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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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| In the Matter of | ) | |
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| LONG ISLAND LIGHTING COMPANY | ) | Docket No. 50-322 O.L. |
| (Shoreham Nuclear Power Station, Unit 1) | ) | |
| | ) | |

PREPARED DIRECT TESTIMONY OF

MARC W. GOLDSMITH, DALE G. BRIDENBAUGH AND VERA BARLIT

ON BEHALF OF SUFFOLK COUNTY

REGARDING SUFFOLK COUNTY

CONTENTION 26 - ALARA

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## Summary Outline of Suffolk County Contention 26 Testimony*

Suffolk County contends that LILCO has not adequately demonstrated that Shoreham meets the requirements of 10 CFR 20.1(c) with regard to provisions for maintaining occupational radiation exposure as low as is reasonably achievable (ALARA).

The Nuclear Regulatory Commission (NRC) regulates its licensees to restrict an individual's exposure to within prescribed limits. In addition the NRC requires that nuclear plant operators maintain collective and individual exposures as far below the limit as is reasonably achievable. This means that every activity at a nuclear facility involving exposure to radiation should be planned to minimize unnecessary exposure to individual workers and to the worker population. According to the NRC, this can be done by: establishing an ALARA program; properly designing facilities and selecting equipment; establishing a radiation control program, plans, and procedures; and making support equipment, instrumentation and facilities available.

Maintaining occupational exposures ALARA is a requirement of 10 CFR 20.1(c). The specific concerns relate to implementing an ALARA program at Shoreham. These concerns arise from inadequate features and procedures to minimize occupational radiation exposures primarily during maintenance. Specifically there are:

- inadequate design features to separate and isolate equipment;

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*/ ASLB Memorandum and Order, March 15, 1982, pg. 30.

- inadequate materials and equipment selection procedures that do not appear to have followed ALARA considerations in certain cases;
- inadequate procedures to control the water chemistry to minimize crud buildup;
- inadequate procedures to monitor and control occupational radiation doses; and
- inadequate means to provide action if in-plant radiation levels significantly exceed U.S. plant averages.

This testimony discusses the importance of maintaining occupational radiation exposures to the ALARA standard, the elements of the ALARA program at Shoreham, the specific inadequacies listed above, and recommendations relative to LILCO's program. These recommendations include implementing or improving procedures, design features, and programs to minimize occupational radiation exposure at Shoreham.

Exhibits*

1. Regulatory Guide 8.8, "Information Relevant to Ensuring That Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable", Revision 3, June 1978.

2. Final Safety Analysis Report, Figures 12.3.1-16, 5.1.3-1, and 12.3.1-18.

3. Final Safety Analysis Report, Table 12.4.3-1, Volume 12.

4. NUREG-0713, "Occupational Radiation Exposure at Commercial Nuclear Power Reactors 1980", Volume 2, December 1981, cover page and page 18.

5. "Compilation and Analysis of Data on Occupational Radiation Exposure Experiences at Operating Nuclear Power Plants", SAI Services, September 1974, cover page and page 12.

6. Radiation Buildup Effects, by Dr. William R. Dehollander, March 1980, cover page and page 24.

7. Radiation Buildup Effects, by Dr. William R. Dehollander, March 1980, cover page and page 13.

8. NUREG-0855, "Health Physics Appraisal Program", March 1982, cover page and abstract.

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*/ ASLB Memorandum and Order, March 15, 1982, p. 30.

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MARC W. GOLDSMITH, DALE G. BRIDENBAUGH AND VERA BARLIT

ON BEHALF OF SUFFOLK COUNTY

REGARDING SUFFOLK COUNTY CONTENTION 26 - ALARA

## I. INTRODUCTION

This testimony was prepared by Marc W. Goldsmith, Dale G. Bridenbaugh, and Vera Barlit.[1/] A statement of our qualifications and experience has been separately provided to this Board.

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1/ The primary/secondary authors of each section of this testimony are as follows:

Sections I and II -- M. W. Goldsmith/V. Barlit
Section III and IV -- M. W. Goldsmith/D. G. Bridenbaugh/V. Barlit

M. W. Goldsmith was responsible for overall coordination.

Testimony on S.C. Contention 26: ALARA

Q. Would you please state the contention on which you are testifying?

A. The Suffolk County Contention 26 reads as follows:

Suffolk County contends that LILCO has not adequately demonstrated that Shoreham meets the requirements of 10 CFR 20.1(c), with regard to provisions for maintaining occupational radiation exposure as low as is reasonable achieveable (ALARA). Demonstration of compliance is inadequate as follows:

(a) Plant and equipment design has not been shown to be optimally developed for minimization of radiation exposure during maintenance of the plant by:
   (i) Selection of low cobalt materials;
   (ii) Separation or isolation of various components and piping systems;
   (iii) Provisions for flushing or decontamination;
   (iv) Equipment layout and arrangement for ease and automation of maintenance and refueling; and
   (v) Condenser design utilizing the minimum number of shell connections.

(b) Procedures have not been developed and emplaced to provide:
   (i) Limitation of iron-cobalt buildup in the primary system through water chemistry control;
   (ii) Monitoring and control of individual and plant total annual occupational radiation doses, with invididual exceedance of three rem per quarter and five rem per year occurring only on an emergency basis and requiring special management approval; and

(iii) Action to reduce radiation levels and/or exposure if the in-plant totals significantly exceed U.S. plant averages.

Q. What is the purpose of your testimony?

A. The purpose of this testimony is to discuss the importance of maintaining occupational radiation exposures to the as low as reasonably achievable standard (ALARA). Thus the testimony discusses ALARA, elements of the ALARA program at Shoreham, and specific concerns and recommendations with respect to LILCO's program. Specific concerns discussed are:

- design of shielding and cubicles for radioactive maintenance;
- selection of equipment and materials;
- procedures for water chemistry, decontamination and, personnel doses; and,
- the ALARA monitoring program.

I. Introduction - The Importance of ALARA

Q. Why is it important to maintain occupational radiation exposures as low as is reasonably achievable?

A. It is generally accepted by the scientific community that any exposure to radiation is cumulative and ultimately may cause harmful biological effects. Immediate or prompt effects are very unlikely since large exposures would normally occur only if there were a radiation accident. However, a significant and widely recognized concern is the delayed incidence of cancer. The chance of delayed cancer is believed to depend on how much radiation exposure a person receives. Therefore, every reasonable effort should be made to keep exposures low and therefore to lessen the probability of concerns. The regulations specifically recognize this concern by making ALARA part of the regulations in 10 CFR 20.1(c).

Q. How are workers exposed to radiation in nuclear power plants.

A. Radiation exposure can result from external sources or from ingestion of materials (absorbed or inhaled) that are radioactive. Radiation doses to personnel in nuclear power stations are predominantly from external exposure, i.e., from radiation received from sources external to the body, although careful control of ingestion, particularly during maintenance operation is essential. The intensity of the external radiation field is determined primarily by four factors: the quantity of radioactive material; the characteristics of the emitted radiation; shielding between the radiation source and the receptor; and, distances between source and receptor. Important parameters in determining doses from external exposures are: the length of time the receptor remains in the radiation field; and the intensity of the radiation field.

Internal exposure to radiation results when radioactive materials are taken into the body by breathing, ingestion, or absorption through the skin. Radioactive materials usually concentrate in different organs in the body, resulting in a dose to a specific organ (i.e., radioactive iodine concentrates in the thyroid gland). Internal exposure is controlled by limiting the release of radioactive material into the air and by carefully monitoring the work area for airborne radioactivity and surface contamination.

Q. How is exposure to radiation regulated?

A. The Nuclear Regulatory Commission (NRC) regulates its licensee's to restrict an individual's exposure to within prescribed limits. The radiation dose limits for both the public and workers are set forth in the Code of Federal Regulations, Title 10, Part 20 "Standards for

Protection Against Radiation." The standards currently limit external occupational radiation dose to 1-1/4 rems[2/] in any calendar quarter or specified 3-month period for whole body exposure.

Limits for internal exposure are set by calculating the quantity of radioactive material that has been taken into the body and the total organ dose that would result. Then, based on limits established for particular body organs similar to 1-1/4 rems in a calendar quarter for whole-body exposure, the regulations specify maximum permissible concentrations (MPC) of radioactive material in the air to which a worker can be exposed for 40 hours per week. Individual internal dosages are added to external exposure dosages. Exposure to radiation that results from radioactive materials taken into the body is measured, recorded, and reported to the worker separately from external dose. The internal dose to the whole body or to specific organs does not at this time count against the 3 rems per calendar quarter limit.

Q. Are there regulations limiting collective doses to all station personnel?

A. No. Upper limits are placed on individual doses, but not on collective doses. The collective occupational dose (man-rems) is the sum of all occupational radiation-exposures received by all the workers in an entire worker population. For example, if 100 workers each receive 2 rems, the individual worker dose is 2 rems and the collective dose is 200 man-rems. The total additional risk of cancer and genetic effects in an exposed population is assumed to depend on the collective dose. However, the NRC does not impose collective dose limits.

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2/ The rem is the unit used for dose comparison and stands for roentgen equivalent man. A rem is equal to the absorbed radiation dose multiplied by a factor that takes into account the way a particular radioactive particle distributes energy in tissue, thus including its effectiveness in causing harm.

Q. How does NRC provide guidance on controlling collective doses?

A. In addition to providing an upper limit on an individual's permissible radiation exposure, the NRC also requires that nuclear plant operators maintain exposures as far below the limit as is reasonably achievable. This also means that every activity at a nuclear facility potentially involving exposure to radiation should be planned to minimize unnecessary exposure to individual workers and thus to the worker population. According to the NRC,[3/] a job that involves exposure to radiation should be done only when it is clear that the benefit justifies the risks assumed.

Section 20.1(c) of 10 CFR Part 20, "Standards for Protection Against Radiation," states that "persons engaged in activities under licenses issued by the NRC. . .[should]. . .make every reasonable effort to maintain radiation exposures as far below the limits specified in Part 20 as is reasonably achievable. The Series 8 Regulatory Guides provide specific guidance on the Staff's suggested means of meeting the Part 20 requirements. Thus, Regulatory Guide 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations will be As Low As is Reasonably Achievable" (Exhibit 1) provides information relevant to attaining goals and objectives for planning, designing, constructing, operating, and decommissioning to meet the criterion that exposures will be ALARA.

## II. The Establishment of an ALARA Program

Q. What are the goals of ALARA as set by NRC?

A. As stated in Regulatory Guide 8.8,

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3/ Regulatory Guide 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations will be As Low As is Reasonably Achievable."

"the goals of the effort to maintain occupational radiation exposures ALARA are (1) to maintain the annual dose to individual station personnel as low as is reasonably achievable and (2) to keep the annual integrated (collective) dose to station personnel (i.e., the sum of annual doses (expressed in man-rems) to all station personnel) as low as is reasonably achievable.

The NRC staff believes that the stated objectives are attainable with current technology and with good operating practices.

Q. How can these goals be met?

A. According to the NRC Staff, as set forth in Regulatory Guide 8.8, these goals can be met by:

1. Establishing a program to maintain radiation exposures ALARA.

   "To attain the integrated effort needed to keep exposures of station personnel ALARA, each applicant and licensee should develop an ALARA program that reflects the efforts to be taken by the utility, nuclear steam supply system vendor, and architect-engineer to maintain radiation exposure ALARA in all phases of a station's life."

2. Properly designing facilities and selecting appropriate equipment.

   "Design concepts and station features should reflect consideration of the activities of station personnel (such as maintenance, refueling, inservice inspections, processing of radioactive wastes, decontamination, and decommissioning) that might be anticipated and that might lead to personnel exposure to substantial sources of radiation. Radiation protection aspects of decommissioning should be factored into planning, designing, construction, and modification activities. Station design features should be provided to reduce the anticipated exposures of station personnel to these sources of radiation to the extent practicable.

Specifications for equipment should reflect the objectives of the ALARA program, including considerations of reliability, serviceability, limitations of internal accumulations of radioactive material, and other features addressed in this guide. Specifications for replacement equipment also should reflect modifications based on experience gained from using the original equipment."

3. Establishing a radiation control program, plans, and procedures.

"A substantial portion of the radiation dose to station personnel is received while they are performing services such as maintenance, refueling, and inspection in high radiation areas. Objectives discussed previously can provide station design features conducive to an effective program to maintain occupational radiation exposures ALARA. However, an effective program also requires station operational considerations in terms of procedures, job planning, recordkeeping, special equipment, operating philosophy, and other support."

4. Making support equipment, instrumentation and facilities available.

"A radiation protection staff with facilities, instrumentation, and protective equipment adequate to permit the staff to function efficiently is an important element in achieving an effective program to maintain occupational radiation exposures ALARA. The selection of instrumentation and other equipment and the quantities of such equipment provided for normal station operations should be adequate to meet the anticipated needs of the station during normal operations and during major outages that may require supplemental workers and extensive work in high radiation areas."

ALARA objectives should be considered throughout the planning, designing, constructing, operating, maintenance, and decommissioning of a LWR station to provide reasonable assurance that exposures of station personnel to radiation will be ALARA.

Q. What are the goals of ALARA as specified by LILCO?

A. According to LILCO, as set forth in the FSAR Chapter 12, the plant and equipment design criteria and the use of appropriate procedures ensure that Shoreham meets the requirments of 10 CFR 20.1(c) and maintains occupational radiation exposure ALARA. However, LILCO's assertion cannot be accepted out-of-hand because the FSAR discussion, entitled "Radiation Protection", Chapter 12, describes LILCO's program to meet ALAP (as low as practical), a concept that was superceded by ALARA in 1979. Thus as stated in the FSAR:

> It is the policy of the Long Island Lighting Company to keep occupational radiation exposure (ORE) as low as practicable (ALAP), consistent with plant construction, maintenance, and operation requirements, and within the applicable regulations. This ALAP policy applies to total man-rems accumulated by all personnel, as well as to individual exposures. LILCO management will make every effort to provide the environment for this policy to function in a proper manner. Management's commitment to this policy is reflected in the design of the plant, the careful preparation of plant operating and maintenance procedures, the provisions for review of these procedures and for review of equipment design to feed back the results of operating experience, and most importantly, the establishment of an extensive, on-going training program. Sufficient training will be provided for all personnel so that each individual is capable of carrying out his responsibility for maintaining his own exposure ALAP consistent with discharging his duties and also for observing rules adopted for his own safety and that of others. The development of the proper attitudes and awareness of the potential problems in the area of health physics, by proper training of all plant personnel, is the cornerstone of LILCO's policy.4/

4/ FSAR, Volume 12, Section 12.1.1.1., pg. 12-1-1.

Q. Does ALARA represent a strengthened policy over the ALAP? Please explain.

A. ALARA represents a strengthened policy over ALAP. ALARA represents an affirmation of the use of a quantification rationale (benefit-cost analysis) in regulation. ALARA, ". . .has an improved structure, (over ALAP) with numbers to refer to during the design process, limits for protection of the most-exposed individuals, and clear directions for measures to reduce the population dose. . ." "ALARA is one of the most important of numerous design factors built into NRC regulations for licensing new facilities and also has implications for 'back fitting' existing plants as well."[5/]

Q. Is there agreement on the ALARA goals?

A. It appears that the goals set forth for ALARA are similar for all parties. The area of disagreement relates to the implementation of the program to meet the ALARA goals. As discussed above the multiple goals are interrelated and dependent on proper implementation to achieve the objective of low worker doses. As discussed in the subsequent sections, implementation of the program at Shoreham needs to be improved in several areas.

## III. Specific Concerns Relative to the ALARA Program Implementation at Shoreham

Q. What are the concerns relative to maintaining Shoreham occupational radiation exposures ALARA?

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5/ Considerations of Health Benefit-Cost Analysis for Activities Involving Ionizing Radiation Exposurs and Alternatives EPA 520/4-77-003, 1977, p. 93.

A. Concerns arise from inadequate design features and procedures at Shoreham to minimize radiation exposures during maintenance. Specifically, design features to separate and isolate equipment are inadequate; materials and equipment selection does not appear to have followed ALARA considerations in certain cases; procedures either do not exist or are inadequate to control the water chemistry at Shoreham to minimize crud buildup; procedures to monitor and control occupational radiation doses are not adequate, and there are inadequate means to take positive action if in-plant radiation levels significantly exceed U.S. plant averages is not present. Therefore, 10 CFR 20.1(c) with respect to ALARA is not met at Shoreham.

Q. What are some of the specific design concerns relative to maintaining exposures ALARA at Shoreham?

A. The equipment configuration and layout associated with the Mark II containment at Shoreham results in a cramped and crowded configuration. Examples of problems created by this condition are: (1) the main steam isolation valves (with extremely difficult access in the pipe tunnel and dose contributions from the multiple valves and pipes); (2) the common location of the recirculation pumps, recirculation piping, and the transport carriers for control rod drives to the CRD maintenance area; and, (3) location of Safety Relief Valves, piping snubbers, main steam line nozzles, etc. high in the drywell.

Access to this equipment is required during the refueling/maintenance outage and all such work is normally carried out simultaneously (or as near to simultaneously as can be achieved). Much of this work is often done while refueling is underway, and workers in the drywell, particularly the upper regions could receive non-ALARA or even overexposures from improperly handled or dropped fuel. The problems described above are apparent on the marked-up figures taken from the FSAR appended as Exhibit 2.

Q. What is the reason for this problem?

A. Plant arrangement was primarily dictated by economics of plant construction cost and that evaluation of ALARA aspects a decidedly secondary consideration. Use of the pressure suppression containment concept was successful in reducing containment size, and therefore, cost, but it resulted in minimum space for maintenance activities.

Q. Do these space problems potentially cause greater radiation exposure?

A. It would certainly appear so. The highest exposure tasks are the same ones that are the most closely crowded together. A copy of Table 12.4.3-1 from the FSAR is appended as Exhibit 3. It shows that the highest exposure rate jobs are expected to be MSIV maintenance, recirculation pump maintenance, ISI-drywell piping, and CRD work. These are precisely the tasks impacted by the cramped drywell, and their close proximities will compound the effect.

Q. Could some of these deficiencies be corrected without a complete redesign of the plant?

A. In some cases they could. For example, the use of additional block shield walls (either permanent or semi-permanent shielding) can be increased and such walls could be described in the radiation protection program. In the formal ALARA program review of equipment access including identification of additional catwalks and ladders that may be needed. Temporary shielding and necessary monorails and equipment handling hoists for maintenance should be identified prior to operation of the plant and installed in the appropriate locations before the system is made radioactive. The ALARA program should include evaluation of such provisions.

Q. Why is equipment selection so important to the minimization of occupational radiation exposures?

A. In operating nuclear power plants, it is not the operators - but the maintenance personnel - who are subjected to the highest levels of radiation exposure. Exhibit 4 from NUREG-0713,[6/] provides a detailed summary of the distribution of collective dose by work function and personnel types for BWRs, PWRs and all LWRs. It shows that contract workers performing special maintenance at LWRs incur the largest portion of the collective dose. At BWRs, workers involved in these activities received 80.8% of the cumulative dose for BWRs, an increase of about 10% from the 1980 value, while at PWRs these workers received 70.6% of the cumulative dose, an increase of only 3.6% over the 1980 value. The portions of the collective dose received by workers during inservice inspection and refueling at BWRs are 3.3% and 5.2% respectively; at PWRs such workers received 8.2% and 7.1%, respectively, of the collective dose. Overall, contractor personnel received 68.4% of the collective dose (about 10% more than in 1980), and the station and utility employees received the remaining 31.6% at LWRs.

It is possible by careful equipment selection and attention to layout to reduce exposure received during maintenance. There are four ways in which this can be accomplished:

1. Reduce the amount or frequency of maintenance required;
2. Shorten the time spent working in a radioactive environment;
3. Reduce the radiation level in the work area; it includes, use of shielding and reducing the coolant activity level and/or deposited activated corrosion produces; and
4. Reduce the number of workers required.

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6/ NUREG-0713, Occupational Radiation Expousre at Commercial Nuclear Power Reactors 1980, Volume 2, December 1981, p. 18.

Q. Are there other areas where shielding is inadequate for maintenance?

A. It is difficult to make a definitive statement because the type of detailed analysis necessary to judge post-shutdown radiation levels has not been performed. The maintenance worker is subject to the radiation fields existing after shutdown during refueling outages when the majority of maintenance and inspections are performed. The shielding diagrams showing radiation levels (FSAR Section 12.3) show some limited post-shutdown levels. However, no derivation of the post shutdown levels is presented. It is, therefore, difficult to determine the adequacy or accuracy of the post shutdown levels in order to place a relative importance of one action or activity over another.

Specific concerns are pieces of equipment that are doubled or tripled up in cubicles. This has the potential to cause higher doses than if equipment was individually segregated. Specific equipment that could present problems are: the fuel pool clean-up pumps; pumps in the radwaste building; and, the reactor coolant water clean up heat exchangers. This equipment requires periodic maintenance and shared cubicle arrangement has the potential to complicate the maintenance process. This could add to worker exposure.

Q. What is a specific concern relative to equipment design at Shoreham?

A. According to an EPRI report,[7/] one source of radiation is radioactive crud which collects on the condenser surfaces. Much of this comes from the location of inlet connections on the condenser shell. Adding a dump tank to collect all lines before they enter the condenser would reduce this problem. It would also have distinct advantages:

7/ Limiting Factor Analysis of High Availability Nuclear Plants (BWR), Volume 1, August 1979, pg. 2.2-68

1. It would reduce the amount of radioactive crud on the tube surfaces, thus reducing the field strength;
2. It would reduce the number of connections to the condenser shell and thus reduce the number of potential air leaks that would require location and repair and hence exposure to radioactivity (these leaks are largely at valves in the connecting lines); and,
3. It would reduce the number of tube failures due to either direct impingement or broken-off baffles.

LILCO states it has minimized the condenser shell connections at Shoreham.[8/] However, LILCO has not added a dump tank to collect these connections to provide the above advantages. Therefore, radiation dosages will not be minimized during condenser maintenance operations and additional maintenance may be required.

Q. Why is it important to select materials which would minimize occupational radiation exposures?

A. Erosion and corrosion of materials particularly in the primary system are large contributors to the radiation fields in the plant. Selection of materials with good wear and corrosion resistance would help minimize this problem. In addition, certain materials have alloying elements that have long half-lifes when activated. These alloys should be avoided where possible to reduce the long half-life activation products.

Q. What is the specific concern relative to the selection of materials at Shoreham?

A. Reg. Guide 8.8 suggests the use of materials bearing low nickel and low cobalt concentrations for primary coolant piping, vessel internal

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8/ Information received through the discovery process.

surfaces, and other components that are in contact with primary coolant. This suggestion was made because materials containing nickel or cobalt produce long active half-life corrosion products, that accumulate in the system resulting in an increase in radiation. Information submitted to date by LILCO does not indicate that LILCO selected materials are low in nickel and cobalt. For example, NRC Information Request 331.1 states:

> "This section [FSAR Section 12.1] discusses theoretical approaches to the reduction of radioactive crud; however, except for flushing tap provisions, no other commitments are described. Expand this section to include a listing of specific techniques used to minimize radiation from activated corrosion products. . ."9/

The response provided by LILCO to the NRC request is incorporated in Section 12.1.3.1.2 of the FSAR. A review of that Section of the FSAR indicates only that 1) piping system geometry, 2) elimination of crud pockets, 3) avoidance of low flow velocities, and 4) utilization of full flow condensate demineralization are utilized to minimize the buildup of cobalt 60. No indication is given demonstrating that any attempt was made to specify low cobalt or low nickel materials and a review of the piping material section in the FSAR (Section 5.2.3) gives no indication that any consideration was given to ALARA recommendations in the selection of reactor coolant pressure boundary material. This section in fact indicates that stellite hard facing material is one of the materials of construction exposed to reactor coolant. Stellite is commonly used for valve seats and discs and contains a high percentage of cobalt, which could potentially result in a high accumulation of corrosion products, causing an increase in plant radiation. In addition, the careful selection of materials would help to minimize maintenance resulting from corrosion failures such as pipe cracking.

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9/ FSAR, Volume 15, p. 331-1.

Q. What are the specific concerns relative to the implementation of such procedures at Shoreham?

A. Water chemistry control procedures which would optimally minimize corrosion products at Shoreham have not been documented. As can be seen from Exhibit 5, annual exposures at BWRs were found to increase with plant age, increasing by a factor of two to three each year for the first three to five years. The observed increases in annual exposure are believed to have resulted from an increase in radiation fields during these years, which are due to the accumulation of activated corrosion products. Annual exposures at newer BWRs are expected to follow the same pattern. Reduction of radiation fields can be accomplished by reducing activated corrosion products.

The radiation field buildup after initial operation at the BWR plants is caused when corrosion products generated in the primary coolant system are carried into the reactor and activated on the fuel surface. They are then deposited on the piping and components in the primary circuit. To reduce the external radiation fields, it is important that the mechanism of transport, activation, deposition, and release of corrosion products be thoroughly understood, and that effective countermeasures be taken.

According to an EPRI Journal report,[10/] "plant monitoring has established Co-60 as the major contributor to BWR radiation fields." This isotope is produced by activation of natural cobalt (Co-59) which is released to the coolant through wear and corrosion of alloys within the system. Cobalt is a major material in wear-resistant alloys, and is present as a low-level impurity in numerous iron-nickel alloys. Presently, efforts are underway at EPRI to identify the significant sources of cobalt in BWR materials. Because it is impossible to eliminate cobalt in some materials and undesirable to do so in other materials, cobalt will remain in the

10/ "BWR Radiation Control", EPRI Journal, October 1980, pg. 51-52.

system as a low-level, inpurity. Therefore, cobalt control techniques are being developed. With better identification of cobalt sources, corrosion products can be minimized by selecting alternative materials for replacement when needed.

Iron corrosion products are believed to play a fundamental role in cobalt activation and transport. Iron is released from corroding surfaces and is transported through the feedwater system to the reactor. The control of iron is important because it is only via the medium of iron oxide that cobalt-59 (the natural isotope) can reside in the high neutron flux within the core long enough to become cobalt-60. Dissolved cobalt absorbs on iron oxide and is carried to the fuel surface. The oxide adheres to the heated zircalloy fuel rod, thus holding the cobalt-59 in the flux for a period of time sufficient to activate the cobalt to cobalt-60. According to a G.E. report on radiation field buildup,[11/] how long the iron remains on the fuel and thus how much cobalt-60 is released to the water is a function of the quality of the iron oxide.

According to the G.E. Report it is believed that very small particle size iron oxide (colloidal, less than 0.2 microns) adheres firmly to the fuel and virtually never leaves the surface again. Thus, the cobalt-60 can be high but it never leaves the fuel; so it cannot deposit on the piping. Middle size iron oxide particles (0.2 - 1 micron) are small enough to adhere to the fuel rod but large enough so the bonds are weak. After some residence time on the rod, the particles can be released again into the water, carrying the cobalt-60, and thus making cobalt-60 available to the piping. Therefore, this middle size iron oxide should be controlled. Larger size iron oxide particles (greater than 1 micron) are usually erosion generated and are generally harmless with respect to radiation buildup as they usually remain as sediment.

11/ "Radiation Effects of Water Quality", by Dr. William R. Dehollander of G.E., March 1980.

Q. How can the activation of corrosion products be minimized.

A. According to the G.E. report it is believed that the variable oxygen content in the feedwater assists in the release of middle size iron oxide from the feedwater piping. Therefore, a controlled oxygen level should be attained to minimize middle size iron oxide particles. The most desirable constant value is specific reactor system dependent and should be determined based on an analysis of iron oxide released as a function of the controlled oxygen level.

However, results have shown that corrosion was minimized between a bond of 20 PPB to 200 PPB. The rate of corrosion of stainless steel, is a linear function with conductivity (see Exhibit 6). Therefore, measures should be taken to keep the conductivity of the reactor water low.

Q. Have any nuclear plants been successful in controlling oxygen, iron and conductivity levels?

A. Countermeasures against corrosion were successfully carried out at the Tsuruga Nuclear Power Station in Japan. The Tsuruga plant has the largest operating experience in Japan - commercial operation started in March 1970. In 1973, a steep increase in the iron concentration due to an increase of corrosion product generation in the feedwater system was experienced. A comprehensive program review of plant chemistry was conducted at Tsuruga and countermeasures against corrosion were taken. Since Tsuruga's sixth annual inspection, the rate of iron feed from the feedwater has been reduced at Tsuruga by the following measures:

1. the control of oxygen dissolved in feedwater ( 60 PPB to minimize corrosion products).
2. flushing of feedwater system before startup (to keep the conductivity low);

3. improvement of performance of condensate demineralizers (resin exchange to keep the conductivity low);
4. hot draining off of condensate water and feedwater during long outages (to keep the conductivity low).

The following results were obtained since the countermeasures were taken:

1. radiation field strength resulting from accumulated corrosion products dropped by a factor of two in two years; (from 250 mr/h to 150 mr/h, see Exhibit 7);
2. iron input to the feedwater dropped by a factor of ten resulting in a decrease of corrosion products;
3. soluble and insoluble iron particles were reduced resulting in a decrease or corrosion products; and
4. Cobalt-60 on the inside of the primary system piping was reduced.

Q. Could a similar water chemistry control program be implemented at Shoreham to minimize corrosion buildup?

A. Yes, preventive measures such as those taken at the Tsuruga plant could be taken at Shoreham. Procedures for preventing corrosion during long outages could be implemented along with procedures to flush the feedwater system before startup and measures could be taken to control the oxygen dissolved in the feedwater within the 20-200 PPB range.

Q. What procedures are involved in having an adequate radiation monitoring program?

A. Station technical and supervisory personnel, working closely with radiation protection personnel, can reduce exposure. Procedures to reduce exposures include planning activities of personnel who must enter radiation areas, by studying the actions and procedures of individuals working in such areas, and by conducting postoperation

debriefings on projects resulting in substantial exposures to identify how procedures might be modified to reduce exposures on subsequent similar tasks. Training programs for all station personnel can establish and reinforce the principles of radiation protection as applied to specific job functions. By making personnel aware of the methods and the special equipment and protective equipment available to them, potential radiation doses can be reduced.

Q. What are the specific concerns relative to the radiation monitoring program at Shoreham?

A. It does not appear that LILCO management and organization is fully committed to a meaningful ALARA program. This is apparent from LILCO's response to NRC Request 331.31 contained in the Final Safety Analysis Report. It admits that Shoreham's radiation protection program does not fully comply with Regulatory Guide 8.8, Revision 3, June 1978.[12/] A significant deficiency is the failure of the Shoreham radiation protection program to include a specific measurement sytem. Such a program is very important. In a recent report documenting an appraisal of the light water reactor health physics programs throughout the country,[13/] the NRC reported on deficiencies in ALARA programs they had reviewed at existing plants. Included in the deficiencies cited was the following:

> "There were no apparent measurable goals set for the ALARA effort; there was no management system developed that would indicate the degree of success of ALARA effort undertaken, that is, if the goal has been achieved."[14/]

12/ Final Safety Analysis Report, p. 331-31, Revision 18, June 1980.

13/ Exhibit 8, NUREG-0855, Health Physics Appraisal Program, March 1982.

14/ NUREG-0855, p. 19.

In the suggested actions for improving health physics programs, the NRC stated that one of the most frequent omissions in audit programs is performance audits. They found that most radiation protection programs include functional audits which determine whether selected activities are performed and if they are performed at the proper frequency, but assessment of the effectiveness of the program is frequently left out of the audit. This noted deficiency is related specifically to Reg. Guide 8.8 C.1.b (1)(b) and (c). These provisions call for that ensuring effective measurement systems are established in the radiation protection program and that the measurement system results are reviewed on a periodic basis and corrective actions taken. LILCO's failure to incorporate this critical step in the radiation protection program at Shoreham is a significant deficiency and one that should be corrected.

Q. Does it appear LILCO is correcting this deficiency (lack of measurement program) in the ALARA procedures?

A. Yes, there is evidence of some additional work underway. We have recently obtained a copy of a draft procedure entitled "ALARA Goals and Measurement". This draft has not been approved and is dated March 26, 1982. It does specify that ALARA goals shall be set by the LILCO Section Heads.

Q. If this procedure is adopted, will that correct the lack of measurement deficiency?

A. No it will not. The draft procedure requires only that goals be set and records kept and reviewed. It lacks definition of action steps. It even shows that acceptance criteria are not applicable.

Q. Does this lack of action criteria represent a significant deficiency?

A. Yes it does. The apparent reluctance of LILCO to identify action level guidelines but instead to apparently rely on the Review Operations Committee for corrective action does not signify a formal commitment to the program. This lack of commitment was also a significant finding in the health physics appraisal program documented in NUREG-0855. That appraisal identified lack of management support as a significant weakness that existed at approximately one-third of the facilities inspected.[15/] The lack of management support was reflected in several ways as reported by the NRC. At some facilities, the radiation protection manager did not report directly to the station manager and this apparently contributed to causing the quality of radiation protection to be significantly less at some plants.

Q. Does the radiation protection manager report directly to the station manager at the Shoreham Plant?

A. LILCO's response to question 331.31 in the FSAR indicates that the responsibility for health physics rests with the HP engineer and HP supervisor. It goes on to state however that the HP engineer "has direct recourse to the plant manager" which indicates to me that this is an optional path rather than a direct reporting function. This indirect reporting path is confirmed in Section 13 of the FSAR.

Q. What other deviations from Regulatory Guide 8.8, Rev. 3 exist?

A. As reported by LILCO's response to Request 331.31, health physics technicians are presently assigned to work only on the day shift from Monday thru Friday. This does not comply with RG 8.8, Rev. 3, B.(1). The Reg. Guide recommends that health physics

15/ NUREG-0855, p. 5.

protection should be provided for each shift operating crew. This incidently was discovered to be a common problem at approximately one-third of the U.S. operating plants as reported in NUREG-0855. That report recommended that adequate staff be provided so that the assigned responsibilities can be accomplished. We certainly agree that HP coverage should be present at all shifts unless it is known that no unusual situation may arise that no maintenance work is underway.

Q. What would satisfy the concerns you have expressed relative to maintaining occupational radiation as low as is reasonably achievable at Shoreham?

A. The following are the minimum steps needed for maintaining occupational radiation as low as is reasonably achievable at Shoreham:

1. Increase the use of shield walls in areas previously discussed;
2. Document that a thorough study of equipment access will be conducted;
3. Identify temporary shielding, monorails, and equipment handling hoists for maintenance purposes prior to operation;
4. Document procedures to reduce cobalt bearing materials during normal equipment replacement programs.
5. Install a dump tank connecting all the lines going into the condenser;
6. Implement water chemistry control procedures similar to the Tsuruga plant. Procedures for preventing corrosion during long outages could be implemented along with procedures to flush the feedwater system before startup and measures could be taken to control the oxygen disolved in the feedwater within 20-200 PPB range.

7. Improve the radiation protection program at Shoreham by:
   a. including a specific measurement system into the program.
   b. ensuring that effective measurement systems being established and the measurement system results are reviewed on a periodic basis and corrective actions taken;
   c. committing to setting specific numerical goals (level guidelines) by management;
   d. assigning health physics technicians to each shift operating crew.

8. It appears that the future elements of the radiation protection program are beginning to be developed for Shoreham. Since they are in such a preliminary state, we recommend a detailed review by experienced outside consultants after the program is nearly completed.

EXHIBIT 1

Regulatory Guide 8.8, "Information Relevant to Ensuring
That Occupational Radiation Exposures at Nuclear Power Stations
Will Be As Low As Is Reasonably Achievable"
Revision 3, June 1978.

U.S. NUCLEAR REGULATORY COMMISSION

Revision 3
June 1978

# REGULATORY GUIDE

OFFICE OF STANDARDS DEVELOPMENT

## REGULATORY GUIDE 8.8

## INFORMATION RELEVANT TO ENSURING THAT OCCUPATIONAL RADIATION EXPOSURES AT NUCLEAR POWER STATIONS WILL BE AS LOW AS IS REASONABLY ACHIEVABLE

### A. INTRODUCTION

Paragraph 20.1(c) of 10 CFR Part 20, "Standards for Protection Against Radiation," states that licensees should make every reasonable effort to maintain exposures to radiation as far below the limits specified in Part 20 as is reasonably achievable. This guide provides information relevant to attaining goals and objectives for planning, designing, constructing, operating, and decommissioning a light-water reactor (LWR) nuclear power station to meet the criterion that exposures of station personnel[1] to radiation during routine operation of the station will be "as low as is reasonably achievable" (ALARA). This guide is also responsive to the admonition of the Federal Radiation Council (now EPA) that occupational radiation exposures be maintained ALARA. Major accident situations and emergency procedures are not within the scope of this guide.

Much of the information presented in this guide also is applicable to nuclear power stations other than those cooled with light water. The applicable goals and objectives should be used for all nuclear power stations until more specific goals and objectives are available for other types of power reactors.

### B. DISCUSSION

The relationship between radiation dose and biological effects is reasonably well known only for doses that are high compared with current annual dose limits and only when such doses are delivered at high dose rates.[2] An ad hoc committee of the National Council on Radiation Protection and Measurements (NCRP) (Ref. 1) chose in 1959 to make the cautious assumptions that a proportional relationship exists between dose and biological effects and that the effect is not dependent on dose rate. Essentially, this amounts to assumptions of a nonthreshold, "linear" (straight line) dose-effect relationship.

The International Commission on Radiological Protection ICRP), the Federal Radiation Council (FRC) whose functions now reside in the Environmental Protection Agency (EPA), and committees of the National Academy of Sciences/National Research Council (NAS/NRC) have used this hypothesis to estimate conservatively the number of possible biological effects that statistically may be associated with exposures to radiation.

The NAS/NRC Biological Effects of Ionizing Radiation (BEIR) Committee (Ref. 2) reiterated that the assumptions of a nonthreshold linear relationship between dose and biological effects independent of the dose rate should be applied for radiation protection purposes. This recommendation has been adopted by EPA (41 FR 28409) for the purpose of estimating the potential human health impact of low levels of ionizing radiation. The radiation protection goal is to reduce doses wherever and whenever reasonably achievable, thereby reducing the risk that is assumed (for radiation protection purposes) to be proportional to the dose.

In 1973, the ICRP (Ref. 3) stated:

"Whilst the values proposed for maximum permis-

* Lines indicate substantive changes from previous issue.

[1] "Station personnel," as used in this guide, includes all persons working at the station, whether full-time or part-time and whether employed by the licensee or by a contractor for the licensee.

[2] Throughout this guide the word "dose" will allude to "dose equivalent," the term used for radiation protection purposes, with the unit expressed in "rems."

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Comments and suggestions for improvements in these guides are encouraged at all times, and guides will be revised, as appropriate, to accommodate comments and to reflect new information or experience. This guide was revised as a result of substantive comments received from the public and additional staff review.

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sible doses are such as to involve a risk which is small compared to the other hazards of life, nevertheless, in view of the incomplete evidence on which the values are based, coupled with the knowledge that certain radiation effects are irreversible and cumulative, it is strongly recommended that every effort be made to reduce exposure to all types of ionizing radiation to the lowest possible level."

Merely controlling the maximum dose to individuals is not sufficient; the collective dose to the group (measured in man-rems) also must be kept as low as is reasonably achievable. "Reasonably achievable" is judged by considering the state of technology and the economics of improvements in relation to all the benefits from these improvements. (However, a comprehensive consideration of risks and benefits will include risks from nonradiological hazards. An action taken to reduce radiation risks should not result in a significantly larger risk from other hazards.)

Under the linear nonthreshold concept, restricting the doses to individuals at a fraction of the applicable limit would be inappropriate if such action would result in the exposure of more persons to radiation and would increase the total man-rem dose. The radiation protection[3] community has recognized for many years that it is prudent to avoid unnecessary exposure to radiation and to maintain doses ALARA. In addition to reduced biological risks, the benefits of such practices may include avoidance of costs for extra personnel to perform maintenance activities and avoidance of nonproductive station shutdown time caused by restrictions on station personnel working in radiation areas.

Annual collective radiation dose equivalents received by personnel working at an LWR nuclear power station have ranged from less than 10 man-rems to over 5,000 man-rems (Refs. 4 and 5). Typically, annual collective dose equivalents range from 400 to 1,000 man-rems at LWR stations that have been in operation from 2 to 14 years and have generating capacities ranging from less than 100 MWe to 800 MWe. In view of the anticipated growth of nuclear power stations over the next few decades and the radiation exposure experience to date, additional efforts to reduce radiation doses to nuclear power station personnel are warranted.

The wide range in collective radiation doses to station personnel among the various stations appears to be primarily a function of doses received in maintenance operations in radiation areas. Some data are available to permit estimates of the distribution of doses among broad job categories and among the equipment systems or components that represent substantial sources of exposures. Doses to station personnel are influenced by many variables, including the ability of fuel elements to retain fission products, the extent of deposition of activated corrosion products throughout the primary and auxiliary coolant systems, the reliability of other specific equipment, the station layout, and radiation protection programs.

If design reviews or inspections had revealed that radiation exposures at nuclear power stations were unavoidable or that the cost of reducing the exposures would be unreasonable, the exposures might be considered ALARA by definition. However, this has not always been the case, and this guide is intended to assist in achieving a status wherein exposures are considered to be ALARA.

A major portion of the radiation exposure of station personnel is received during maintenance, radwaste handling, inservice inspection, refueling, and nonroutine operations (Ref. 6). The decommissioning process also has a potential for substantial exposures to personnel. Effective design of facilities and selection of equipment for systems that contain, collect, store, process, or transport radioactive material in any form will contribute to the effort to maintain radiation doses to station personnel ALARA.

Products of erosion or corrosion (i.e., "crud"[4]) that become mobile and are activated constitute an important (perhaps principal) source of radiation with respect to the exposure of station personnel. (Crud is accumulated in and transported by the coolant. Some components of the crud become radioactive when passing through the reactor core. Migration of crud to other systems occurs with coolant or steam. Specific radionuclides that have been identified in crud and that can contribute substantially to the radiation source are Co-58, Co-60, Mn-54, Zn-65, and Zr-95.)

Exposures of station personnel who service equipment contaminated by crud can generally be reduced substantially by minimizing the formation of crud and by designing or modifying equipment to minimize locations where crud can deposit and accumulate. Provisions for isolating components and flushing with crud-removing fluid such as demineralized water can often reduce accumulations prior to activities such as maintenance or equipment replacement.

Station and equipment layout also can affect the potential for radiation exposures. Exposures at sites where multiple radiation sources exist sometimes can be reduced by additional separation of individual sources. Adequate space for ease of maintenance and other operations can permit the tasks to be completed more quickly, thereby reducing the length of expo-

[3] The term "radiation protection," as used in this guide, is considered to be synonymous with the term "applied health physics"; i.e., the development and implementation of methods and procedures necessary to evaluate radiation hazards and to provide protection to man and his environment from unwarranted exposure.

[4] "Crud" is corrosion and erosion products and other solids that are formed by chemical and physical reaction between the reactor coolant and structural materials.

sures. Shielding by structural materials, equipment, and auxiliary or permanent shields can reduce exposures by isolating radiation sources. Where equipment components constitute a substantial radiation source that cannot be effectively reduced in place, features that permit the removal of such components for maintenance at remote locations often can be effective in reducing exposures. The use of remote-handling features also can reduce exposures of station personnel in certain instances.

Station technical and supervisory personnel, working closely with radiation protection personnel, can reduce exposures by planning activities of personnel who must enter radiation areas, by studying the actions and procedures of individuals working in such areas, and by conducting postoperation debriefings on projects resulting in substantial exposures to identify how procedures might be modified to reduce exposures on subsequent similar tasks. Training programs for all station personnel can establish and reinforce the principles of radiation protection as applied to specific job functions. By making personnel aware of the methods and the special equipment and protective equipment available to them, potential radiation doses can be reduced.

The concept of maintaining occupational radiation exposures ALARA does not embody a specific numerical guideline value at the present time. Rather, it is a philosophy that reflects specific objectives for radiation dose management in:

1. Establishing a program to maintain occupational radiation exposures ALARA;
2. Designing facilities and selecting equipment;
3. Establishing a radiation control program, plans, and procedures; and
4. Making supporting equipment, instrumentation, and facilities available.

When an adequate data base, including economic information, is available, the criteria for keeping annual collective doses to station personnel ALARA might be derived or selected in numerical terms. However, a data base of operating experience and cost information to provide quantitative guidance for establishing such criteria is not available at this time, and the criteria for meeting the provision of paragraph 20.1(c) of 10 CFR Part 20 must therefore take the form of qualitative guidance (e.g., goals, objectives, and statements of good practice).

The NRC staff has not performed a cost-benefit analysis for each of the considerations discussed or presented in Section C of this guide. This guide presents goals and objectives that were selected to satisfy the principles, philosophy, and criteria for maintaining occupational radiation exposures ALARA. Attaining these goals and objectives will require good engineering judgment on a case-by-case basis. A cost-benefit analysis may be helpful in arriving at the judgment, but it should not be the decisive factor in all cases.

The nuclear steam supply system (NSSS) vendor, the designer, the architect-engineer (A/E), the constructor, and the operator of the nuclear power facility each have responsibilities related to the effort of maintaining occupational radiation exposures ALARA. Thus, coordination and cooperation are essential to achieving these goals and objectives of maintaining occupational radiation exposures ALARA.

This guide is written primarily for the applicant or licensee. However, the designer, the A/E, and the constructor will find many of the guide's considerations helpful in the design and construction process to ensure that their efforts are consistent with the needs of the applicant or licensee to maintain radiation exposures ALARA.

Specific design or operational objectives for maintaining radiation exposures ALARA are suggested by the parameters that determine the magnitude of doses to station personnel, both as individuals and as a group. Doses to personnel in nuclear power stations are predominantly from external exposure, i.e., from radiation sources external to the body. However, there also exists a potential for doses from internal exposures, i.e., from radioactive materials taken into the body.

Important parameters in determining doses from external exposures are (1) the length of time that the receptor remains in the radiation field and (2) the intensity of the radiation field. Some degree of exposure of station personnel cannot be avoided during the operation and maintenance of nuclear power stations. However, there are many ways by which the exposures and resultant doses can be lowered by reducing the time interval of the exposure and the intensity of the radiation field. The intensity of the radiation field is determined by (1) the quantity of radioactive material, (2) the nature (i.e., characteristics) of the emitted radiation, (3) the nature of the shielding between the radiation source and the receptor, and (4) geometry (e.g., distances and dimensions).

Parameters important in determining doses from internal exposures are (1) the quantity of radioactive material taken into the body, (2) the nature (isotopical and body deposition characteristics) of the material, and (3) the time interval over which the material is retained by the body. The principal modes by which radioactive material can be taken into the body are (1) inhalation, (2) ingestion, (3) skin absorption, and (4) injection through wounds. At nuclear power stations, radioactive materials are generally confined, but some dispersion within the station is unavoidable and constitutes the source of (1) contaminated air and liquids that present the potential for intake by inhala-

tion and absorption and (2) contaminated surfaces that present the potential for intake by ingestion and through cuts or abrasions in the skin. Absorption generally is not an important intake mode at nuclear power stations except for tritium, which can be absorbed through the skin.

Consequently, the basic variables that can be controlled to limit doses from internal exposures are those that limit (1) the amount of contamination, (2) the dispersal of the contamination, and (3) the length of time that personnel must spend in contaminated areas. Protective equipment can keep the intake of the contaminant to a minimum. Physical and chemical methods can be used to hasten the elimination of radioactive material taken into the body; however, because of the risks associated with the use of these methods, they are reserved for very serious cases where the probability of experiencing biological effects is quite substantial, e.g., large intakes such as those that might occur in serious accident situations.

Objectives stated in this guide for maintaining occupational radiation exposures ALARA are derived by considering the parameters that affect dose, the variables that exist in the station design features, and the variables that can be provided by station administrative actions. Section C, Regulatory Position, states objectives in a manner that encourages innovation by permitting considerable flexibility on the part of the utility, the NSSS vendor, the designer, the constructor, and the A/E. However the regulatory position also describes a large number of specific concerns that should be addressed in meeting the goals and objectives.

## C. REGULATORY POSITION

The goals of the effort to maintain occupational radiation exposures ALARA are (1) to maintain the annual dose to individual station personnel as low as is reasonably achievable and (2) to keep the annual integrated (collective) dose to station personnel (i.e., the sum of annual doses (expressed in man-rems) to all station personnel) as low as is reasonably achievable.

The NRC staff believes that the stated objectives are attainable with current technology and with good operating practices. The costs for attaining these objectives have not been established and are expected to vary widely depending on the features of the specific power reactor facility and the method selected to accomplish the objectives. The favorable cost-benefit ratio for achieving some of these objectives may be obvious without a detailed study. For other objectives, however, a cost-benefit study might be required to determine whether the objectives are reasonably achievable. Doses to station personnel can affect station availability, and this factor should be considered in assessing the cost-benefit ratio.

Attaining the following objectives to the extent practicable throughout the planning, designing, constructing, operating, maintenance, and decommissioning of an LWR station will be considered to provide reasonable assurance that exposures of station personnel to radiation will be ALARA. The methods are deliberately stated such that considerable flexibility can be used in the manner by which the objectives can be achieved. Differences among stations might necessitate further innovation in methods used to achieve the objectives.

### 1. Program for Maintaining Station Personnel Radiation Doses ALARA

To attain the integrated effort needed to keep exposures of station personnel ALARA, each applicant and licensee should develop an ALARA program that reflects the efforts to be taken by the utility, nuclear steam supply system vendor, and architect-engineer to maintain radiation exposure ALARA in all phases of a station's life. This program should be in written form and should contain sections that cover the generally applicable guidance presented in this guide, as a minimum, and more specific guidance as required to address the particular LWR that is the subject of the licensing action. This program may be combined with the station's radiation protection manual, safety analysis report, or other documents or submittals. It need not be an independent document.

#### a. Establishment of a Program To Maintain Occupational Radiation Doses ALARA

(1) A management policy for, and commitment to, ensuring that the exposure of station personnel to radiation will be ALARA should be established.

(2) The policy and commitment should be reflected in written administrative procedures and instructions for operations involving potential exposures of personnel to radiation and should be reflected in station design features. Instructions to designers, constructors, vendors, and station personnel specifying or reviewing station features, systems, or equipment should reflect the goals and objectives to maintain occupational radiation exposures ALARA. (Few utilities design or build their nuclear power stations; but as *customers* of designers and builders, utilities should expect the designers and builders to be responsive to their needs and instructions.)

#### b. Organization, Personnel, and Responsibilities

(1) In view of the need for upper-level management support, responsibility and authority for implementing the program to maintain occupational radiation exposures ALARA should be assigned to an individual (or committee) with organizational freedom to ensure development and implementation. Responsibilities and authorities should include:

(a) Ensuring that a corporate program that integrates management philosophy and regulatory re-

quirements is established, with specific goals and objectives for implementation included;

(b) Ensuring that an effective measurement system is established and used to determine the degree of success achieved by station operations with regard to the program goals and specific objectives;

(c) Ensuring that the measurement system results are reviewed on a periodic basis and that corrective actions are taken when attainment of the specific objectives appears to be jeopardized;

(d) Ensuring that the authority for providing procedures and practices by which the specific goals and objectives will be achieved is delegated; and

(e) Ensuring that the resources needed to achieve goals and objectives to maintain occupational radiation exposures ALARA are made available.

In view of the responsibilities required to implement a program to maintain occupational radiation exposures ALARA, the individual (or committee) selected for this function might also be chosen to coordinate the effort among the several corporate functional groups (such as the operations, maintenance, technical support, engineering, safety, and radiation protection groups) and to represent the corporate interests in dealing with the NSSS designer, vendor, A/E, and builder during the design and construction phases. If the expertise for performing this function is not within the corporation when the station is in the design stage, consultants who possess the required expertise should be used. The utility should obtain assurance that available data and experience obtained from similar nuclear power stations are considered and reflected in the work of the NSSS designer, vendor, A/E, and builder so as to provide features in the new station that permit an effective ALARA program.

(2) The Plant Manager (Superintendent or equivalent) is responsible for all aspects of station operation, including the onsite radiation protection program.

Responsibilities of the Plant Manager with respect to a program to maintain occupational radiation exposures ALARA should include:

(a) Ensuring support from all station personnel;

(b) Participating in the selection of specific goals and objectives for the station;

(c) Supporting the onsite Radiation Protection Manager (RPM) in formulating and implementing a station program in maintaining occupational radiation exposures ALARA; and

(d) Expediting the collection and dissemination of data and information concerning the program to the corporate management.

(3) The Radiation Protection Manager (RPM) (onsite) has a safety function and responsibility to both employees and management that can be best fulfilled if the individual is independent of station divisions, such as operations, maintenance, or technical support, whose prime responsibility is continuity or improvement of station operability. The RPM should have direct recourse to responsible management personnel in order to resolve questions related to the conduct of the radiation protection program.

(The specific responsibilities given here for the RPM are illustrative and not intended to be all-inclusive with respect to the ALARA program or effort. They do not include any of the responsibilities in areas other than ALARA efforts.)

Responsibilities of the RPM with respect to a program to maintain occupational radiation exposures ALARA should include:

(a) Participating in design reviews for facilities and equipment that can affect potential radiation exposures;

(b) Identifying locations, operations, and conditions that have the potential for causing significant exposures to radiation;

(c) Initiating and implementing an exposure control program;

(d) Developing plans, procedures, and methods for keeping radiation exposures of station personnel ALARA;

(e) Reviewing, commenting on, and recommending changes in job procedures to maintain exposures ALARA;

(f) Participating in the development and approval of training programs related to work in radiation areas or involving radioactive materials;

(g) Supervising the radiation surveillance program to maintain data on exposures of and doses to station personnel, by specific job functions and type of work;

(h) Supervising the collection, analysis, and evaluation of data and information attained from radiological surveys and monitoring activities;[5]

(i) Supervising, training, and qualifying the radiation protection staff of the station; and

(j) Ensuring that adequate radiation protection coverage is provided for station personnel during all working hours.

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[5] Data collected during outages can indicate trends of radiation buildup in equipment that can permit estimates of probable radiation levels to be encountered during subsequent outages.

Qualifications[6] needed for the RPM job, as well as those needed for other positions in organizations operating nuclear power stations, are presented in Regulatory Guide 1.8, "Personnel Selection and Training."

**c. Training and Instruction**

A training program in the fundamentals of radiation protection and in station exposure control procedures should be established. It should include instructing all personnel whose duties require (1) working with radioactive materials, (2) entering radiation areas, or (3) directing the activities of others who work with radioactive materials or enter radiation areas. The training program also should include sufficient instruction in the biological effects of exposures to radiation to permit the individuals receiving the instruction to understand and evaluate the significance of radiation doses in terms of the potential risks.

The training should be commensurate with the duties and responsibilities of those receiving the instructions, as well as with the magnitude of the potential doses and dose rates that can be anticipated. Personnel (including contractor personnel) who direct the activities of others should be familiar with the licensee's radiation control program and should have the authority to implement the licensee's commitment to ensure the radiation exposures of station personnel will be ALARA.

The training program should include instruction on (1) radiation protection rules for the station and (2) the applicable Federal regulations. Copies of these rules and regulations should be made available to those receiving the instructions. The training program should be approved by the RPM and presented by competent instructors. The information presented in the training program should be reviewed periodically and modified, where necessary, to reflect contemporary techniques and adjustments based on experience in station operations. Instruction of station personnel should stress the importance of exposure-reduction efforts by every individual and should emphasize the need for feedback of information obtained when similar tasks were performed previously.

Station personnel should receive instruction at periodic intervals to reinforce their knowledge and keep it current. Station personnel whose duties do not require entering radiation areas or working with radioactive materials should receive sufficient instruction in radiation protection and station rules and regulations to understand why they should not enter such areas.

Training programs that have as their goal an increase in craft skills provide a broader base of knowledgeable station personnel available to service equipment in radiation areas and permit the services to be performed more reliably and more efficiently. This can promote lower individual and collective dose levels.

**d. Review of New or Modified Designs and Equipment Selection**

(1) Since several groups within a utility (e.g., maintenance, operations, radiation protection, technical support, engineering, and safety groups) are interested in station design and equipment selection, the utility should ensure that these groups are adequately represented in the review of the design of the facility and the selection of equipment. A coordinated effort by the several functional groups within the utility is required to ensure that station features will permit the goals and objectives of the ALARA program to be achieved. Although the A/E and designers greatly influence station design features, utilities should not delegate all responsibilities for station design review and equipment selection to the NSSS designer, vendor, or A/E.

(2) Design concepts and station features should reflect consideration of the activities of station personnel (such as maintenance, refueling, inservice inspections, processing of radioactive wastes, decontamination, and decommissioning) that might be anticipated and that might lead to personnel exposure to substantial sources of radiation. Radiation protection aspects of decommissioning should be factored into planning, designing, construction, and modification activities. Station design features should be provided to reduce the anticipated exposures of station personnel to these sources of radiation to the extent practicable.

(3) Specifications for equipment should reflect the objectives of the ALARA program, including considerations of reliability, serviceability, limitations of internal accumulations of radioactive material, and other features addressed in this guide. Specifications for replacement equipment also should reflect modifications based on experience gained from using the original equipment.

**2. Facility and Equipment Design Features**

Radiation sources within a nuclear power station differ appreciably with respect to location, intensity, and characteristics. The magnitude of the dose rates that results from these sources is dependent on many

[6] Consideration has been given to peer group certification, i.e., certification of health physicists by the American Board of Health Physics (ABHP), as representing evidence of adequate qualifications for RPM candidates. While the staff believes that peer group certification is desirable, the present ABHP certification is not necessarily specifically applicable to applied health physics or radiation protection needs in nuclear power stations. However, the staff is discussing with the ABHP the prospects for a special certification program specifically directed toward the needs of radiation protection personnel at nuclear power stations.

factors, including the facility and equipment design, layout, mode and length of operation, and radiation source strength and characteristics.

To provide a basis for design, the quantity and isotopic composition of the radioactive material that can be anticipated to be contained, deposited, or accumulated in the station equipment should be estimated. Fission product source terms should be estimated using these bases: (1) an offgas rate of 100,000 $\mu$Ci/sec after 30 minutes delay for BWRs and (2) 0.25% fuel cladding defects for PWRs. Activation source terms, including activated corrosion products, should be based on measurements and experience gained from operating stations of similar design. ANSI N237-1976 (Ref. 7) is based on such experience and provides information that can be used as a basis for estimating activation source terms. When operating measurements are used, extrapolation of data to equilibrium conditions may be needed to estimate ultimate activation source terms. Neutron and prompt gamma source terms should be based on applicable operating experience and reactor core physics calculations.

ALARA program objectives are presented below for each of several station features or functions. Each statement of objective is followed by a number of specific concerns or suggestions that should be addressed.

**a. Access Control of Radiation Areas**

To avoid unnecessary and inadvertent exposures of personnel to radiation, the magnitude of the potential dose rates at all locations within the station should be estimated during station design. Actual dose rates should be measured periodically during operation to determine current exposure potentials. Zones associated with the higher dose rates should be kept as small as reasonably achievable consistent with accessibility for accomplishing the services that must be performed in those zones, including equipment laydown requirements. Radiation zones where station personnel spend substantial time should be designed to the lowest practical dose rates.

(It is common practice to identify "radiation zones" within a nuclear power station. The zone designations are established to reflect the design maximum dose rates that may exist in areas within the station where station personnel must have access to perform required services. Several systems for designating "radiation zones" currently exist among the utilities, and ANSI Committee 6.7 is developing a standard that should prove useful in attaining common designations and terminology in this matter. To avoid ambiguity, no reference to radiation zone numbers is made in this guide at this time.)

A system should be established to permit effective control over personnel access to the radiation areas and control over the movement of sources of radiation within the station. Where high radiation areas (>100 mrem/h) exist, § 20.203 of 10 CFR Part 20 requires that station design features and administrative controls provide effective ingress control, ease of egress, and appropriate warning devices and notices. Access control of radiation areas also should reflect the following considerations:

(1) Extraordinary design features are warranted to avoid any potential dose to personnel that is large enough to cause acute biological effects and that could be received in a short period of time. Positive control of ingress to such areas, permanent shielding, source removal, or combinations of these alternatives can reduce the dose potential.

(2) Administrative controls such as standard operating procedures can be effective in preventing inadvertent exposures of personnel and the spread of contamination when radioactive material or contaminated equipment must be transported from one station location to another and when the route of transport through lower radiation zones or "clean" areas cannot be avoided.

(3) Station features such as platforms or walkways, stairs, or ladders that permit prompt accessibility for servicing or inspection of components located in higher radiation zones can reduce exposure of personnel who must perform these services.

**b. Radiation Shields and Geometry**

Radiation shields should be designed using the design basis assumptions explained in regulatory position 2 and conservative assumptions for geometries. Calculational methods known to provide reliable and accurate results (i.e., methods and modeling techniques that have been demonstrated to give acceptable accuracy in analyses similar to the problem of concern) should be used to determine appropriate shield thicknesses. Shield design features should reflect the following considerations to maintain occupational radiation exposures ALARA:

(1) Exposure of personnel servicing a specific component (such as a pump, filter, or valve) to radiation from other components containing radioactive material can be reduced by providing shielding between the individual components that constitute substantial radiation sources and the receptor.

(2) Where it is impracticable to provide permanent shielding for individual components that constitute substantial radiation sources, the exposure of personnel maintaining such components can be reduced (a) by providing as much distance as practicable between the serviceable components and the substantial radiation sources in the area and (b) by providing temporary shields around components that contribute substantially to the dose rate.

(3) Potential exposure of station personnel to radiation from certain systems containing radiation sources can be reduced by means of a station layout that permits the use of distance and shielding between the sources and work locations. These systems include (but are not limited to) the NSSS and the reactor water cleanup, offgas treatment, solid waste treatment, and storage systems, as well as systems infrequently containing radiation sources such as the standby gas treatment and residual heat removal systems.

Radiation from an operating BWR turbine can constitute a substantial source of exposure for construction personnel or others who have access to the site for extended periods of time if insufficient shielding is provided.

(4) Streaming or scattering of radiation from locally shielded components (such as cubicles) can be reduced by providing labyrinths for access. However, such labyrinths or other design features of the cubicle should permit the components to be removed readily from the cubicle for repair or replacement where such work is expected or anticipated. Single-scatter labyrinths may be inadequate if the cubicle contains a substantial radiation source.

(5) Streaming of radiation into accessible areas through penetrations for pipes, ducts, and other shield discontinuities can be reduced (a) by means of layouts that prevent substantial radiation sources within the shield from being aligned with the penetrations or (b) by using "shadow" shields such as shields of limited size that attenuate the direct radiation component. Streaming also can occur through roofs or floors unless adequate shielding encloses the source from all directions.

(6) The exposure of station personnel to radiation from pipes carrying radioactive material can be reduced by means of shielded chases.

(7) Design features that permit the rapid removal and reassembly of shielding, insulation, and other material from equipment that must be inspected or serviced periodically can reduce the exposure of station personnel performing these activities.

(8) Space within cubicles and other shielding to provide laydown space for special tools and ease of servicing activities can reduce potential doses by permitting the services to be accomplished expeditiously, thus reducing exposure time.

(9) The exposure of personnel who service components that constitute substantial radiation sources or are located in high radiation fields can be minimized by removing the components and transporting them to low radiation zones where shielding and special tools are available. Design features that permit the prompt removal and installation of these components can reduce the exposure time.

(10) Floor and equipment drains, piping, and sumps that are provided to collect and route any contaminated liquids that might leak or be spilled from process equipment or sampling stations can become substantial radiation sources. The drain lines can be located in concrete floors, concrete ducts, columns, or radwaste pipe chases to provide shielding. These systems can also become a source of airborne contamination because of the potential for gases to form in, and be released by, such systems (see regulatory position 2.d(6)).

**c. Process Instrumentation and Controls**

Appropriate station layout and design features should be provided to reduce the potential doses to personnel who must operate, service, or inspect station instrumentation and controls. The following considerations should be reflected in selecting the station features:

(1) The exposure of personnel who must manually operate valves or controls can be reduced through the use of "reach rods" or remotely operated valves or controls. However, these devices can require lubrication and maintenance that can be the source of additional exposures, and these factors should be taken into consideration.

(2) The exposure of personnel who must view or operate instrumentation, monitors, and controls can be reduced by locating the readouts or control points in low radiation zones.

(3) Instrumentation must satisfy functional requirements, but the exposure of personnel can be reduced if the instruments are designed, selected, specified, and located with consideration for long service life, ease and low frequency of maintenance and calibration, and low crud accumulation. Operating experience should be recorded, evaluated, and reflected in the selection of replacement instrumentation.

(4) The use of instrumentation that contains minimal quantities of contaminated working fluid (e.g., pressure transducers rather than bellows-type pressure gauges) can reduce the potential for exposure at the readout locations.

**d. Control of Airborne Contaminants and Gaseous Radiation Sources**

Station design features should be provided in all station work areas to limit the average concentrations of radioactive material in air to levels well below the values listed in Appendix B, Table 1, Column 1 of 10 CFR Part 20. Effective design features can minimize the occurrence of occasional increases in air contamination and the concentrations and amounts of contaminants associated with any such occasional increases. Designs that permit repeated, identified releases of large amounts of radioactive materials into the air

spaces occupied by personnel are contrary to a program to maintain occupational radiation exposures ALARA.

Station design features should provide for protection against airborne radioactive material by means of engineering controls such as process, containment, and ventilation equipment. The routine provision of respiratory protection by use of individually worn respirators rather than engineered design features is generally unacceptable. The use of respirators, however, might be appropriate in certain nonroutine or emergency operations when the application of engineering controls is not feasible or while such controls are being installed.

The approved use of respirators is subject to the requirements of § 20.103, "Exposure of Individuals to Concentrations of Radioactive Materials in Air in Restricted Areas," of 10 CFR Part 20 and to regulatory guidance on acceptable use. (See Regulatory Guide 8.15, "Acceptable Programs for Respiratory Protection," and NUREG-0041, "Manual of Respiratory Protection Against Airborne Radioactive Materials" (Ref. 8).) Design features of the station ventilation system and gaseous radwaste processing systems should reflect the following considerations:

(1) The spread of airborne contamination within the station can be limited by maintaining air pressure gradients and airflows from areas of low potential airborne contamination to areas of higher potential contamination. Periodic checks would ensure that the design pressure differentials are being maintained.

(2) Effectively designed ventilation systems and gaseous radwaste treatment systems will contain radioactive material that has been deposited, collected, stored, or transported within or by the systems. Exposures of station personnel to radiation and to contamination from ventilation or gaseous radwaste treatment components occur as a result of the need to service, test, inspect, decontaminate, and replace components of the systems or perform other duties near these systems. Potential doses from these systems can be minimized by providing ready access to the systems, by providing space to permit the activities to be accomplished expeditiously, by separating filter banks and components to reduce exposures to radiation from adjacent banks and components, and by providing sufficient space to accomodate auxiliary ventilation or shielding of components.

(3) Auxiliary ventilation systems that augment the permanent system can provide local control of airborne contaminants when equipment containing potential airborne sources is opened to the atmosphere. Two types of auxiliary ventilation systems have proved to be effective. In areas where contaminated equipment must be opened frequently, dampers and fittings can be provided in ventilation ducts to permit the attachment of flexible tubing or "elephant trunks" without imbalancing the ventilation system. In areas where contaminated equipment must be opened infrequently, portable auxiliary ventilation systems featuring blowers, HEPA filters, and activated charcoal filters (where radioiodine might be anticipated) on carts can be used effectively. Portable auxiliary ventilation systems should be tested frequently to verify the efficiency of the filter elements in their mountings. When the efficiency has been verified, the system may be exhausted to the room or the ventilation exhaust duct without further treatment and thus imbalance of the permanent ventilation system can be avoided.

(4) Machining of contaminated surfaces (e.g., welding, grinding, sanding, or scaling) or "plugging" of leaking steam generator or condenser tubes can be substantial sources of airborne contamination. These sources can be controlled by using auxiliary ventilation systems.

(5) Sampling stations for primary coolant or other fluids containing high levels of radioactive material can constitute substantial sources of airborne contamination. Such sources can be controlled by using auxiliary ventilation systems.

(6) Wet transfer or storage of potentially contaminated components will minimize air contamination. This can be accomplished by keeping contaminated surfaces wet, by spraying, or, preferably, by keeping such surfaces under water.

**e. Crud Control**

Design features of the primary coolant system, the selection of construction materials that will be in contact with the primary coolant, and features of equipment that treat primary coolant should reflect considerations that will reduce the production and accumulation of crud in stations where it can cause high exposure levels. The following items should be considered in the crud control effort:

(1) Production of Co-58 and Co-60, which constitute substantial radiation sources in crud, can be reduced by specifying, to the extent practicable, low-nickel and low-cobalt bearing materials for primary coolant pipe, tubing, vessel internal surfaces, heat exchangers, wear materials, and other components that are in contact with primary coolant. Alternative materials for hard facings of wear materials of high-cobalt content should be considered where it is shown that these high-cobalt materials contribute to the overall exposure levels. Such consideration should also take into account potential increased service/repair requirements and overall reliability of the new material in relation to the old. Alternative materials for high-nickel alloy materials (e.g., Inconel 600) should be considered where it is shown that these materials contribute to overall exposure levels. Such consideration should also take into account potential increased

service/repair requirements and overall reliability of the new materials in relation to the old.

(2) Loss of material by erosion of load-bearing hard facings can be reduced by using favorable geometrics and lubricants, where practicable, and by using controlled leakage purge across journal sleeves to avoid entry of particles into the primary coolant.

(3) Loss of material by corrosion can be reduced by continuously monitoring and adjusting oxygen concentration and pH in primary coolant above 250°F and by using bright hydrogen-annealed tubing and piping in the primary coolant and feedwater systems.

(4) Consideration should be given to cleanup systems (e.g., using graphite or magnetic filters) for removal of crud from the primary coolant during operation.

(5) Deposition of crud within the primary coolant system can be reduced by providing laminar flow and smooth surfaces for coolant and by minimizing crud traps in the system to the extent practicable.

**f. Isolation and Decontamination**

Potential doses to station personnel who must service equipment containing radioactive sources can be reduced by removing such sources from the equipment (decontamination), to the extent practicable, prior to servicing. Serviceable systems and components that constitute a substantial radiation source should be designed, to the extent practicable, with features that permit isolation and decontamination. Station design features should consider, to the extent practicable, the ultimate decommissioning of the facility and the following concerns:

(1) The necessity for decontamination can be reduced by limiting, to the extent practicable, the deposition of radioactive material within the processing equipment—particularly in the "dead spaces" or "traps" in components where substantial accumulations can occur. The deposition of radioactive material in piping can be reduced and decontamination efforts enhanced by avoiding stagnant legs, by locating connections above the pipe centerline, by using sloping rather than horizontal runs, and by providing drains at low points in the system.

(2) The need to decontaminate equipment and station areas can be reduced by taking measures that will reduce the probability of release, reduce the amount released, and reduce the spread of the contaminant from the source (e.g., from systems or components that must be opened for service or replacement). Such measures can include auxiliary ventilation systems (see regulatory position 4.b), treatment of the exhaust from vents and overflows (see regulatory position 2.h(8)), drainage control such as curbing and floors sloping to local drains, or sumps to limit the spread of contamination from leakage of liquid systems.

(3) Accumulations of crud or other radioactive material that cannot be avoided within components or systems can be reduced by providing features that will permit the recirculation or flushing of fluids with the capacity to remove the radioactive material through chemical or physical action. The fluids containing the contaminants will require treatment, and this source should be considered in sizing station radwaste treatment systems.

(4) Continuity in the functioning of processing or ventilation systems that are important for controlling potential doses to station personnel can be provided during servicing of the systems if redundant components or systems are available so that the component (with associated piping) being serviced can be isolated.

(5) The potential for contamination of "clean services" (such as station service air, nitrogen, or water supply) from leakage from adjacent systems containing contaminants can be reduced by separating piping for these services from piping that contains radioactive sources. Piping that carries radioactive sources can be designed for the lifetime of the station, thus avoiding the necessity for replacement (and attendant exposures) and lessening the potential for contamination of clean services if it is impracticable to provide isolation through separate chases.

(6) Surfaces can be decontaminated more expeditiously if they are smooth, nonporous, and free of cracks, crevices, and sharp corners. These desirable features can be realized by specifying appropriate design instructions, by giving attention to finishing work during construction or manufacture, and by using sealers (such as special paints) on surfaces where contamination can be anticipated. (ANSI N101.2 provides helpful guidance on this matter (Ref. 9).)

(7) Where successful decontamination of important systems could be prevented by an anticipated failure of a critical component or feature, additional features that permit alternative decontamination actions can be provided.

(8) Contaminated water and deposited residues in spent fuel storage pools contribute to the exposure at accessible locations in the area. Treatment systems that remove contaminants from the water can perform more efficiently (a) if intake and discharge points for the treatment systems are located to provide enhanced mixing and to avoid stagnation areas in the pool and (b) if pool water overflows and skimmer tanks are provided. Fluid jet or vacuum-cleaner-type agitators can help reduce the settling of crud on surfaces of the pool system.

**g. Radiation Monitoring Systems**

Central or "built-in" monitoring systems that give information on the dose rate and concentration of airborne radioactive material in selected station areas can reduce the exposure of station personnel who would be required to enter the areas to obtain the data if such systems were not provided. These systems also can provide timely information regarding changes in the dose rate or concentrations of airborne radioactive material in the areas. (The installation of a central monitoring system is easier and less expensive if it is a part of the original station design.) The selection or design and installation of a central monitoring system should include consideration of the following desirable features:

(1) Readout capability at the main radiation protection access control point;

(2) Placement of detectors for optimum coverage of areas (Ref. 10);

(3) Circuitry that indicates component failure;

(4) Local alarm and readout;

(5) Clear and unambiguous readout;

(6) Ranges adequate to ensure readout of the highest anticipated radiation levels and to ensure positive readout at the lowest anticipated levels; and

(7) Capability to record the readout of all systems.

**h. Resin and Sludge Treatment Systems**

Systems used to transport, store, or process resins or slurries of filter sludge present a special hazard because of the concentrated nature of the radioactive material. Design features for resin- and sludge-handling systems should reflect this concern and the following specific considerations:

(1) The accumulation of radioactive material in components of systems used to process resin and sludges can be reduced by:

(a) Reducing the length of piping runs;

(b) Using larger diameter piping (to minimize plugging);

(c) Reducing the number of pipe fittings;

(d) Avoiding low points and dead legs in piping;

(e) Using gravitational flow to the extent practicable; and

(f) Minimizing flow restrictions of processed material.

(2) The need for maintenance and the presence of intense local radiation sources can be reduced by:

(a) Using full-ported valves constructed such that the slurry will not interfere with the opening or closing of the valve and

(b) Avoiding cavities in valves.

(3) The deposition of resin and sludge that would occur if elbow fittings were used can be reduced by using pipe bends of at least five pipe diameters in radius. Where pipe bends cannot be used, long radius elbows are preferred.

(4) Smoother interior pipe surfaces at connections (with attendant reductions in friction losses, deposition of material, and tendencies to "plug") can be achieved by using butt welds rather than socket welds and by using consumable inserts rather than backing rings.

(5) Where the use of tees cannot be avoided, line losses can be reduced if the flow is through the run (straight section) of the tee, and accumulations of material in the branch of the tee can be reduced by orienting the branch horizontally or (preferably) above the run.

(6) Slurry piping is subject to plugging that may require backflushing from the tank and equipment isolation valves and pressurizing with water, nitrogen, or air to "blow out" plugged lines. However, the use of pressurized gas for blowing out lines can present a potential contamination source and may not be effective in relieving plugged lines.

(7) Water, air, or nitrogen for sparging can be used to fluidize resins or sludges in storage tanks. The use of gases, however, presents a potential source of airborne contamination and tank rupture from overpressures.

(8) The spread of contamination by the loss of resin or sludge through overflows and vents can be reduced by using screens, filters, or other features that will collect and retain solids. However, such features generally require cleaning by remote flushing, by rapid replacement, or by other means to reduce exposures during servicing.

Consideration should be given to ANS N197, "Design and Performance of BWR Liquid Radioactive Waste Processing Systems (N18)" (Ref. 11); ANS 55.1, "Design Criteria for the Solid Radwaste Processing System of BWR, PWR, and HTGR" (Ref. 12); and ANS N199, "PWR Liquid Waste System Design (N18)" (Ref. 13). These standards cover some aspects of slurry systems.

**i. Other Features**

Station layout and station tasks should be reviewed to identify and provide special features that complement the ALARA program. Station design should reflect consideration of the following concerns:

(1) The selection of radiation-damage-resistant materials for use in high radiation areas can reduce the need for frequent replacement and can reduce the probability of contamination from leakage.

(2) The use of stainless steel for constructing or lining components, where it is compatible with the process, can reduce corrosion and can provide options for decontamination methods.

(3) Field-run piping that carries radioactive material can cause unnecessary exposures unless due consideration is given to the routing. Such unnecessary exposures can be avoided if the routing is accomplished under the cognizance of an individual familiar with the principles of radiation protection or if a detailed piping layout is provided, i.e., if the piping is not field-run.

(4) Where filters or other serviceable components can constitute substantial radiation sources, exposures can be reduced by providing features that permit operators to avoid the direct radiation beam and that provide remote removal, installation, or servicing. Standardization of filters should be considered.

(5) The servicing of valves can be a substantial source of doses to station personnel. These doses can be reduced by providing adequate working space for easy accessibility and by locating the valves in areas that are not in high radiation fields.

(6) Leakage of contaminated coolant from the primary system can be reduced by using live-loaded valve packings and bellow seals.

(7) Potential doses from servicing valves and from leakage can be reduced by specifying and installing reliable valves for the required service, by using radiation-damage-resistant seals and gaskets, and by using valve back seats. The use of straight-through valve configurations can avoid the buildup of accumulations in internal crevices and the discontinuities that exist in valves of other configurations. In most cases, valves can be installed in the "stem-up" orientation to facilitate maintenance and to minimize crud traps. The desired features are reliability, good performance, and the ability to be maintained infrequently and rapidly.

(8) Leaks from pumps can be reduced by using canned pumps where they are compatible with the service needs, provided that lower personnel exposures can be achieved thereby. If mechanical seals are used on a pump in a slurry service, features that permit the use of flush water to clean pump seals can reduce the accumulation of radioactive material in the seals. Drains on pump housings can reduce the radiation field from this source during servicing. Provision for the collection of such leakage or disposal to a drain sump is appropriate.

(9) The sources of radiation such as sedimentation that occurs in tanks used to process liquids containing radioactive material and residual liquids can be reduced when servicing by draining the tanks. The design can include sloping the tank bottoms toward outlets leading to other reprocessing equipment and, where practicable, providing built-in spray or surge features.

(10) Spare connections on tanks or other components located in higher radiation zones may be desirable to provide flexibility in operations. Exposures of personnel can be avoided if these connections are provided as a part of the original equipment rather than by subsequent modification of the equipment in the presence of radiation.

(11) Inspections to satisfy the ASME Code (Ref. 14) and regulatory requirements can result in exposures of station personnel to radiation. Many of the objectives presented above will aid in reducing potential exposures to personnel who perform the required inspections. Station features and design should, to the extent practicable, permit inspections to be accomplished expeditiously and with minimal exposure of personnel. The effort to maintain occupational radiation exposures ALARA can also be aided by prompt accessibility, shielding and insulation that can be quickly removed and reinstalled, and special tools and instruments that reduce exposure time or permit remote inspection of components or equipment containing potential radiation sources.

(12) Components can be removed from processing systems more expeditiously if adequate space is provided in the layout of the system and if the interconnections permit prompt disconnects.

(13) Station features that provide a favorable working environment such as adequate lighting, ventilation, working space, and accessibility (via such means as working platforms, cat walks, and fixed ladders) can promote work efficiency.

(14) The exposure of station personnel who must replace lamps in high radiation areas can be reduced by using extended service lamps and by providing design features that permit the servicing of the lamps from lower radiation areas.

(15) An adequate emergency lighting system can reduce potential exposures of station personnel by permitting prompt egress from high radiation areas if the station lighting system fails.

### 3. Radiation Protection Program

A substantial portion of the radiation dose to station personnel is received while they are performing services such as maintenance, refueling, and inspection in high radiation areas. The objectives that were presented in regulatory position 2 can provide station design features conducive to an effective program to

maintain occupational radiation exposures ALARA. However, an effective program also requires station operational considerations in terms of procedures, job planning, recordkeeping, special equipment, operating philosophy, and other support. This section deals with the manner in which the station administrative efforts can influence the variables of (1) the number of persons who must enter high radiation areas or contaminated areas, (2) the period of time the persons must remain in these areas, and (3) the magnitude of the potential dose.

**a. Preparation and Planning**

Before entering radiation areas where significant doses could be received, station personnel should have the benefit of preparations and plans that can ensure the exposures are ALARA while the personnel are performing the services. Preparations and plans should reflect the following considerations:

(1) A staff member who is a specialist in radiation protection can be assigned the responsibility for contributing to and coordinating ALARA efforts in support of operations that could result in substantial individual and collective dose levels.

(2) To provide the bases for planning the activity, surveys can be performed to ascertain information with respect to radiation, contamination, airborne radioactive material, and mechanical difficulties that might be encountered while performing services.

(3) Radiation surveys provided in conjunction with inspections or other activities can define the nature of the radiation fields and identify favorable locations where personnel may take advantage of available shielding, distance, geometry, and other factors that affect the magnitude of the dose rate or the portions of the body exposed to the radiation.

(4) Photographs of "as installed" equipment or components can be valuable for planning purposes and can be augmented by additional photos taken during the surveys. The use of portable TV cameras with taping features has considerable merit as both an operational aid and a teaching aid.

(5) The existing radiation levels frequently can be reduced by draining, flushing, or other decontamination methods or by removing and transporting the component to a lower radiation zone. An estimate of the potential doses to station personnel expected to result from these procedures is germane in selecting among alternative actions.

(6) A preoperational briefing for personnel who will perform services in a high radiation area can ensure that service personnel understand the tasks about to be performed, the information to be disseminated, and the special instructions to be presented.

(7) A program can be implemented to provide access control and to limit exposures to those persons needed to perform the required services in the radiation areas. Such a program would address conditions that require a special work permit or other special procedures.

(8) A work permit form with an appropriate format can be useful for recording pertinent information concerning tasks to be performed in high radiation areas so that the information is amenable to cross-referencing and statistical analysis. Information of interest would include the following items:

(a) Designation of services to be performed on specific components, equipment, or systems;

(b) Number and identification of personnel working on the tasks;

(c) Anticipated radiation, airborne radioactive material, and contamination levels, based on current surveys of the work areas, and date of survey;

(d) Monitoring requirements such as continuous air monitoring or sampling equipment;

(e) Estimated exposure time required to complete the tasks and the estimated doses anticipated from the exposure;

(f) Special instructions and equipment to minimize the exposures of personnel to radiation and contamination;

(g) Protective clothing and equipment requirements;

(h) Personnel dosimetry requirements;

(i) Authorization to perform the tasks; and

(j) Actual exposure time, doses, and other information obtained during the operation.

(9) Consideration of potential accident situations or unusual occurrences (such as gross contamination leakage, pressure surges, fires, cuts, punctures, or wounds) and contingency planning can reduce the potential for such occurrences and enhance the capability for coping with the situations expeditiously if they occur.

(10) Portable or temporary shielding can reduce dose rate levels near "hot spots" and in the general area where the work is to be performed.

(11) Portable or temporary ventilation systems or contamination enclosures and expendable floor coverings can control the spread of contamination and limit the intake by workers through inhalation.

(12) "Dry runs" on mockup equipment can be useful for training personnel, identifying problems that can be encountered in the actual task situation, and selecting and qualifying special tools and procedures to reduce potential exposures of station personnel.

(13) Adequate auxiliary lighting and a comfortable environment (e.g., vortex tube coolers for supplied air suits) can increase the efficiency of the work and thus reduce the time spent in the higher radiation zones.

(14) Radiation monitoring instruments selected and made available in adequate quantities can permit accurate measurements and rapid evaluations of the radiation and contamination levels and changes in levels when they occur. Routine calibration of instruments with appropriate sources and testing can ensure operability and accuracy of measurements.

(15) Performing work on some components inside disposable tents or, for less complicated jobs, inside commercially available disposable clear plastic glove bags can limit the spread of contamination. Such measures can also avoid unnecessary doses resulting from the need to decontaminate areas to permit personnel access or to allow for entry with less restrictive protective clothing and equipment requirements.

(16) Careful scheduling of inspections and other tasks in high radiation areas can reduce exposures by permitting decay of radiation sources during the reactor shutdown period and by eliminating some repetitive surveys. Data from surveys and experience attained in previous operations and current survey data can be factored into the scheduling of specific tasks.

**b. Operations**

During operations in radiation areas, adequate supervision and radiation protection surveillance should be provided to ensure that the appropriate procedures are followed, that planned precautions are observed, and that all potential radiation hazards that might develop or that might be recognized during the operation are addressed in a timely and appropriate manner.

(1) Assigning a health physics (i.e., radiation safety or radiation protection) technician the responsibility for providing radiation protection surveillance for each shift operating crew can help ensure adequate radiation protection surveillance.

(2) Personnel monitoring equipment such as direct-reading dosimeters, alarming dosimeters, and personal dose rate meters can be used to provide early evaluation of doses to individuals and the assignment of those doses to specific operations (see Regulatory Guides 1.16, "Reporting of Operating Information—Appendix A Technical Specifications," and 8.4, "Direct-Reading and Indirect-Reading Pocket Dosimeters").

(3) Communication systems between personnel in high radiation zones and personnel who are monitoring the operation in other locations can permit timely exchanges of information and avoid unnecessary exposures to monitoring personnel.

**c. Postoperations**

Observations, experience, and data obtained during nonroutine operations in high radiation zones should be ascertained, recorded, and analyzed to identify deficiencies in the program and to provide the bases for revising procedures, modifying features, or making other adjustments that may reduce exposures during subsequent similar operations.

(1) Formal or informal postoperation debriefings of station personnel performing the services can provide valuable information concerning shortcomings in preoperational briefings, planning, procedures, special tools, and other factors that contributed to the cause of doses received during the operation.

(2) Dose data obtained during or subsequent to an operation can be recorded in a preselected manner as part of a "Radiation Work Permit" or similar program [see regulatory position 3.a(8)] so that the data are amenable to statistical analyses.

(3) Information concerning the cause of component failures that resulted in the need for servicing in high radiation areas can provide a basis for revising specifications on replacement equipment or for other modifications that can improve the component reliability. Such improvements can reduce the frequency of servicing and thus reduce attendant exposures.

(4) Information gained in operations can provide a basis for modifying equipment selection and design features of new facilities.

(5) Summaries of doses received by each category of maintenance activity can be reviewed periodically by upper management to compare the incremental reduction of doses with the cost of station modifications that could be made.

**4. Radiation Protection Facilities, Instrumentation, and Equipment**

A radiation protection staff with facilities, instrumentation, and protective equipment adequate to permit the staff to function efficiently is an important element in achieving an effective program to maintain occupational radiation exposures ALARA. The selection of instrumentation and other equipment and the quantities of such equipment provided for normal station operations should be adequate to meet the anticipated needs of the station during normal operations and during major outages that may require supplemental workers and extensive work in high radiation areas. (Accident situations are not considered in this guide.) Station design features and provisions should reflect the following considerations:

**a. Counting Room**

A low-radiation background counting room is needed to perform routine analyses on station samples containing radioactive material collected from air, wa-

ter, surfaces, and other sources. An adequately equipped counting room would include:

(1) Multichannel gamma pulse height analyzer (Regulatory Guide 5.9, "Specifications for Ge(Li) Spectroscopy Systems for Material Protection Measurements—Part 1: Data Acquisition Systems," provides guidance for selecting Ge(Li) spectroscopy systems);

(2) Low-background alpha-beta radiation proportional counter(s) or scintillation counter(s);

(3) End-window Geiger-Muller (G-M) counter(s); and

(4) A liquid scintillation counter for tritium analyses. Analyses of bioassay and environmental samples and whole-body counting (see Regulatory Guide 8.9, "Acceptable Concepts, Models, Equations, and Assumptions for a Bioassay Program") call for additional equipment and laboratory space if the analyses are performed by station personnel rather than by other specialists through contractual arrangements.

**b. Portable Instruments**

Portable instruments needed for measuring dose rates and radiation characteristics would include:

(1) Low-range (nominally 0 to 5 R per hour) ion chambers or G-M rate meters;

(2) High-range (0.1 to at least 500 R per hour) ion chambers;[7]

(3) Alpha scintillation or proportional count rate meters;

(4) Neutron dose equivalent rate meters;

(5) Air samplers for short-term use with particulate filters and iodine collection devices (such as activated charcoal cartridges); and

(6) Air monitors with continuous readout features.[7]

**c. Personnel Monitoring Instrumentation**

Personnel monitoring instrumentation selection should include consideration of:

(1) G-M 'Friskers" for detecting low levels of radioactive material;

(2) Direct-reading low-range (0 to 200 mR) and intermediate-range (0 to 1000 mR) pocket dosimeters (see Regulatory Guide 8.4);

(3) Alarm dosimeters;

(4) Film badges and/or thermoluminescent dosimeters (TLD);

(5) Hand and foot monitors; and

(6) Portal monitors.

**d. Protective Equipment**

Utility-supplied protective equipment selection should include consideration of :

(1) Anticontamination clothing and equipment that meet the requirements of ANSI Z-88.2 (Ref. 15) for use in atmospheres containing radioactive materials or the National Institute of Occupational Safety and Health's (NIOSH) "Certified Personal Protective Equipment List," and current supplements from DHEW/PHS (Ref. 16).

(2) Respiratory protective equipment, including a respirator fitting program that satisfies the guidance of Regulatory Guide 8.15 and NUREG-0041 (Ref. 8).

**e. Support Facilities**

Design features of radiation protection support facilities should include consideration of:

(1) A portable-instrument calibration area designed and located such that radiation in the calibration area will not interfere with low-level monitoring or counting systems;

(2) Personnel decontamination area (this facility should be located and designed to expedite rapid cleanup of personnel and should not be used as a multiple-purpose area or share ventilation with food-handling areas) with showers, basins, and installed "frisker" equipment;

(3) Facilities and equipment to clean, repair, and decontaminate personnel protective equipment, monitoring instruments, hand tools, electromechanical parts, or other material (highly contaminated tools or other equipment should not be decontaminated in the area used to clean respiratory equipment);

(4) Change rooms that (preferably) connect with the personnel decontamination area and a control station area equipped with sufficient lockers to accommodate permanent and contract maintenance workers who may be required during major outages;

(5) Control stations for entrance or exit of personnel into radiation- and contamination-controlled access areas of the station such as the personnel entrance to the containment buildings and the main entrance to the radwaste processing areas; these control stations also may be used as the control point for radioactive material movements throughout the station and for the storage of portable radiation survey equipment, signs, ropes, and respiratory protective equipment;

(6) Equipment to facilitate communication between all areas throughout the station; and

(7) Sufficient office space to accommodate the temporary and permanent radiation protection staff, permanent records, and technical literature.

[7] Variable alarm setpoint features on these instruments can be valuable in providing a warning when unexpected substantial changes in dose rate or air concentration occur.

## D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

This guide reflects current NRC staff practice in license application reviews. Therefore, except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the methods described herein are being and will continue to be used in the evaluation of submittals for construction permits and operating license applications until this guide is revised as a result of suggestions from the public or additional staff review.

At the operating license review stage, the radiation protection design presented in the applicant's final safety analysis report will be reviewed against regulatory position 2 of this guide and differences from the recommendations of the guide will be identified (particularly for plants designed before Regulatory Guide 8.8 was issued). However, no substantive design changes will be required at the operating license stage unless the design change can prevent substantial man-rem exposures that cannot be prevented by procedural measures and the design change is consistent with the cost-effectiveness principle of maintaining occupational radiation exposures ALARA.

Methods other than those set forth in this guide may be substituted for those stated herein, provided they satisfy the criterion "as low as is reasonably achievable" of paragraph 20.1(c) of 10 CFR Part 20.

## REFERENCES


1. Ad Hoc Committee of the National Council on Radiation Protection and Measurements, "Somatic Radiation Dose for the General Population," Science 131, 482 (1960).

2. "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," National Academy of Sciences/National Research Council, DHEW Contract PH-43-64-44, November 1972.

3. International Commission on Radiological Protection (ICRP), "Implications of Commission Recommendations That Doses Be Kept As Low As Readily Achievable," ICRP Publication 22, Pergamon Press, 1973. Copies may be obtained from Pergamon Press, Maxwell House, Fairview Park, Elmsford, New York 10523.

4. C. A. Pelletier et al., "Compilation and Analysis of Data on Occupational Radiation Exposure Experienced at Operating Nuclear Power Plants," Atomic Industrial Forum, 1974.

5. T. D. Murphy, N. J. Dayem, J. Stewart Bland, and W. J. Pasciak, "Occupational Radiation Exposure at Light-Water-Cooled Power Reactors, 1969-1975," NUREG-0109, U.S. Nuclear Regulatory Commission, August 1976. Copies may be obtained from the National Technical Information Service, Springfield, Va. 22161.

6. NUREG-0322, "Ninth Annual Occupational Radiation Exposure Report, 1976." Copies may be obtained from the National Technical Information Service, Springfield, Va. 22161.

7. ANSI N237, "Source Term Specification." Copies may be obtained from the American Nuclear Society, 555 North Kensington Avenue, La Grange Park, Illinois 60525.

8. Copies of NUREG-0041 may be obtained from the National Technical Information Service, Springfield, Va. 22161.

9. ANSI N101.2, "Protective Coatings (Paints) for Light Water Nuclear Reactor Containment Facilities." Copies may be obtained from the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

10. ANS/HPS 56.8, "Location and Design Criteria for Area Radiation Monitoring Systems for LWRs," (draft).

11. ANS N197, "Design and Performance of BWR Liquid Radioactive Waste Processing Systems (N18)." Copies may be obtained from the American Nuclear Society, 555 North Kensington Avenue, La Grange Park, Illinois 60525.

12. ANS 55.1, "Design Criteria for the Solid Radwaste Processing System of BWR, PWR, and HTGR." Copies may be obtained from the American Nuclear Society, 555 North Kensington Avenue, La Grange Park, Illinois 60525.

13. ANS N199, "PWR Liquid Waste System Design (N18)." Copies may be obtained from the American Nuclear Society, 555 North Kensington Avenue, La Grange Park, Illinois 60525.

14. Section XI, ASME Boiler and Pressure Vessel Code and Addenda. Copies may be obtained from the American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N.Y. 10017.

15. ANSI Z-88.2, "Practices for Respiratory Protection." Copies may be obtained from the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

16. NIOSH, "Certified Personal Protective Equipment List," July 1974, and supplements by DHEW/PHS. Published by U.S. Department of Health, Education, and Welfare, Public Health Service, Center of Disease Control, National Institute of Occupational Safety and Health. Copies are available from the Office of Technical Publications, National Institute of Occupational Safety and Health, Post Office Building, Cincinnati, Ohio 45202.

EXHIBIT 2

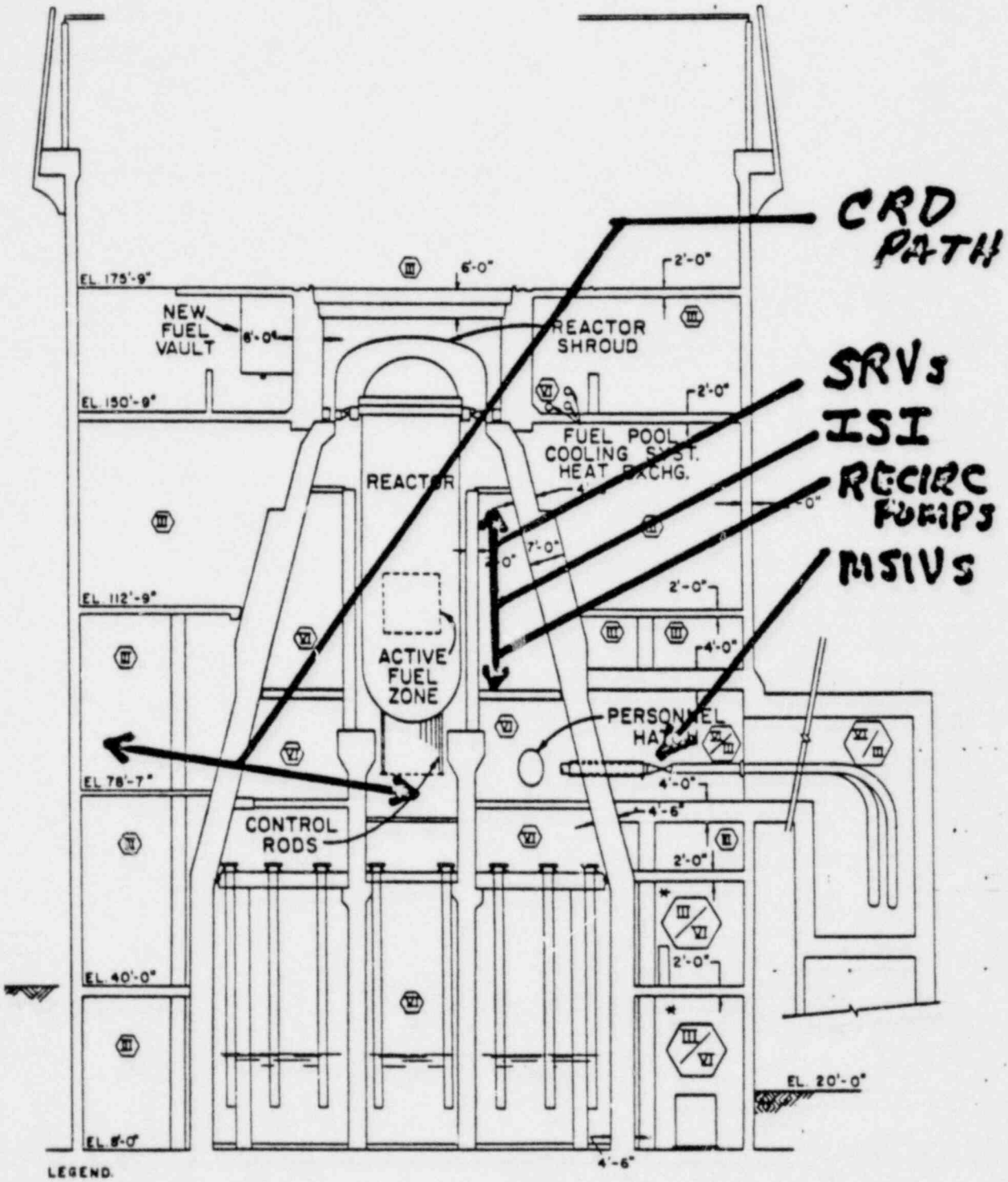
Final Safety Analysis Report
Figures 12.3.1-16, 5.1.3-1, and 12.3.1-18.

APPLICANT'S
FINAL SAFETY ANALYSIS REPORT

# SHOREHAM NUCLEAR POWER STATION
# UNIT 1

LILCO
LONG ISLAND LIGHTING

VOL. 12




LEGEND.

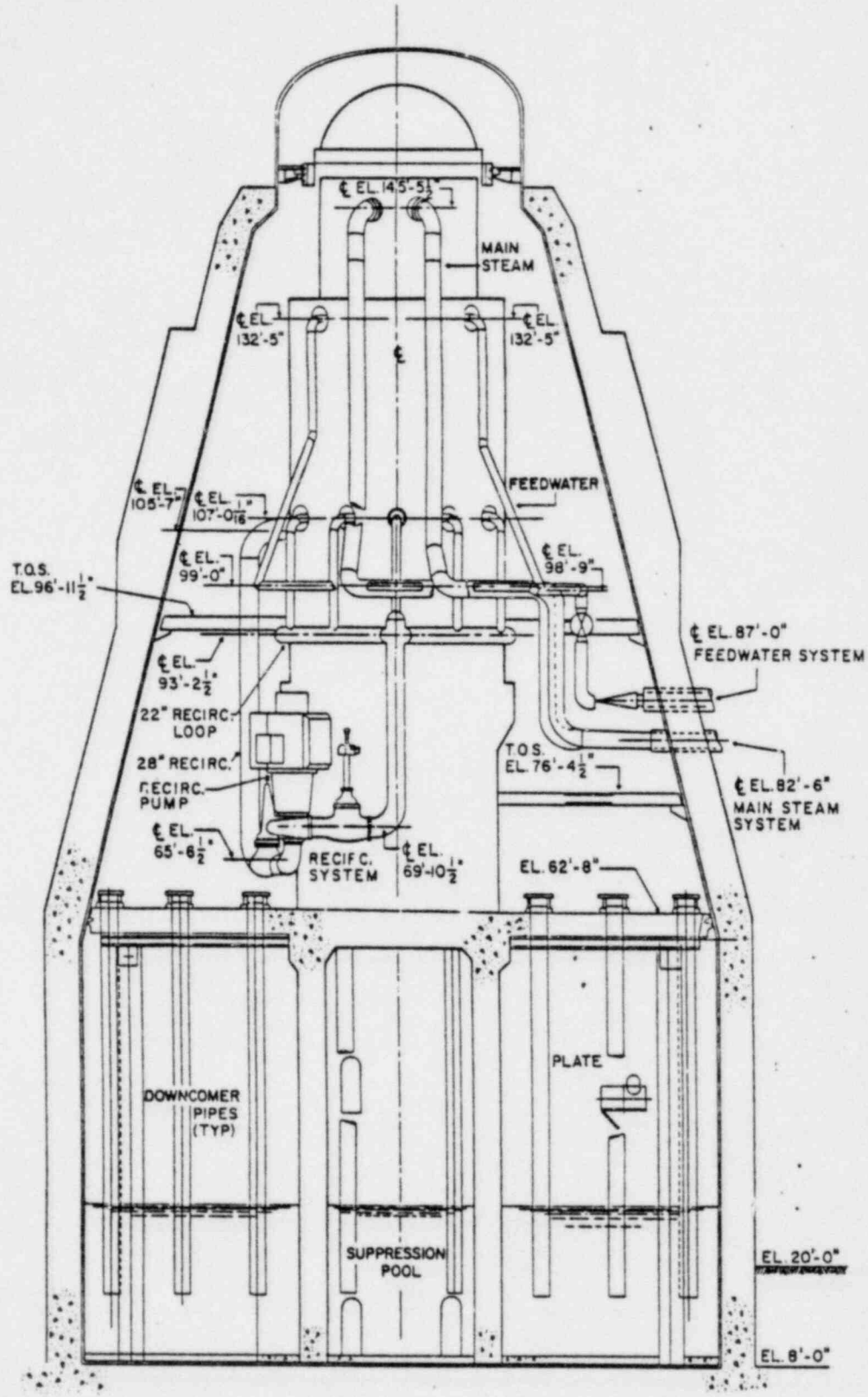
III DURING NORMAL OPERATION.
VI WHEN HPIC OR RCIC IN OPERATION.

VI DURING NORMAL OPERATION
III POST SHUTDOWN

FIG. 12.3.1-16

SHIELDING ARRANGEMENT AND RADIATION ZONE DESIGNATIONS FOR THE REACTOR BUILDING SECTION 1-1

SHOREHAM NUCLEAR POWER STATION - UNIT 1
FINAL SAFETY ANALYSIS REPORT




NOTES:
ALL DIMENSIONS ARE APPROXIMATE
EL. 0'-0" = SEA LEVEL

FIG. 5.1.3-1

REACTOR COOLANT SYSTEM ELEVATION DRAWING

SHOREHAM NUCLEAR POWER STATION - UNIT I
FINAL SAFETY ANALYSIS REPORT

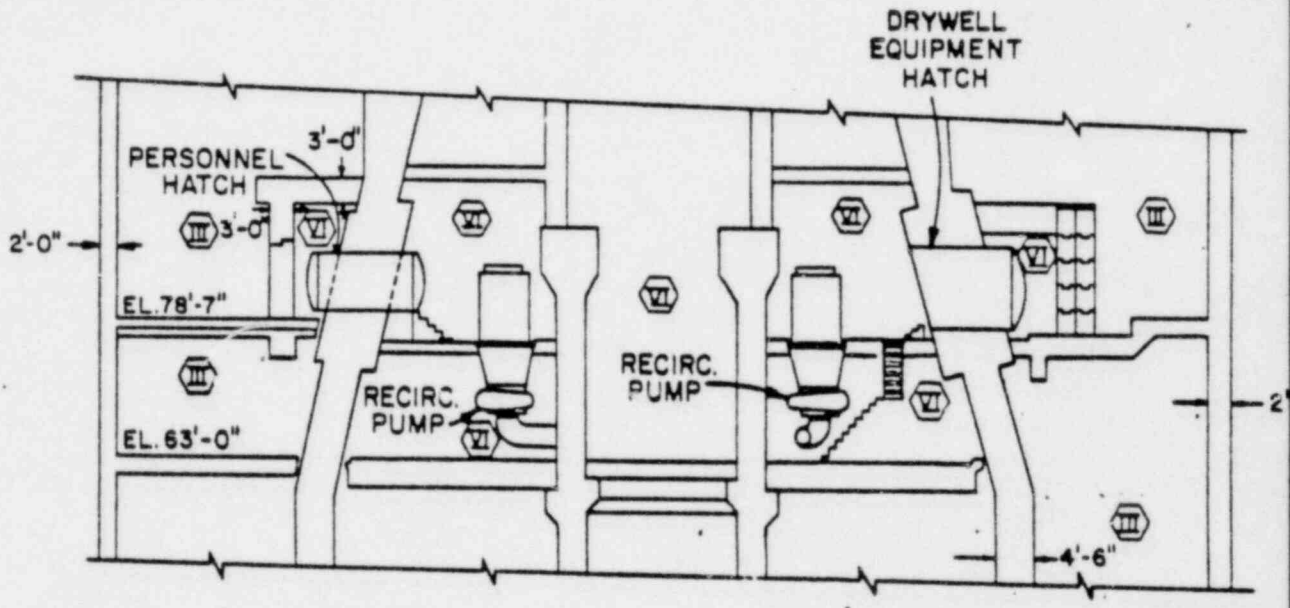



FIG. 12.3.1-18

SHIELDING ARRANGEMENT AND RADIATION ZONE DESIGNATIONS FOR THE REACTOR BUILDING SECTION 3-3

EXHIBIT 3

Final Safety Analysis Report,
Table 12.4.3-1, Volume 12.

APPLICANT'S
FINAL SAFETY ANALYSIS REPORT

# SHOREHAM NUCLEAR POWER STATION
# UNIT 1

LILCO
THE LONG ISLAND LIGHTING

VOL. 12

TABLE 12.4.3-1

ESTIMATES OF ANNUAL DOSES[1]

| Task (Sub-Task) | Work Area Exposure Rate (mrem/hr) | Productive Work Time (hr/man) | Man-Power | Exposure[2] (man-rem) |
|---|---|---|---|---|
| CRD Change Out | | | | |
| (I&C Techs) | 123 | 11 | 2 | 2.9 |
| (Mechanics) | 123 | 78 | 12 | 20.9 |
| CRD Repair | | | | |
| (Mechanics) | 40 | 78 | 3 | 9.6 |
| ISI-Drywell Piping | | | | |
| (Mechanics) | 150 | 48 | 16 | 31.6 |
| (NDT Techs) | 150 | 11.1 | 2 | 3.6 |
| Refueling | | | | |
| (Mechanics) | 20 | 130 | 5 | 13.4 |
| Recirc. Pump Maint. | | | | |
| (I&C Techs) | 205 | 0.4 | 1 | 0.09 |
| (Mechanics) | 75 | 70 | 12 | 21.5 |
| Radwaste Syst. Maint. | | | | |
| (Mechanics) | 150 | 75 | 12 | 36.7 |
| Main Steam Relief Valve Maint. | | | | |
| (I&C Techs) | 75 | 6 | 1 | 0.54 |
| (Mechanics) | 100 | 40 | 6 | 17.8 |
| LPRM Maint. | | | | |
| (I&C Techs) | 100 | 12 | 4 | 6.1 |
| MSIV Maint. | | | | |
| (Electricians) | 100 | 2 | 2 | 0.62 |
| (Mechanics) | 250 | 25 | 12 | 30.9 |
| Snubber Inspection/ Repair (Mechanics) | 120 | 20 | 6 | 9.4 |
| RWCS Maint. | | | | |
| (Electricians) | 250 | 5 | 2 | 2.6 |
| (Mechanics) | 200 | 13 | 3 | 8.2 |

TABLE 12.4.3-1 (CONT'D)

| Task (Sub-Task) | Work Area Exposure Rate (mrem/hr) | Productive Work Time (hr/man) | Man-Power | Exposure[2] (man-rem) |
|---|---|---|---|---|
| RHR System Maint. (Mechanics) | 86 | 24 | 2 | 5.0 |
| Turbine Work (Mechanics) (NDT Techs) | 2 | 180 | 8 | 3.1 |
| Special Maint. (Laborers) | 100 | 125 | 20 | 53.8 |
| (Mechanics) | 300 | 125 | 34 | 83.3 |
| Health Physics Personnel | - | - | - | 65 |
| Outage & Routine Operations | - | - | - | 437[3] |
| Routine Maint. (Mechanics) | - | - | - | 146 |
| TOTAL | | | | 583 |

(1) Data obtained from Atomic Industrial Forum, Inc.; "Study of the Effects of Reduced Radiation Exposure Limits on the Commerical Nuclear Power Industry"; July 1979. Estimates given are based on a 3 rem/quarter occupational dose limit.

(2) An ingress/egress factor, discussed in the AIF Study, is included.

(3) Although the estimate for the selected tasks given is 427 man-rem, a total estimate of 437 man-rem is estimated in the AIF Study for all outages and routine operation.

EXHIBIT 4

NUREG-0713, "Occupational Radiation Exposure at Commercial Nuclear Power Reactors 1980" Volume 2, December 1981, cover page and page 18.

NUREG-0713
Vol. 2

# Occupational Radiation Exposure at Commercial Nuclear Power Reactors 1980

Annual Report

Manuscript Completed: December 1981
Date Published: December 1981

B. G. Brooks

Licensee Operations Evaluation Branch
Office of Management and Program Analysis
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

## TABLE 8

## ANNUAL COLLECTIVE DOSES BY WORK FUNCTION AND PERSONNEL TYPE

1980

| Work Function | Station Employees | | Utility Employees | | Contract Workers & Others | | Total per Function | |
|---|---|---|---|---|---|---|---|---|
| | MAN-REMS | % OF TOTAL | MAN-REMS | % OF TOTAL | MAN-REMS | % OF TOTAL | MAN-REMS | % OF TOTAL |
| **BOILING WATER REACTORS** | | | | | | | | |
| REACTOR OPERATIONS & SURVEILLANCE | 1615.1 | 5.8 % | 82.1 | 0.3 % | 421.0 | 1.5 % | 2118.2 | 7.6 % |
| ROUTINE MAINTENANCE | 2487.9 | 8.9 % | 1448.2 | 5.2 % | 7984.7 | 28.6 % | 11920.8 | 42.8 % |
| INSERVICE INSPECTION | 108.4 | 0.4 % | 142.9 | 0.5 % | 655.8 | 2.4 % | 907.1 | 3.3 % |
| SPECIAL MAINTENANCE | 745.2 | 2.7 % | 606.4 | 2.2 % | 9262.5 | 33.2 % | 10614.1 | 38.1 % |
| WASTE PROCESSING | 524.2 | 1.9 % | 12.7 | 0.0 % | 343.7 | 1.2 % | 880.6 | 3.1 % |
| REFUELING | 557.6 | 2.0 % | 67.0 | 0.2 % | 814.6 | 3.0 % | 1439.2 | 5.2 % |
| TOTALS | 6038.4 | 21.7 % | 2359.3 | 8.4 % | 19482.3 | 69.9 % | 27880.0 | 100.0 % |
| **PRESSURIZED WATER REACTORS** | | | | | | | | |
| REACTOR OPERATIONS & SURVEILLANCE | 1784.0 | 7.6 % | 95.2 | 0.4 % | 822.6 | 3.5 % | 2701.8 | 11.5 % |
| ROUTINE MAINTENANCE | 1719.1 | 7.3 % | 627.2 | 2.7 % | 4003.5 | 17.0 % | 6349.8 | 27.0 % |
| INSERVICE INSPECTION | 158.6 | 0.7 % | 126.9 | 0.5 % | 1637.6 | 7.0 % | 1922.1 | 8.2 % |
| SPECIAL MAINTENANCE | 1019.6 | 4.3 % | 1042.0 | 4.4 % | 8215.6 | 34.9 % | 10277.2 | 43.6 % |
| WASTE PROCESSING | 333.9 | 1.4 % | 31.0 | 0.1 % | 264.7 | 1.1 % | 629.6 | 2.6 % |
| REFUELING | 603.3 | 2.6 % | 319.4 | 1.4 % | 731.5 | 3.1 % | 1654.2 | 7.0 % |
| TOTALS | 5620.5 | 23.9 % | 2241.7 | 9.5 % | 15675.5 | 66.6 % | 23535.7 | 100.0 % |
| **ALL LIGHT WATER REACTORS** | | | | | | | | |
| REACTOR OPERATIONS & SURVEILLANCE | 3399.1 | 6.6 % | 177.3 | 0.3 % | 1243.6 | 2.4 % | 4820.0 | 9.3 % |
| ROUTINE MAINTENANCE | 4207.0 | 8.2 % | 2075.4 | 4.0 % | 11988.2 | 23.3 % | 18270.6 | 35.5 % |
| INSERVICE INSPECTION | 267.0 | 0.5 % | 269.8 | 0.5 % | 2293.4 | 4.5 % | 2830.2 | 5.5 % |
| SPECIAL MAINTENANCE | 1764.8 | 3.4 % | 1648.4 | 3.2 % | 17478.1 | 34.0 % | 20891.3 | 40.6 % |
| WASTE PROCESSING | 858.1 | 1.7 % | 43.7 | 0.1 % | 608.4 | 1.2 % | 1510.2 | 3.1 % |
| REFUELING | 1160.9 | 2.3 % | 386.4 | 0.8 % | 1546.1 | 3.0 % | 3093.4 | 6.0 % |
| TOTALS | 11658.9 | 22.7 % | 4601.0 | 8.9 % | 35157.8 | 68.4 % | 51415.7 | 100.1 % |

EXHIBIT 5

"Compilation and Analysis of Data on Occupational Radiation Exposure Experiences at Operating Nuclear Power Plants", SAI Services September 1974, cover page and page 12.

# Compilation and Analysis of Data on Occupational Radiation Exposure Experienced at Operating Nuclear Power Plants

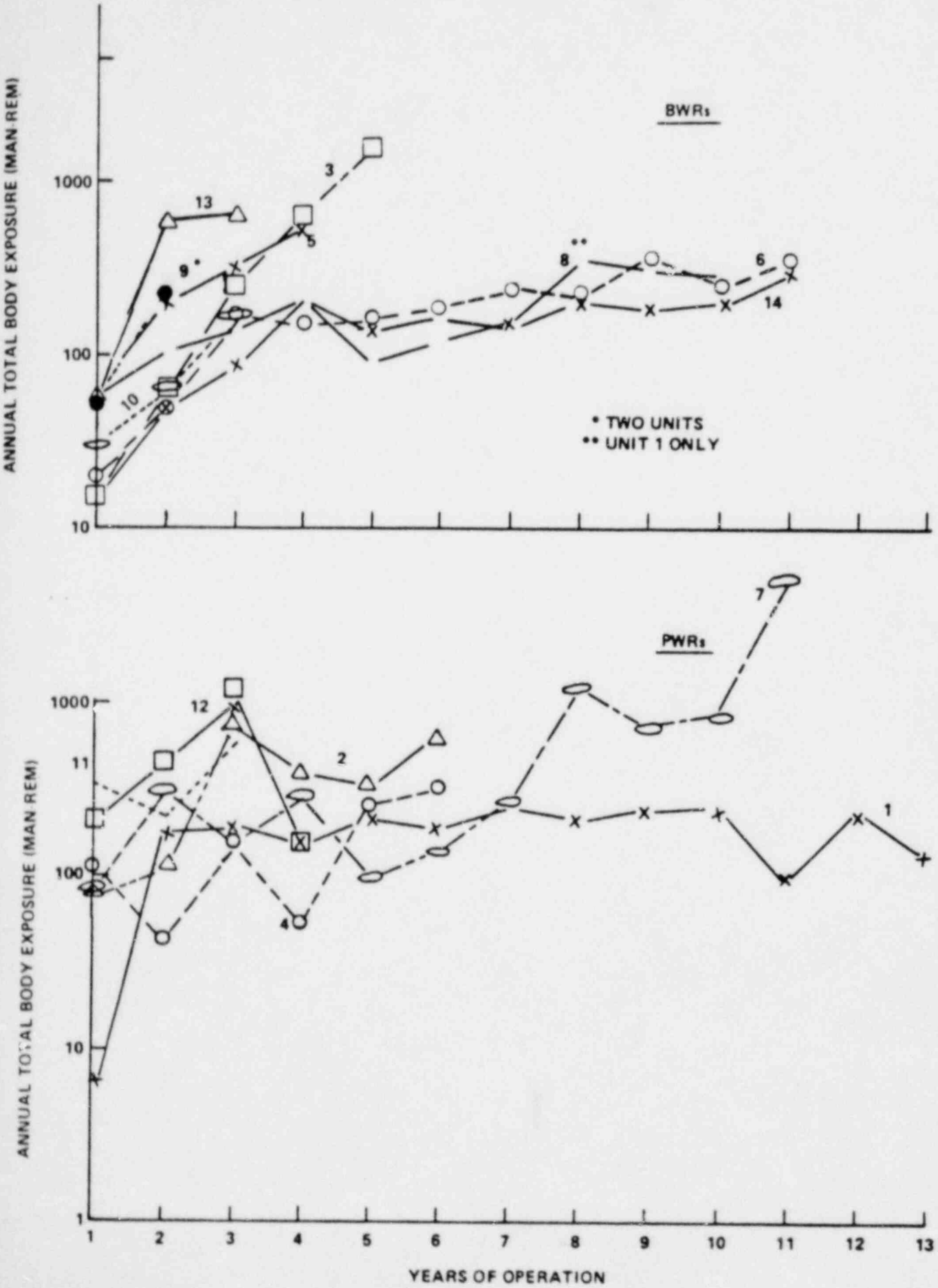
Prepared by

SAI Services

A Division of Science Applications, Inc.

Atomic Industrial Forum, Inc.

Figure 4-1 Annual Total Body Exposure As A Function of Plant Age






Symbols represent various plants

EXHIBIT 6

Radiation Buildup Effects, by Dr. William R. Dehollander
March 1980, cover page and page 24.

# RADIATION BUILDUP EFFECTS

# OF

# WATER QUALITY

BY

DR. WILLIAM R. DEHOLLANDER

MARCH 1980

SET IV

# MEAN CORROSION OF CARBON STEEL IN AIR-SATURATED WATER AT 125°F

| CONDUCTIVITY | VELOCITY FT/SEC | RATES: CORROSION $mg/dm^2$ –mo | RATES: RELEASE $mg/dm^2$ –mo |
|---|---|---|---|
| 0.1 | 0 | 347 | 278 |
| | 1 | 16 | 12 |
| | 3 | 9 | 3 |
| | 6 | 2 | 2 |
| 3.6 | 0 | 930 | 515 |
| | 1 | 839 | 46 |
| | 3 | 303 | 52 |
| | 6 | 7 | 12 |

- KEEP WATER CIRCULATING AND AVOID STAGNANT WATER
- KEEP WATER CONDUCTIVITY LOW

EXHIBIT 7

Radiation Buildup Effects, by Dr. William R. Dehollander
March 1980, cover page and page 13.

# RADIATION BUILDUP EFFECTS

# OF

# WATER QUALITY

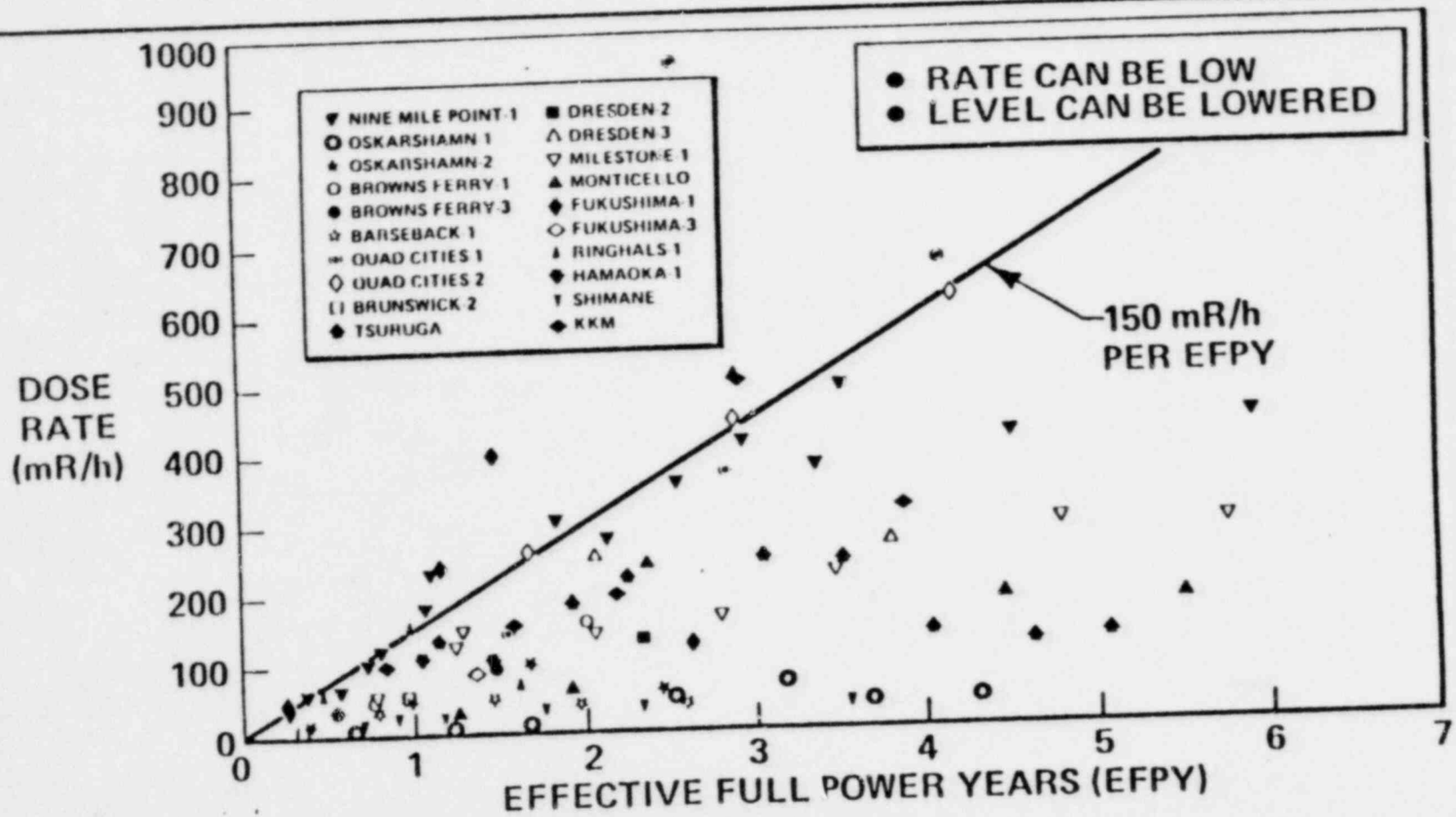
BY

DR. WILLIAM R. DEHOLLANDER

MARCH 1980

SET IV

# RADIATION FIELD BUILDUP ON RECIRCULATION PIPING




SET IV
WRD-13

EXHIBIT 8

NUREG-0855, "Health Physics Appraisal Program"
March 1982, cover page and abstract.

NUREG-0855

APR 05 1982

# Health Physics Appraisal Program


U.S. Nuclear Regulatory Commission

Office of Inspection and Enforcement

L. J. Cunningham, J. E. Wigginton, E. D. Flack

## ABSTRACT

The accident at Three Mile Island in March 1979 and subsequent investigations identified, among other items, serious concerns involving several aspects of the radiation protection program. Significantly, some concerns involved areas not addressed by regulations or facility technical specifications. This in turn led to initiation of a major effort to evaluate the adequacy and effectiveness of radiation protection programs at all currently operating nuclear power facilities during calendar year 1980 by the Office of Inspection and Enforcement (IE), Nuclear Regulatory Commission. This inspection effort was termed an appraisal since it was structured to facilitate an integrated look at the total radiation protection program, delve into matters for which explicit regulatory requirements did not exist, and emphasized evaluation of capability and performance rather than compliance with regulations. This report discusses the results of the 48 appraisals and the anticipated regulatory actions that may be taken to further address the concerns.