years) and great uncertainty concerning its environmental behavior, environmental releases of this isotope should be also maintained at the lowest level reasonably achievable. The prevention of unlimited discharges of krypton-85 to the environment from fuel cycle operations is of high priority because of its potential for significant long-term public health impact over the entire world. Finally, carbon-14 and tritium, both of which rapidly enter worldwide pathways as gaseous radioactive materials, are of particular concern because carbon and hydrogen are principal constituents of the chemical structures of all life forms.

These long-lived radionuclides should only be discharged to the environment after careful consideration of the tradeoffs between the societal benefits of the power generated, the current and projected health risks to populations, and the costs and effectiveness of methods available to limit their release. Since the anticipated maximum dose to any single individual from any of these materials is very small, the primary concern is the cumulative risk to population groups over long periods of time. For this reason, it is not of primary importance where or when in the fuel cycle any such materials are released, since the committed impact will be

similar. What is important is to assure that any permitted discharge has been offset by a beneficial product, i.e., a quantity of electricity, and that every reasonable effort has been made to minimize it. It is also important to assure that society is not burdened with unreasonable expenditures to minimize these risks in order to gain the necessary benefits of electric power. Fortunately the vast majority of potential health effects due to release of these radionuclides can be avoided at a reasonable cost. The Agency estimates the cost of implementing the proposed standards for these long-lived radioactive materials to be less than $100,000 per potential case of cancer, leukemia, or serious genetic effect averted (less than $75 per person-rem). In view of the above considerations, the Agency believes that the proposed standards, which limit the number of curies of certain of these radionuclides released to the general environment for each gigawatt-year of electricity produced by the fuel cycle, represent the most reasonable means of providing required protection of the general environment for present and future generations. The standards will assure that any environmental burdens of long-lived radioactive materials accumulate only as the necessary result of the generation of an offsetting quantity of electrical energy.

The proposed standards for long-lived materials fall into two categories: those which can be achieved using currently available methods for control of environmental releases, and those that require use of methods that have been demonstrated on a laboratory or larger scale, but have not yet achieved routine use. In the former case, exemplified by the

standard of 0.5 millicuries per gigawatt-year for plutonium and other long-lived alpha-emitting transuranics, the standard limits the environmental burden to the lowest level reasonably achievable using currently available control methods. In the latter case, that of the proposed standard of 50,000 curies per gigawatt-year for krypton-85 and 5 millicuries per gigawatt-year for iodine-129, these limiting levels of environmental burdens are not those achievable by best demonstrated performance, but instead by minimum performance reasonably anticipated from introduction of these new systems into commercial operations. As experience is gained with the ability of the industry to limit fuel cycle releases of these materials to the environment, it may be appropriate to reconsider the standards limiting the maximum environmental burdens of these particular radionuclides.

Similarly, as knowledge becomes available concerning the practicability of limiting environmental releases of tritium and carbon-14, the appropriate levels of maximum environmental burdens of these radionuclides due to fuel cycle operations will be carefully considered by the Agency. However, the knowledge base now available is inadequate for such a determination, and no standards are presently proposed for these radionuclides. The potential for a long-term impact due to carbon-14 released from fuel cycle operations was not recognized until the Agency considered environmental dose commitments from the industry in the course of developing these standards; thus consideration of methods for limiting its release to the general environment are only now beginning. Tritium

levels in the general environment from fuel cycle operations are not expected to become significant until the late 1980's, and development programs are in existence for control of releases of this radionuclide from its principal source, fuel reprocessing operations. The Agency believes that the development and installation of controls to minimize environmental burdens of both carbon-14 and tritium are important objectives, and will carefully follow the development of new knowledge concerning both the impact and controllability of these radionuclides.

To allow adequate time for implementing the standards for krypton-85 and iodine-129 control, including the necessary testing and analysis required prior to licensing of these control systems, the effective date is proposed as January 1, 1983. Implementation by this date would result in control of these releases before any substantial potential health impact from these materials due to uranium fuel cycle operations can occur and would, in the judgment of the Agency, provide adequate protection of public health thereafter.

The proposed standard for maximum dose to organs excludes radon and its daughter products. Radon is released as a short-lived (3.8 days half-life) inert gas, mainly from tailings piles at mills, and produces its principal potential impact through deposition of its daughter products in the lung. There exists considerable uncertainty about the public health impact of existing levels of radon in the atmosphere, as well as over the best method for management of new sources of radon created by man's activities, which remove this naturally occurring material and its

precursors from beneath the earth's protective crust. Radon levels in the general environment are substantial and are dominated by natural sources, except in the immediate vicinity of man-made sources. Exposures from radon and its daughters have previously been the subject of Federal Radiation Protection Guidance, in the case of underground uranium miners (F.R. Doc. 71-7210 and F.R. Doc. 71-9697), and of guidance from the Surgeon General, in the case of public exposure due to the use of uranium mill tailings in or under structures occupied by members of the general public ("Use of Uranium Mill Tailings for Construction Purposes," Hearings before the Subcommittee on Raw Materials of the Joint Committee on Atomic Energy, October 28 - 29, 1971, pp.226-233). The Agency has concluded that the problems associated with radon emissions are sufficiently different from those of other radioactive materials associated with the fuel cycle to warrant separate consideration, and has underway an independent assessment of man-made sources of radon emissions and their management.

IMPLEMENTATION OF THE STANDARDS. These proposed standards are expected to be implemented for the various components of the uranium fuel cycle, operating under normal conditions, by the Nuclear Regulatory Commission. The mechanisms by which these standards are achieved will be a matter between the NRC and the industries that are licensed to carry out various uranium fuel cycle operations, but, in general, will be based on regulations and guides for the design and operation of the various facilities. The Agency is confident that these proposed standards can be effectively implemented by such procedures.

Current rules and regulations applicable to fuel cycle operations generally contain provisions which have the effect of limiting doses to individuals, thus implementation of the proposed standards for maximum doses to individuals should be straightforward. Protection of the public from the environmental accumulation of long-lived radioactive materials may require some changes in regulatory requirements. For example, this standard limits environmental accumulations of certain radionuclides associated with the generation of a gigawatt-year of electrical energy, which is generated only at the power reactor. Since other operations in the cycle which do not generate power are more likely to discharge such materials, it may be necessary for the regulatory agency to make an appropriate allocation to each facility and to determine the emission rates required to satisfy the standard for the entire fuel cycle. This is especially the case for a radionuclide like krypton-85 which can be released either at reactors, during fuel storage, or during fuel reprocessing. The standards do not specify the time, location, or concentration of emissions of long-lived radionuclides. Once a given quantity of electrical power has been generated the specified amount of the radionuclide may be released at any time and at any rate or location that does not exceed the individual dose limitations. Demonstration of compliance with the standard requires only that the total quantity of electricity generated after the effective date of the standards be recorded to determine the maximum quantity of these long-lived radionuclides that may eventually be released.

The Agency recognizes that implementation of the standards for krypton-85 and iodine-129 by the proposed effective date of January 1, 1983, will require successful demonstration of control technology for commercial use that is now in advanced stages of development. The Agency, as stated above, intends to review all of these standards in at least five year intervals. If substantial difficulty should develop for implementing the standards for krypton-85 and iodine-129 with respect to the proposed levels, facility safety, or cost, the Agency will give these factors careful and appropriate consideration prior to the effective date.

With respect to operations associated with the supply of electrical power it is important not only to set standards which will provide satisfactory public health protection, consistent with technical and economic feasibility, but also to minimize societal impacts which may occur as the result of temporary interruptions in those fuel cycle operations that are necessary to assure the orderly delivery of electric power. Such a two-fold objective requires consideration of the question whether to impose stricter standards which achieve lower levels of radiation exposure and environmental burdens of long-lived radioactive materials, but which may force temporary shutdowns which may not be justified on a risk-benefit basis for such periods; or to establish more liberal standards which decrease the possibility of such shutdowns, but may be overly permissive with respect to public exposure and long-term environmental releases. The Agency has attempted to avoid this dilemma by proposing standards that are not permissive with respect to either public exposures or long-term

environmental releases and at the same time providing a variance which allows the standards to be temporarily exceeded under unusual conditions. The use of such variances by the regulatory agency will depend to a large degree upon their value judgments concerning the necessity of the fuel cycle operation concerned to a region, overall facility safety, and the possible impact on public health. The proposed variance provides that temporary increases above the standards for normal operations are allowable when the public interest is served, such as to maintain a dependable source of continuous power or during a power crisis. The Agency anticipates that the need to use such variances will be infrequent and of short duration, and that the overall impact on population and individual radiation doses from the operations of the entire fuel cycle will be minimal.

With respect to regulatory implementation of the flexibility provided by this proposed variance provision, the Agency has carefully examined the guidance for design objectives and limiting conditions for operation of light-water-cooled nuclear power reactors as set forth recently by the NRC in Appendix I to 10 CFR 50. It is the view of the Agency that this guidance for reactors will provide an appropriate and satisfactory implementation of these proposed environmental radiation standards for the uranium fuel cycle with respect to light-water-cooled nuclear reactors utilizing uranium fuel. The various monitoring and reporting procedures required by the AEC in the past and supplemented by Appendix I are expected to provide continuing information sufficient to determine that these standards are being satisfied during the course of normal operations of the fuel cycle.

Although the Agency has attempted to limit the effect of radioactive discharges from the fuel cycle on populations and on individuals through these proposed standards, it has not attempted to specify constraints on the selection of sites for fuel cycle facilities, even though the Agency recognizes that siting is an important factor which affects the potential health impact of most planned releases from operations in the fuel cycle. The standards were developed, however, on the assumption that sound siting practices will continue to be promoted as in the past and that facility planners will utilize remote sites with low population densities to the maximum extent feasible.

The Agency has also considered the need for special provisions for single sites containing large numbers of facilities, of single or mixed types, as exemplified by the "nuclear park" concept. Present construction projections by utilities indicate that no such sites are likely to be operational during the next ten years. In view of the need to accumulate operating experience for the new large individual facilities now under construction and the intent of the Agency to review these standards at reasonable intervals in the future, it is considered premature and unnecessary to predicate these standards on any siting configurations postulated for the next decade and beyond. The Agency will consider changes in these standards based on such considerations when they are needed and justified by experience.

It is the conclusion of the Agency that implementation of the proposed standards for normal operations of the nuclear power industry based on the uranium fuel cycle will provide society protection of its environment and

the health of its citizens and that this protection is obtained without placing unreasonable financial burdens upon society. In this context, these standards are responsive to the President's energy messages of June 4, 1971, and April 18, 1973, which challenged the Nation to the twin objectives of developing sufficient new energy resources while providing adequate protection for public health and the environment.

REQUEST FOR COMMENTS. Notice is hereby given that pursuant to the Atomic Energy Act of 1954, as amended, and Reorganization Plan No. 3 of 1970 (F.R. Doc. 70-13374), adoption of Part 190 of Title 40 of the Code of Federal Regulations is proposed as set forth below. All interested persons who wish to submit comments or suggestions in connection with this proposed rulemaking are invited to send them to the Director, Criteria and Standards Division (AW-560), Office of Radiation Programs, Environmental Protection Agency, Washington, D.C. 20460, within 60 days after publication of this notice in the Federal Register. Within this same time period, interested parties are also invited to indicate their desire to participate in a public hearing on the proposed rulemaking to be scheduled after the comment period ends. Comments and suggestions received after the 60-day comment period will be considered if it is practical to do so, but such assurance can only be given for comments filed within the period specified. Single copies of a Draft Environmental Statement for the proposed standards and a technical report entitled "Environmental Analysis of the Uranium Fuel Cycle" are available upon request at the above address. The above-mentioned technical documents and comments received in response to this notice, as well as comments received in response to the Agency's advance

notice of this proposed rulemaking published on May 10, 1974, and the Agency's response to these comments, constitute part of the background for this rulemaking and may be examined in the Agency's Freedom of Information Office, 401 M Street, S.W., Washington, D.C. 20460.

DATED:

Russell E. Train
Administrator

ENVIRONMENTAL RADIATION PROTECTION STANDARDS FOR NORMAL OPERATIONS OF ACTIVITIES IN THE URANIUM FUEL CYCLE

A new Part 190 is proposed to be added to Title 40, Code of Federal Regulations, as follows:

PART 190 - ENVIRONMENTAL RADIATION PROTECTION STANDARDS FOR NUCLEAR POWER OPERATIONS

SUBPART A - GENERAL PROVISIONS

190.01 Applicability

The provisions of this Part apply to radiation doses received by members of the public in the general environment and to radioactive materials introduced into the general environment as the result of operations which are part of a nuclear fuel cycle.

190.02 Definitions

a) "Nuclear fuel cycle" means the operations defined to be associated with the production of electrical power for public use by any fuel cycle through utilization of nuclear energy.

b) "Uranium fuel cycle" means all facilities conducting the operations of milling of uranium ore, chemical conversion of uranium, isotopic enrichment of uranium, fabrication of uranium fuel, generation of electricity by a light-water-cooled nuclear power plant using uranium fuel, reprocessing of spent uranium fuel, and transportation of any radioactive material in support of these operations, to the extent that these support commercial electrical power production utilizing nuclear energy, but excludes mining operations and the reuse of recovered non-uranium fissile products of the cycle.

c) "General environment" means the total terrestrial, atmospheric and aquatic environments outside sites upon which any operation which is part of a nuclear fuel cycle is conducted.

d) "Site" means any location, contained within a boundary across which ingress or egress of members of the general public is controlled by the person conducting activities therein, on which is conducted one or more operations covered by this Part.

e) "Radiation" means any or all of the following: alpha, beta, gamma, or x rays; neutrons; and high-energy electrons, protons, or other atomic particles; but not sound or radio waves, nor visible, infrared, or ultraviolet light.

f) "Radioactive material" means any material which emits radiation.

g) "Uranium ore" is any ore which contains one-twentieth of one percent (0.05%) or more of uranium by weight.

h) "Curie" (Ci) means that quantity of radioactive material producing 37 billion nuclear transformations per second. (One millicurie (mCi) = 0.001 Ci.)

i) "Dose equivalent" means the product of absorbed dose and appropriate factors to account for differences in biological effectiveness due to the quality of radiation and its spatial distribution in the body. The unit of dose equivalent is the "rem." (One millirem (mrem) = 0.001 rem.)

j) "Organ" means any human organ exclusive of the dermis, the epidermis, or the cornea.

k) "Gigawatt-year" refers to the quantity of electrical energy produced at the busbar of a generating station. A gigawatt is equal to one billion watts. A gigawatt-year is equivalent to the amount of energy output represented by an average electric power level of one gigawatt sustained for one year.

l) "Member of the public" means any individual that can receive a radiation dose in the general environment, whether he may or may not also be exposed to radiation in an occupation associated with a nuclear fuel cycle. However, an individual is not considered a member of the public during any period in which he is engaged in carrying out any operation which is part of a nuclear fuel cycle.

m) "Regulatory agency" means the government agency responsible for issuing regulations governing the use of sources of radiation or radioactive materials or emissions therefrom and carrying out inspection and enforcement activities to assure compliance with such regulations.

SUBPART B - ENVIRONMENTAL STANDARDS FOR THE URANIUM FUEL CYCLE

190.10 Standards for Normal Operations

a) The annual dose equivalent shall not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment from uranium fuel cycle operations and radiation from these operations.

b) The total quantity of radioactive materials entering the general environment from the entire uranium fuel cycle, per gigawatt-year of electrical energy produced by the fuel cycle, shall contain less than 50,000 curies of krypton-85, 5 millicuries of iodine-129, and 0.5 millicuries combined of plutonium-239 and other alpha-emitting transuranic radionuclides with half-lifes greater than one year.

190.11 Variance for Unusual Operations

The standards specified in Paragraph 190.10 may be exceeded if:

a) The regulatory agency has granted a variance based upon its determination that a temporary and unusual operating condition exists and continued operation is necessary to protect the overall societal interest with respect to the orderly delivery of electrical power, and

b) Information delineating the nature and basis of the variance is made a matter of public record.

190.12 Effective Date

a) The standards in this Subpart, excepting those for krypton-85 and iodine-129, shall be effective 24 months from the promulgation date of this rule.

b) The standards for krypton-85 and iodine-129 shall be effective January 1, 1983.

Environmental Protection Agency
Region V, Library
230 South Dearborn Street
Chicago, Illinois 60604