NUREG-0543

Methods for Demonstrating LWR Compliance With the EPA Uranium Fuel Cycle Standard (40 CFR Part 190)

F. J. Congel

Office of
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CONTENT

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Introduction

The U.S. Nuclear Regulatory Commission, on May 5, 1975, issued Appendix I, Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion "As Low As Is Reasonably Achievable" for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents, to 10 CFR Part 50. The rule was the result of a detailed review by the Commission of the record of the public rulemaking proceeding which began in January, 1972.

The U.S. Environmental Protection Agency, on January 13, 1977, issued 40 CFR Part 190, Environmental Radiation Protection Standards for Nuclear Power Operations, pursuant to the Atomic Energy Act, as amended, and Reorganization Plan No. 3 of 1970, which gave the EPA the authority to set radiation standards. The part of these standards affecting nuclear power facilities went into effect December 1, 1979.

The NRC has been issuing radioactive effluent and environmental monitoring Technical Specifications in accordance with the original proposed Appendix I guidance of 1971 and the Appendix I as issued May 5, 1975, for nuclear facilities as they were licensed or as their Technical Specifications were amended. The NRC has also been in the process of developing a standardized radiological effluent and environmental technical specification to implement Appendix I to 10 CFR Part 50 (NUREG-0472[1] and 0473[2]). These standardized specifications must now assure that 40 CFR Part 190 is implemented.

The purpose of this document is to: 1) present the specifications that implement 40 CFR Part 190 and Appendix I to 10 CFR Part 50, 2) explain the rationale for using Appendix I to demonstrate compliance with 40 CFR Part 190 for sites with four or less nuclear power reactors, and 3) describe acceptable methods for demonstrating compliance with 40 CFR Part 190 for sites whose radioactive effluents exceed the Appendix I portion of the specifications.

I. Technical Specification Implementation of 40 CFR Part 190

NUREG-0472[1] and 0473[2] contain the following Technical Specification to implement 40 CFR Part 190:

3.11.4 The dose or dose commitment to a member of the public, due to releases of radioactivity and radiation, from uranium fuel cycle sources shall be limited to 25 mrem, or less, to the total body and/or any organ (except the thyroid, which shall be limited to 75 mrem, or less), over any 12 consecutive months.

APPLICABILITY: At all times

ACTION:

A. Whenever the calculated radiation doses from the release of radioactive materials in liquid or gaseous effluents exceed twice the limits of Specification 3.11.1.2.a, 3.11.1.2.b, 3.11.2.2.a, 3.11.2.2.b, 3.11.2.3.a, or 3.11.2.3.b, in lieu of any other report required by Specification 6.9.1, prepare and submit a Special Report to the Director, Nuclear Reactor Regulation, within 30 days, which defines the corrective action to be taken to reduce subsequent releases to prevent exceeding or the recurrence of exceeding the limits of Specification 3.11.4 (i.e., 40CFR190.10). This Special Report shall include an analysis which estimates the radiation dose to a member of the public from uranium fuel cycle sources (including all effluent pathways and direct radiation) for a 12 consecutive month period that includes the release(s) covered by this report. If the estimated radiation dose exceeds the limits of Specification 3.11.4, and if the release condition which led to violation has not already been corrected, the Special Report shall include a request for a variance in accordance with the provisions of 40 CFR 190 and shall include the information specified in §190.11(b). Submittal of the report is considered a timely request, and a variance is granted until staff action on the request is complete. The variance only relates to the limits of 40 CFR 190, and does not apply in any way to the requirements for dose limitation of 10 CFR Part 20, as addressed in other sections of this technical specification.

II. Technical Specification Implementation of 10 CFR Part 50, Appendix I

NUREG-0472[1] and 0473[2] contain the following technical specification to implement 10 CFR Part 50, Appendix I:

LIMITING CONDITION FOR OPERATION - Liquid Effluents

3.11.1.2 The dose or dose commitment to an individual from radioactive materials in liquid effluents released from the site (see Figure 5.1-4) shall be limited:

a. During any calendar quarter: $\leq$ 1.5 mrem to the total body and $\leq$ 5 mrem to any organ, and

b. During any calendar year: $\leq$ 3 mrem to the total body and $\leq$ 10 mrem to any organ.

APPLICABILITY: At all times.

ACTION:

a. With the calculated dose from the release of radioactive materials in liquid effluents exceeding any of the above limits, in lieu of any other report required by Specification 6.9.1, prepare and submit to the Commission within 30 days, pursuant to Specification 6.9.2, a Special Report which identifies the cause(s) for exceeding the limit(s) and defines the corrective actions to be taken to reduce the releases of radioactive materials in liquid effluents during the remainder of the current calendar quarter and during the subsequent three calendar quarters so that the cumulative dose or dose commitment to an individual from such releases during these four calendar quarters is within 3 mrem to the total body and 10 mrem to any organ.

(This Special Report shall also include (1) the results of the radiological analysis of the drinking water source, and (2) the radiological impact on finished drinking water supplies with regard to the requirements of 40 CFR 141, Safe Drinking Water Act.*)

LIMITING CONDITION FOR OPERATION- Noble Gases in Gaseous Effluents

3.11.2.2 The air dose due to noble gases released in gaseous effluents from the site (see Figure 5.1-3) shall be limited to the following:

a. During any calendar quarter: $\leq$ 5 mrad for gamma radiation and $\leq$ 10 mrad for beta radiation and,

b. During any calendar year: $\leq$ 10 mrad for gamma radiation and $\leq$ 20 mrad for beta radiation.

(The dose design objectives shall be reduced based on predicted noble gas releases from the turbine building if effluent sampling is not provided. The dose design objectives shall also be reduced based on expected public occupancy of areas, e.g., beaches and visitor centers within the site boundary.)

APPLICABILITY: At all times.

ACTION:

a. With the calculated air dose from radioactive noble gases in gaseous effluents exceeding any of the above limits, in lieu of any other report required by Specification 6.9.1, prepare and submit to the Commission within 30 days, pursuant to Specification 6.9.2, a Special Report which identifies the cause(s) for exceeding the limit(s) and define the corrective actions to be taken to reduce the releases of radioactive noble gases in gaseous effluents during the remainder of the current calendar quarter and during the subsequent three calendar quarters so that the cumulative dose during these four calendar quarters is within 10 mrad for gamma radiation and 20 mrad for beta radiation.

LIMITING CONDITION FOR OPERATION - Radiodines and Particulates in Gaseous Effluents

3.11.2.3 The dose to an individual from radioiodines and radioactive materials in particulate form, and radionuclides (other than noble gases) with half-lives greater than 8 days in gaseous effluents released from the site (see Figure 5.1-3) shall be limited to the following:

a. During any calendar quarter: $\leq$ 7.5 mrem to any organ and,

b. During any calendar year: $\leq$ 15 mrem to any organ.

APPLICABILITY: At all times.

ACTION:

a. With the calculated dose from the release of radioiodines, radioactive materials in particulate form, or radionuclides (other than noble gases) with half lives greater than 8 days, in gaseous effluents exceeding any of the above limits, in lieu of any other report required by Specification 6.9.1, prepare and submit to the Commission within 30 days, pursuant to Specification 6.9.2, a Special Report which identifies the cause(s) for exceeding the limit and defines the corrective actions to be taken to reduce the releases of radioiodines and radioactive materials in particulate form, and radionuclides (other than noble gases) with half-lives greater than 8 days in gaseous effluents during the remainder of the current

calendar quarter and during the subsequent three calendar quarters so that the cumulative dose or dose commitment to an individual from such releases during these four calendar quarters is within 15 mrem to any organ.

III. Relationship of Appendix I, 10 CFR Part 50 to 40 CFR Part 190

A. Potential radiation doses to individuals beyond the site boundary in the vicinity of nuclear power reactors are evaluated by the NRC staff and the applicant during the construction permit (CP) and operating license (OL) stages of the licensing process. Based on an engineering evaluation of the facility's radioactive waste treatment system and the resultant estimated release of radioactive effluents, the hydrologic and atmospheric dispersion characteristics, and the land use in the immediate site vicinity, potential doses to real individuals at specific locations are calculated. These potential doses must fall within the numerical design objective doses stated in Appendix I to 10 CFR Part 50 before the final waste treatment and effluent control system designs are approved. Guidance for performing these analyses is contained in Regulatory Guides 1.109[3], 1.110[4], 1.111[5], 1.112[6], and 1.113[7].

Immediately prior to facility operation, radiological effluent Technical Specifications are prepared by the licensee for review by the staff which implement the individual dose design objectives of Appendix I to 10 CFR Part 50 (see preceding section). The design objectives are defined for the following three effluent categories: 1) releases directly to the hydrosphere; 2) noble gas releases to the atmosphere; and 3) radioiodine and particulate releases to the atmosphere. For each effluent release category, it is assumed in the calculations that an individual with the highest dose potential is the receptor. Because of different metabolic factors, internal organ sizes, consumption rates, and diets, the critical individual may be either an infant, a child, a teenager, or an adult. For example, an infant would potentially receive the highest dose via the cow-milk pathway due to his/her relatively high consumption rate (300 litres/year) and small

thyroid mass. However, the infant would receive no dose via the leafy vegetable or fish pathway since no consumption of these foods is considered to be involved. Similarly, children have the potential for receiving the highest dose from consumption of leafy vegetables due to their high consumption rates and relatively small thyroid mass. Adults who consume fish harvested from the receiving waters would potentially receive the highest dose from radionuclides released to the hydrosphere. All individuals exposed externally to noble gases receive the same numerical total body dose. Thus, it is highly unlikely or impossible for the same individual to simultaneously receive the highest dose via all three effluent categories. For most reactor sites, it is also unlikely that all different potential dose pathways would contribute to the dose to a single real individual--for example, the cow-milk and vegetable consumption pathway may not both simultaneously exist for the same real individual.

Since it is difficult or impossible to continually determine actual food use patterns and critical age groups, for calculational purposes, assumptions are made which tend to maximize doses. For example, it is generally assumed that an infant obtains his milk supply exclusively from cows grazing at a location near the facility. In reality, the milk consumer may be in an age group other than an infant, may be obtaining milk from other sources, or may not be consuming at the assumed rate. Any of these changes in the assumptions would reduce the estimated dose. Similar maximizing assumptions are made for other pathways.

For radionuclides released to the hydrosphere, the degree of overestimation in most situations is such that no individual will receive a significant dose (i.e., > 1 mrem/yr to the total body or any organ).

For most cases, the overestimation is due to the following three assumptions: 1) the effluents are either undiluted or only slightly diluted by the receiving water, 2) the fish live in the undiluted or slightly diluted water long enough to reach equilibrium concentrations with the surroundings, and 3) an adult obtains his annual fish consumption from the undiluted or slightly diluted water in the immediate surroundings of the nuclear facility. These assumptions generally result in an overestimation of dose by one or two orders of magnitude. Since these assumptions are reflected in the Technical Specifications limiting radionuclide releases to

design objective individual doses, no off-site individual is likely to actually receive a significant dose (i.e., >1 mrem/year/reactor) via the liquid pathways. The conservatism is considered justified since state of the art liquid radioactive waste treatment is able to achieve these small values of liquid releases.

The EPA uranium fuel cycle standard, 40 CFR Part 190, limits the total dose to an individual from radiation and radioactivity associated with the nuclear fuel cycle to 25 mrem/yr to the total body or any organ except thyroid and 75 mrem/yr to the thyroid. The standard primarily differs from Appendix I in that it does not address specific pathways but includes contributions to a real individual from all uranium fuel cycle facilities and all pathways. In comparing Appendix I to 40 CFR Part 190, the only potentially significant exposure pathway for LWR's included in 40 CFR Part 190 but not addressed by Appendix I is the direct radiation pathway (i.e., radiation from radionuclides in plant equipment and systems, or stored on site). However, since both regulations address individual doses, it is possible to state conditions under which conformance with Appendix I provides reasonable assurance of conformance with 40 CFR Part 190.

Since the doses via liquid releases are very conservatively evaluated, there is reasonable assurance that no real individual will receive a significant dose from radioactive liquid release pathways (<1 mrem/yr/reactor). Therefore, only doses to individuals via airborne pathways and doses resulting from direct radiation need to be considered in determining potential compliance to 40 CFR Part 190.

Direct radiation is radiation due to contained radioactive sources within the facility. Since all primary reactor components for PWR's are within heavily shielded areas of the facility, doses due to contained radioactivity are very small at the site boundaries (<1 mrem/yr). BWR's designed within the past 10 years also have all the primary reactor components shielded and therefore the doses at the site boundaries are small (<1 mrem/yr). However, about 8 to 10 BWR's of an earlier design may have substantial direct radiation doses (>5 mrem/yr) that can occur at locations where members of the public could be. Licensees will be required to evaluate these doses and the staff will review these evaluations on a case-by-case basis.

Another possible source of direct radiation is an outside storage tank. These tanks exist at both PWR's and BWR's. In cases where such tanks are located in areas that can result in exposure to members of the public, an assessment of the magnitude of potential doses must be performed. The staff will review each analysis on a case-by-case basis. Regardless of the source,

substantial direct radiation doses may result in reduced individual dose design objectives to ensure that the EPA fuel cycle standard is met.

Appendix I requires that the off-site location with real pathways (e.g., grazing milk animals), real receptors, and the highest dose potential based on a study of the dispersion characteristics of the site environs, serve to establish airborne radioiodine and particulate release rates. Calculations of maximum organ doses from both noble gases and radioiodines and particulates at that limiting location will provide data for determining compliance with 40 CFR Part 190.

For example, the Appendix I radioiodine and particulate design objective is 15 mrem/yr to any organ and the noble gas design objective is 5 mrem/yr to the total body (see Table I). It is assumed that an external total body dose from noble gases irradiates internal body organs at the same numerical rate. For a four reactor unit site with all four units operating the full year at the design objective values for both the noble gas and the radioiodine and particulate releases (a very unlikely situation), the thyroid organ dose could be 80 mrem/yr. Since the offsite location for food pathway doses is seldomly the same location as the location where the noble gas dose is a maximum, it appears reasonable that even a four unit station could meet the 40 CFR Part 190 dose limit if each unit remained within the Appendix I design objective doses. For sites with less than four units and no significant direct shine dose, conformance with Appendix I should establish conformance with 40 CFR Part 190.

IV. Demonstrating Compliance with 40 CFR 190

The Appendix I Technical Specifications for single unit sites require a report within 30 days if the effluent releases exceed one-half the annual design objectives in a calendar quarter. For multi-unit sites, the reporting requirement is reached at one-fourth the design objective value in a calendar quarter. Absolute upper (shutdown) limits of radioactive releases are based on 10 CFR Part 20 doses and concentrations.

As long as a nuclear plant site operates at a level below the Appendix I reporting requirements, no extra analysis is required to demonstrate compliance with 40 CFR Part 190. If a site's Appendix I reporting requirement dose level is reached or exceeded, the Technical Specifications require an analysis to be performed to determine if any additional limitations will be necessary to ensure continued compliance with 40 CFR Part 190.

Based on experience, most Technical Specification reporting levels are not exceeded by substantial amounts. Thus, in most situations, it should be possible to demonstrate continued compliance with 40 CFR Part 190 by reevaluating the exceeded Appendix I design objective dose using more realistic assumptions. This approach is not only permitted but encouraged since 40 CFR Part 190 applies to real individuals. Appendix I to 10 CFR 50 lists design objectives doses which may or may not apply to real people. For example, referring to Table I, assume that the radioiodine and particulate pathway for a single site is calculated to result in 25 mrem to an infant's thyroid, for one year of operation.

Simple inspection of the potential total dose would immediately show that the 40 CFR 190 limit of 75 mrem/yr to the thyroid could not be reached. If the example dose of 25 mrem/yr applied to an organ other than the thyroid, additional analysis would be necessary. If the calculated dose was the result of consumption of vegetation, then an investigation of the reality of the pathway would be necessary. Does a garden actually exist at the assumed location? Does the garden produce a sufficient amount of vegetables to support an individual at the assumed consumption rate? Does the assumed age of the consumer correspond to the actual consumer? Do the results of the radiological environmental surveillance substantiate the predicted concentrations? The answer to any one of these questions could establish that the real individual dose is clearly within the 40 CFR 190 requirement. The level of effort required will depend upon the dose pathway and magnitude.

For most facilities with significant off-site direct radiation doses (> 5 mrem/yr), it will be necessary to determine the magnitude and distribution of these doses. Most assessments have already been performed. After the dose fields are characterized, the dose due to direct radiation must be added to doses due to effluents at the critical locations. At the present time, since only older BWR's have significant direct radiation doses, there are not many sites where the highest off-site food pathway location could also be in a region where the direct radiation dose is significant. Generally, the food pathway locations are more than 1200 meters from the reactor and thus not in a high direct radiation dose region.

Table I

INDIVIDUAL DOSES AT LIMITING OFF-SITE LOCATION

PATHWAY	APPENDIX I DOSE DESIGN OBJECTIVE	THYROID DOSE AT OFF-SITE LOCATION WITH LIMITING PATHWAY(S)* (MREM/YR)			
		INFANT	CHILD	TEEN	ADULT
NOBLE GAS (SUBMERSION)	5 MREM/YR - T.B. 15 MREM/YR SKIN (SITE BOUNDARY)	<5	<5	<5	<5
RADIOIODINES & PARTICULATES (MILK & LEAFY VEG. CONS. + GROUND PLANE + INHALATION)	15 MREM/YR - ORGAN (NEAREST ACTUAL RECEPTOR)	15+	8	2	2
LIQUID (FISH CONS.)	3 MREM/YR - T.B. 10 MREM/YR - ORGAN (DISCHARGE CANAL)	--	<1	<1	<1
DIRECT RADIATION (TURBINE SHINE)	NOT ADDRESSED BY APPENDIX I	<1	<1	<1	<1

MAXIMUM POTENTIAL SUM IS 21 MREM/YR/REACTOR
PROBABLY REAL SUM IS 20 MREM/YR/REACTOR OR LESS

* E.G. MILK, MEAT, OR VEGETABLE CONSUMPTION
+ IF NO INFANT IS PRESENT, THEN NEXT AGE GROUP PRESENT BECOMES LIMITING, I.E., CHILD.

In several situations, the direct radiation dose may be high enough such that recreational use of the immediate reactor environs could result in doses in excess of the fuel cycle standards. For example, annual doses at some locations have been measured as high as 1 rem/yr, before correction for occupancy time. Such cases must be evaluated individually using site-specific data and land use characteristics before a determination is made regarding the acceptability for use by members of the general public.

V. Conclusion

There is reasonable assurance that sites with up to four operating reactors that have releases within Appendix I design objective values are also in conformace with the EPA Uranium Fuel Cycle Standard, 40 CFR Part 190. The Technical Specifications require that evaluations be performed to ensure this conformance.

REFERENCES

1. NUREG-0472, "Radiological Effluent Technical Specifications for PWR's", Rev. 2, January, 1980.

2. NUREG-0473, "Radiological Effluent Technical Specifications for BWR's", Rev. 2, January, 1980.

3. Regulatory Guide 1.109, "Calculation of Annual Doses to Man From Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I", Rev. 1, October, 1977.

4. Regulatory Guide 1.110, "Cost Benefit Analysis for Radwaste Systems for Light-Water-Cooled Nuclear Power Reactors", March, 1976.

5. Regulatory Guide 1.111, "Methods for Estimating Atmospheric Transport and Dispersion for Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors", Rev. 1, July, 1977.

6. Regulatory Guide 1.112, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors", March, 1976.

7. Regulatory Guide 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I", Rev. 1, April, 1977.

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The U. S. EPA Uranium Fuel Cycle Standard (40 CFR 190) went into effect for nuclear power facilities on December 1, 1979. This document presents the model technical specifications that implement 40 CFR Part 190 and Appendix I to 10 CFR Part 50, explains the rationale for using Appendix I as a basis for demonstrating compliance with 40 CFR Part 190 for sites with four or less reactors, and describes methods for establishing compliance with 40 CFR Part 190 for sites with radioactive effluents exceeding the Appendix I design objectives or sites with significant direct radiation dose rates (> 5 mrem/yr).

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