NUREG/CR-4254
BNL-NUREG-51888

Occupational Dose Reduction and ALARA at Nuclear Power Plants:

Study on High-Dose Jobs, Radwaste Handling, and ALARA Incentives

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Prepared for
U.S. Nuclear Regulatory Commisssion

FOREWORD

It has become progressively more apparent in the U.S. nuclear power industry that operational cost reductions are often accompanied by reductions in the occupational collective dose. For example, if the number of manhours required to perform a maintenance task is reduced through the use of advanced tooling and maintenance training, the costs and the dose both go down. The attention given to these considerations by nuclear utility managers is, of course, very welcome to health physicists. One of the objectives of the NRC Occupational Radiation Protection Branch is to encourage dose-reduction by providing information that will be of use to nuclear power plant licensees in the development and implementation of their radiation protection programs. We believe that information regarding measures which simultaneously reduce costs and dose are particularly appropriate at this time, and the study reported in this document was funded for that reason. We believe this examination of high-dose jobs, low-maintenance equipment selection, radioactive waste handling practices, and ALARA incentives will stimulate additional cost/dose reduction activities that will be of benefit to everyone concerned.

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Available from
Superintendent of Documents
U.S. Government Printing Office
P.O. Box 37082
Washington, DC 20013-7982
and
National Technical Information Service
Springfield, Virginia 22161

NUREG/CR-4254
BNL-NUREG-51888

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Manuscript Completed: April 1985
Date Published: May 1985

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NRC FIN A3259

ABSTRACT

This report provides the NRC and the nuclear industry with information and data which will be useful for occupational dose reduction at nuclear power plants. The objectives of this effort were to:

1. identify the repetitive high-dose jobs, related collective dose ranges and applicable dose-reduction techniques,
2. investigate and recommend improvements in the selection of high reliability and low maintenance equipment to ensure that collective dose received during component repair is considered,
3. recommend improved radioactive waste handling procedures and equipment which could reduce collective dose equivalent, and
4. examine current ALARA incentives and recommend new steps which will provide additional dose-reduction incentives.

Ten nuclear sites were visited by two Brookhaven health physicists to collect the needed dose-reduction data and information. This report summarizes the findings and recommendations on the above objectives.

CONTENTS

PAGE

ILLUSTRATIONS

TABLES

ACKNOWLEDGMENTS

The project discussed in this document was sponsored by the Occupational Radiation Protection Branch, Office of Nuclear Regulatory Research, Division of Radiation Programs and Earth Sciences of the U.S. Nuclear Regulatory Commission. The authors gratefully acknowledge the guidance, input and comments provided by the Ad Hoc D se-Reduction Advisory Committee members.

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The authors wish to thank all the individuals from the participating utilities for the information and comments they provided, the cooperation which we received during the nuclear plant visits and for the quality of their efforts.

We also wish to thank Dennis Trout from Impell Corporation and Robert Ryan from Rensselaer Polytechnic Institute for their assistance in collecting data and information during the nuclear plant visits.

Special thanks go to Marie Cooney, Carrie Lofstad, and Dennis Pennino for their substantial contributions to the preparation of this document.

OCCUPATIONAL DOSE REDUCTION AND ALARA AT NUCLEAR POWER PLANTS

STUDY ON HIGH-DOSE JOBS, RADWASTE HANDLING, AND ALARA INCENTIVES

EXECUTIVE SUMMARY

The average annual collective dose per U.S. light water reactor has increased since 1979. The Nuclear Regulatory Commission's Occupational Radiation Protection Branch has contracted with Brookhaven National Laboratory to provide technical assistance in the collection of data and information useful in the reduction of occupational dose (ALARA) at nuclear power plants. The findings and recommendations will aid in occupational dose reduction by:

1. Identifying dose-reduction target areas for regulators and utility executives.
2. Providing information for utility managers and power plant personnel.

The following ten plant sites were visited by two Brookhaven Health Physicists: Quad Cities, Millstone, Browns Ferry, Zion, Turkey Point, Haddam Neck, Kewaunee, St. Lucie, Maine Yankee, and Oconee. These stations, which encompass 18 nuclear units, were chosen because each has several years of computerized collective-dose data readily available for selected repetitive jobs. Four objectives relating to occupational dose reduction were examined:

1. HIGH-DOSE JOBS

The first objective of this project was the identification of repetitive high-dose jobs, the associated collective dose ranges, and dose-reduction techniques. The goal was to enable industry and the NRC to focus on the major dose-reduction targets.

1.1. Findings

Repetitive jobs at boiling water reactors with an average collective dose equivalent per outage greater than 40 rem are given below in descending order of dose equivalent magnitude.

- Snubber Inspection and Repair
- Torus Repair, Inspection and Modifications
- In-Service Inspection
- CRD Removal, Rebuilding and Replacement
- Scaffold Installation and Removal
- Primary Valve Maintenance and Repair
- Jet Pump Inspection and Repair
- Insulation Removal and Replacement

Repetitive jobs at pressurized water reactors with an average collective dose equivalent per outage greater than 30 rem are given below in descending order of dose equivalent magnitude.

- Snubber, Hanger, and Anchor Bolt Inspection and Repair
- Steam Generator Eddy Current Testing

- o Reactor Disassembly and Assembly
- o Steam Generator Tube Plugging
- o In-Service Inspection
- o Plant Decontamination
- o Primary Valve Maintenance and Repair

The ratio of the maximum to minimum collective dose equivalent for repetitive high-dose jobs, ranged from a factor of 3 to 460. The magnitude of the difference between the minimum and maximum collective dose is an important indicator of the dose-reduction potential for that job. Collective doses for reactors from the three PWR suppliers and from plant to plant differed widely. The most noteworthy difference being the lower collective doses associated with steam generator repetitive jobs for the Babcock and Wilcox units (possibly due to the once- through design of the B&W steam generators).

Appendices A & B contain the dose-reduction data sheets for 21 BWR and 20 PWR repetitive high-dose jobs. These data sheets include generic descriptions of the identified high-dose jobs, the collective-dose ranges indexed by reactor supplier, and a listing of the associated dose-reduction techniques. Numerous innovative dose-reduction techniques were identified at the nuclear plants visited. Implementation of the cost-effective techniques should result in reduction of collective doses for these jobs and the collective dose differences between nuclear plants.

Some of the innovative dose-reduction techniques observed were the following:

- o Rebuilding of the reactor coolant pump seal cartridge underwater.
- o Fabrication of various shields for steam generator manways.
- o Development of a shielding manual with detailed assembly drawings of shields to be used during inspections and repairs of intergranular stress corrosion cracking.
- o Use of shielded and totally enclosed transfer carts for spent filters, CRDs, RCP seal cartridges, pressurizer valves, MSIVs, safety valves, etc.
- o Construction of a room to rebuild reactor water cleanup pumps adjacent to the RWCU cubicle with monorail, ventilation, intercom, viewing window, ultrasonic sink, shields, and special tools to expedite repair.

1.2. Recommendations

Dose-reduction efforts at utilities should be focused on the high-dose targets which have been identified. The dose-reduction data sheet concept should be expanded and continuously updated due to limitations and time dependent variations in the collective-dose data as well as additions of new dose-reduction techniques. This data base of job-specific collective doses and associated dose-reduction techniques should be made accessible to nuclear plant personnel. In addition, all operating nuclear power plants should establish a job-specific collective-dose tracking system. Guidance should be provided to standardize the methodology of categorizing collective doses to allow for intercomparison.

2. EQUIPMENT RELIABILITY

The second objective was the investigation of the use of equipment reliability data, together with the dose received in component repair, and the determin-

ation of the extent to which this information is currently being used by maintenance and engineering personnel during equipment selection. This included the identification of improvements in the use of this data in the selection of high reliability and low maintenance equipment.
This was studied by questioning station personnel and architect engineers on the following:

- The equipment selection process used by engineers.
- The communication feedback process between maintenance, health physics, and engineering groups concerning unreliable components.
- The unreliable components which have caused high repair doses and which have been modified or replaced.

2.1. Findings

Numerous examples of unreliable equipment that was modified or replaced and that reduced dose were identified. We found that data on dose received during component repair and on equipment reliability is seldom quantified for use during the equipment selection process. Quantification of labor and dose savings associated with the selection of low maintenance and high reliability equipment is performed only for large capital investments. Inclusion of dose savings in cost-effectiveness calculations for moderate capital investments would result in implementation of more marginally effective modifications.

2.2. Recommendations

Information on equipment reliability and data on dose due to component repair could be used more effectively if the required information were made readily available. This could best be accomplished by merging information from maintenance work requests with information from health physics radiation work permits. This would allow engineers to readily extract the needed data during the equipment selection process and thereby aid in dose reduction and maintaining plant reliability.

3. RADIOACTIVE WASTE HANDLING

The third objective was the identification of possible improvements in radioactive waste handling equipment and procedures which could reduce collective dose equivalent.

3.1. Findings

Approximately 50 of the major dose-reduction improvements which have been made in radwaste handling are described, and dose-reduction actions are recommended. The major equipment improvements for handling radwaste centered around:

- Bulk solidification,
- Waste evaporation improvements,
- Remote control and automated drumming facilities, and
- Dry active waste volume reduction devices.

Implementation of the cost-effective radwaste dose-reduction improvements will aid in reduction of collective dose from radwaste operations, in reduction of the number of radwaste workers who approach their administrative dose limits, and in associated reduction in labor cost for packaging radwastes.

3.2. Recommendation

A large variety of radwaste handling equipment and systems were found at the plants visited. Numerous radwaste handling dose-reduction improvements were identified. However, a comprehensive review of radwaste systems is needed to determine the optimum combination of these procedural and equipment improvements.

4. ALARA INCENTIVES AND ALARA PROGRAMS

The fourth objective was the examination of current ALARA incentives. This included the identification of the important ALARA incentives, their impact on plant ALARA programs and what can be done by the NRC and the nuclear industry to improve them.

4.1. Incentives Findings

The relative importance of various worker and manager ALARA incentives was judged by the plant manager, the maintenance supervisor, and the radiation protection manager at each of the ten nuclear sites visited. It was found that workers were motivated to reduce dose by:

- Being made aware of radiation risk.
- Receiving recognition.
- Acquiring prestige.
- Experiencing a sense of involvement.
- Receiving positive or negative feedback.
- Being aware of management concern.
- Receiving awards.

Managers were motivated to reduce dose by humanitarian and monetary considerations associated with:

- Increasing the use of experienced plant and utility workers.
- Improving employee attitude and relations due to management's concern for worker safety.
- Receiving an annual salary adjustment for the successful accomplishment of department and station dose-reduction goals.
- Receiving monetary savings from critical path and labor savings resulting from ALARA preplanning efforts.
- Feeling concern for the safety of fellow employees.

4.2. Incentives Recommendations

In general, utility executives and plant managers appeared to advocate ALARA attitudes and to endorse financial and manpower allocations which facilitate dose reductions. However, several managers indicated that their ALARA incentives are being adversely affected by conflicting demands to reduce occupational dose and the increase in dose required to perform NRC initiated backfits, inspections, and modifications. Collective doses caused by the NRC multi-plant actions frequently mask the collective dose savings from plant dose- reduction efforts. Therefore, to improve ALARA incentives, the NRC should continue to carefully evaluate the radiological impact of NRC initiated multi-plant actions. In addition, the NRC should not be too prescriptive in

its regulation of ALARA. The NRC should assist in improving radiological safety by continuing dose-reduction research and by providing this information to industry.

4.3. Program Findings

Lastly, the relative importance of key components of an ALARA program were judged by the radiation protection manager and ALARA coordinator at the nuclear sites visited. The following six components were considered the most important:

- o ALARA policy and management commitment.
- o Collective dose data base system.
- o ALARA job reviews.
- o ALARA design reviews.
- o ALARA Coordinator.
- o Goals and associated tracking system.

4.4. Program Recommendations

Essentially all the plants visited utilized these components, although the emphasis of each varied considerably. Therefore, more attention is needed to properly direct the emphasis of various components of the ALARA program to reflect the needs of individual plants.

5. CONCLUSION

This study revealed numerous jobs with large collective dose differences from plant-to-plant. Many innovative dose-reduction techniques were identified which should be disseminated. These are contained in the high-dose job data sheets in Appendices A & B and should serve as a useful mechanism in reducing both the collective doses for these jobs and the collective dose differences between nuclear plants.

In conclusion, an examination of high-dose jobs, reliable equipment selection, radioactive waste handling improvements, and ALARA incentives at nuclear power plants has been performed. The information and data in this report are being provided to the nuclear power industry by the Nuclear Regulatory Commission not only for purposes of occupational dose reduction at nuclear power plants but also to reduce the cost to generate electricity through cost savings associated with dose reduction.

1. INTRODUCTION

This study was performed by Brookhaven National Laboratory's Safety and Environmental Protection Division's Research Group for the Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission. This project was coordinated with the nuclear industry through the Ad Hoc Dose-Reduction Advisory Committee. This committee consisted of representatives from industry-funded organizations (EPRI, INPO, AIF, and EEI), an architect engineering company (Bechtel), nuclear steam system suppliers (Westinghouse and General Electric), and utilities (Commonwealth Edison, Northeast Utilities, and Tennessee Valley Authority).

The purpose of the project was to provide technical assistance to the NRC and the nuclear industry in the area of occupational dose reduction at nuclear power plants. This document should aid in the reduction of occupational doses to as low as is reasonably achievable (ALARA) levels.

The specific objectives of this effort were to:

- Identify the repetitive high-dose jobs, their collective dose ranges, and applicable dose-reduction techniques.
- Investigate the use of low-maintenance, high-reliability equipment, and recommend positive steps for improvement.
- Recommend improved radioactive waste-handling equipment and procedures.
- Examine current ALARA incentives and recommend new positive steps to provide additional dose-reduction incentives.

Annual collective dose equivalent per reactor has increased since 1979 for the U.S. light water reactors. A downward trend has recently been observed in the annual collective dose equivalent in other technically advanced countries with extensive nuclear power programs, notably Canada, United Kingdom, France, Sweden, and Finland. Currently, the average collective dose per reactor per megawatt year is 3 to 6 times higher for U.S. plants than for similar reactors in the above countries. Even within the U.S., the ratio of the highest and lowest annual collective dose per reactor has been between 10 and 20. This suggests that there is potential to reduce collective dose equivalents at the U.S. nuclear power plants.

The NRC has directed its regulatory program for ALARA at nuclear power plants toward radiological safety reviews, inspections, interaction with industry, and radiation protection research[1]. This NRC sponsored research was initiated to provide technical assistance to the nuclear industry by collecting data and information on dose reduction. It is expected that, by making these data and information available in published form, utilities, industry-funded organizations, architect engineering firms, and nuclear steam system suppliers will implement the cost effective techniques. This would then result in a decreased generation cost for electricity, a reduction of collective dose equivalent, and an improved image for nuclear power in the United States.

2. RECOMMENDATIONS

On the basis of the observations made during visits to ten nuclear power plants, conducted from January to August 1984, the following recommendations are made. These dose-reduction actions should be evaluated and appropriate actions taken by industry and the NRC.

1. Job-specific collective dose tracking systems should be established at all operating nuclear power plants. A standardized methodology of categorizing collective doses should be developed to allow for accurate intercomparisons. (3.3.1.)*

2. The BWR and PWR Dose-Reduction Data Sheets should be used by plant personnel in preplanning during these repetitive high-dose jobs. The Dose-Reduction Data Sheets concept should be expanded and continuously updated. This data base on job-specific doses and associated dose-reduction techniques should be made readily accessible. (3.3.2.)

3. Maintenance work request information should be combined with health physics radiation work permit information. A methodology should be developed to allow engineers to readily extract data on component failure frequency, repair times, repair dose, and impact on plant or system availability. (4.4.)

4. The radwaste packaging dose-reduction improvements listed in this report should be implemented by plant personnel if they are found to be cost-effective. (5.3.2.)

5. Current radwaste solidification systems should be reviewed to determine the best combination of solidification systems. Guidance to standardize the methodology of solidification should be developed. (5.3.1.)

6. Utility executives and plant managers should continue to encourage ALARA attitudes in their managers and workers, endorse specific dose-reduction goals, and approve allocations to cost-effective dose-reduction improvements. (6.3.2.)

7. The NRC should assist in improving radiological safety by continuing dose-reduction research and by providing this information to industry. (6.3.2)

8. The NRC should continue to carefully evaluate the radiological impact of those NRC-initiated actions which result in high collective doses. (6.3.2.)

9. An industry-funded organization such as the Institute for Nuclear Power Operations (INPO) should coordinate and guide the development of station ALARA programs in the following areas: ALARA data base systems, radiological goals and tracking system, ALARA program evaluation, high-dose job good practices, and cost-effectiveness methodologies for dose-reduction modifications. (6.3.3)

* The numbers inside the paretheses indicate the section of this report where additional details concerning the recommendation can be found.

3. REPETITIVE HIGH-DOSE JOBS

3.1 DESCRIPTION

Identify and evaluate, from the point of view of high potential for dose reduction, repetitive high-dose jobs at BWR's and PWR's. Determine the collective dose ranges experienced for these tasks. Determine the dose-reduction techniques being utilized and their impact on reducing doses to workers performing these tasks.

3.2 METHOD

Initially, a literature review was performed to identify past efforts in this area (2-4). Principal investigators from past projects involving determination of collective doses by job were contacted. The problems they reported and their recommendations for improvement are listed below:

- The size of the plant will affect the amount of effort needed to perform some repetitive jobs and will therefore cause variations in the magnitude of the collective dose. Select plants of similar power rating.

- The age of the plant will affect the dose rates, the experience and proficiency level of the workers, and the frequency of repairs. This will therefore cause variations in the magnitude of the collective dose. Collect dose data for those jobs which occurred after four effective full power years (EFPY) of operation. Also correlate job doses by year of operation and effective full power year.

- Variations in the length of an outage and operating cycle for each year will cause variations in the magnitude of the <u>annual</u> collective dose for repetitive jobs which occur only during outages or routine operation. Attempt to collect job dose for the affected jobs over an operating cycle or an outage period.

- Some jobs have multiple repetitions, e.g., CRD rebuild and repairs, steam generator tube plugging; therefore, the number of repetitions will cause variations in the magnitude of the collective dose. Obtain information on the number of repetitions, frequency, or extent of work for the affected jobs.

- Variations in the methods of performing the same job and assigning dose to that job will cause variations in the magnitude of the collective dose. Obtain descriptions of the work associated with the collective dose for each job and determine the method of dose assignment by job.

- Variations in the method of logging dose on Radiation Work Permits (RWP), e.g., logging of dose upon entering and exiting the radiation control area, or upon entering and exiting containment, or upon starting and stopping the actual work, will cause variation in the magnitude of collective dose. Obtain a description of how, where, and when doses are logged on the RWP.

- o Collection of dose totals for jobs by manual sorting of all the associated RWPs with manual totaling of workers doses can be time consuming and inaccurate. Because of the volume of RWPs and the vague written description of the work performed, inaccuracies occur due to the difficulty of sorting all RWPs associated with a job. Select plants with the capability to perform computerized sorts of RWPs by job.

Following this, the repetitive jobs with high doses were identified and an initial list of BWR and PWR high-dose jobs was generated. Then several utility health physicists at power plants having collective dose data for jobs were contacted. Based on their suggestions, additions and deletions were made to form the list of the BWR and PWR high-dose jobs shown below:

Boiling Water Reactors High-Dose Jobs

Reactor Assembly/Disassembly
Fuel Shuffle/Sipping and Inspection
CRD Removal/Rebuild and Replacement
Recirculation Pump Seal Replacement
Main Steam Isolation Valve Repair and Inspection
Safety Valve Repair and Inspection
Primary Valve Maintenance and Repair
In-Service Inspection
Jet Pump Inspection and Repair
Insulation Removal/Replacement
Instrumentation Repair and Calibration
Scaffold Installation/Removal
Local Leak Rate Test*
Torus Repair, Inspection, and Modification
Residual Heat Removal System Repair and Maintenance
Snubber Inspection and Repair
Reactor Water Cleanup System Repair and Maintenance*
TIP/SRM/IRM or PRM Calibration, Repair, and Maintenance
Turbine Overhaul and Repair
Condensate Pump Repair and Maintenance
Refueling Pool Decontamination
Plant Decontamination and Shielding
Radwaste Systems Repair, Operation and Maintenance
Operations - Surveillance and Inspection
Operations - Valve Lineups
Seismic Inspection and Repair*
Desludging of Tanks, Sumps, and Drains
Cavity Filter Changeout*

Pressurized Water Reactors High-Dose Jobs

Reactor Assembly/Disassembly
Fuel Shuffle/Sipping and Inspection
Steam Generator Manway Removal
Steam Generator Eddy Current Testing
Steam Generator Tube Plugging
Residual Heat Removal System Maintenance and Repair
Reactor Coolant Pump Seal Replacement
Primary Valve Maintenance and Repair
In-Service Inspection
Insulation Removal/Replacement
Scaffold Installation/Removal
Anchor Bolt Inspection and Repair
Snubber Inspection and Repair
Seismic Inspection and Repair
Radwaste System Repair, Operation, and Maintenance
Secondary Side of the Steam Generator Inspection and Repair
Chemical, Volume, and Control System Repair and Maintenance
Charging Pump Repair and Maintenance*
Cavity Decontamination
Plant Decontamination and Shielding
Pressurizer Valve Inspection, Testing, and Repair
Operations - Surveillance and Inspection
Operations - Valve Lineups
Instrumentation Repair and Calibration

* Insufficient information was collected. These jobs are not reported in Section 3.3.

Next, two Brookhaven health physicists with past nuclear power plant experience visited ten nuclear sites to collect the needed information. This encompassed 18 nuclear units, which were selected based on the availability of several years of computerized job-specific data on occupational doses.

Table 3-1 shows the plants that were visited. This table includes the Power Rating to indicate size, the Years of Operation to indicate age, and the Plant-Years of Data to indicate the weight of that plant's collective dose data.

The six Westinghouse units had 23 plant-years of man-rem data, the six General Electric units had 15 plant-years, the three Combustion Engineering units had 15 plant-years, and the three Babcock and Wilcox units had 8 plant-years. The data on job doses were collected from the period 1974 to 1984. The power plants selected had similar power ratings, namely, 600-1100 MWe and they all had been operating in excess of four effective full power years. The geographical distribution of the plants was somewhat representative with the exception that no nuclear plants on the West Coast were included.

To determine the collective dose ranges for the high-dose jobs, generic descriptions of the jobs were prepared prior to the plant visits. These descriptions were modified by station personnel to define the work associated with that station's man-rem data. The station ALARA Coordinator retrieved computer printouts, ALARA reports, and/or letters which contained the needed man-rem data. In addition, information was collected on the computerized method of dose assignment by job and the history of the RWP coding system. The data was collated by date, unit, year of operation, effective full power year, outage, operating cycle, and year, whenever possible. In addition, for those jobs having multiple repetitions, the number, frequency, or extent of the effort was recorded, whenever possible. All man-rem data were then stored in the BNL ALARA Center man-rem data base.

To determine the dose-reduction techniques which were used for each of the repetitive high-dose jobs, the responsible engineer, maintenance foreman, and knowledgeable health physicist were interviewed during these nuclear plant information visits. After a review of the job descriptions, they were questioned on "tricks of the trade" to reduce doses and/or the spread of radioactive contamination. The dose-reduction techniques which were collected at the ten nuclear sites have been consolidated and tabulated in a check-list-type format for each of the high-dose jobs evaluated.

To determine the impact of dose-reduction techniques on reducing doses to workers performing these tasks, collective-dose trends were prepared for selected repetitive high-dose jobs. The collective doses for selected repetitive jobs were graphed for those plants which had three or more years of data.

TABLE 3-1 NUCLEAR PLANTS VISITED

Plant Name	Power Rating (MWe)	Years of Operation (through 1984)	Plant Years of Data
Westinghouse Plants			
Zion 1 & 2	1040	11	8
Turkey Point 3 & 4	666	12	3
Haddam Neck	600	18	4
Kewaunee	535	11	8
6 Units	-	-	23 Total
General Electric Plants			
Quad Cities 1 & 2	789	13	7
Millstone 1	660	15	4
Browns Ferry 1,2 & 3	1076	10	4
6 Units	-	-	15 Total
Combustion Engineering Plants			
St. Lucie 1	777	8	6
Millstone 2	870	9	4
Maine Yankee 1	825	12	5
3 Units	-	-	15 Total
Babcock and Wilcox Plants			
Oconee 1, 2 & 3	860	11	8
3 Units	-	-	8 Total

3.3 FINDINGS

To reduce the total station collective dose equivalent, a logical approach is to identify the repetitive jobs which cause the highest collective dose equivalent, then to determine their relative dose-reduction potential, and finally to implement the most cost-effective dose-reduction techniques. Therefore, a list of the high-dose jobs, their relative dose-reduction potential, and the associated dose-reduction techniques to be evaluated is given below.

3.3.1 Collective-Dose Summaries

The collective dose summaries for outage high-dose jobs for the General Electric, Westinghouse, Combustion Engineering, and Babcock and Wilcox plants are shown in Tables 3-2, 3-3, 3-4, and 3-5, respectively. The minimum, maximum, and average dose equivalent for the repetitive jobs are indicated in order of decreasing magnitude of the average collective dose. The dose difference between the minimum and maximum collective doses for a job can be a rough indication of its relative dose reduction potential. It should be noted, that these dose ranges typify the dose experiences of the plants listed in Table 3-1 and any comparison of these collective doses with those at other plants must consider the differences between plant size, age, design, operating experience, and job procedures.

Review of the population size for the collective dose summaries indicates that the data base for outage high-dose jobs is rather limited. This was due to the limited number of plants which could provide several years of computerized collective dose data on the high-dose jobs. During 1984, 35 of the 74 operating nuclear units had the computer capability to provide automated sorts of radiation work permit information to extract job-related dose totals. Out of the 35 operating units which had job dose tracking systems, approximately 60% had several years of useful data.

Despite attempts to standardize the job dose data that were collected, inconsistencies did occur. The major causes for variations were:

1. Differences in the method of performing a job.
2. Differences in the method of assignment of dose to that job.
3. Differences in the automated sort capability and computerized output format.

Since it is not reasonable to standardize the method of performing a job, the method of performing jobs should be documented so that plant to plant differences can be identified. The differences in the method of assignment of dose to that job, the various job-sorting parameters, and the format of the computer output could be standardized.

The collective dose data presented in Tables 3-2 through 3-5 should be considered as being as accurate as can be obtained with reasonable effort and given the data systems available during the period 1974 to 1984.

3.3.2 Dose-Reduction Data Sheets

Appendices A and B contain the 21 BWR and 20 PWR Repetitive High-Dose Job Dose-Reduction Data Sheets, respectively. These data sheets include generic descriptions of the identified high-dose jobs, the collective dose ranges by reactor supplier and the consolidated dose reduction-techniques being utilized. It should be noted that not all the listed dose-reduction techniques will be applicable to each plant. Plant personnel must evaluate the cost and the benefit of each in order to determine whether implementation for the existing plant conditions is reasonably achievable.

These Repetitive High-Dose Job Dose-Reduction Data Sheets can have the following applications to job preplanning. The job description can be used to brief new workers and HP technicians about the general scope of the job. They also provide a common foundation for the method of assignment of dose for these jobs, to assure consistency in the accounting of job doses. The collective dose data can be used to estimate job doses for those plants that do not have historical dose data. The job collective dose range, i.e., minimum and maximum man-rem, by reactor supplier can provide a gauge to compare performance between similar units. Lastly, the dose-reduction techniques can be used as a checklist of techniques to be considered during preplanning for these high-dose jobs.

The dose-reduction data sheet concept should be expanded and continuously updated. This data base of job-specific collective doses and associated dose-reduction techniques should be made accessible to nuclear plant personnel. In addition, all operating nuclear power plants should establish a job specific collective dose tracking system. Guidance should be provided to standardize the methodology of categorizing collective doses to allow for intercomparison.

3.3.3 Collective Dose Trends for Selected High-Dose Jobs

Figures 3-1 through 3-6 depict the impact of various plant dose-reduction techniques on reducing workers' collective dose for selected repetitive high-dose jobs. These figures indicate which plants have been effective in the reduction of occupational doses as indicated by the downward trend in job collective dose equivalent. It should be noted that even when comparing the dose for a repetitive job at the same plant some variations in the collective dose will occur because of variations in the job procedure, existing plant conditions, and unforeseen problems.

It should be noted that the dose trends in Figures 3-1 through 3-6 typify the experiences of those plants listed in Table 3-1 which had three or more years of collective dose data for that particular job.

Collective dose trends for selected repetitive high-dose jobs can be used by ALARA coordinators and health physicists to evaluate the effectiveness of job preplanning and dose-reduction techniques.

TABLE 3-2 GENERAL ELECTRIC BOILING WATER REACTORS
COLLECTIVE DOSE SUMMARIES FOR OUTAGE HIGH-DOSE JOBS

Job Title	Collective Dose (man-rem) Minimum	Maximum	Average	Population Size
Snubber Inspection and Repair[A]	2.6	1400	290	15
Torus Repair, Inspection, and Modification[B]	100	600	280	14
In-Service Inspection[C]	32	380	150	15
CRD Removal/Rebuild and Replacement[D]	6.3	230	60	15
Scaffold Installation/Removal	24	120	57	3
Primary Valve Maintenance and Repair[E]	7.0	150	57	6
Jet Pump Inspection and Repair[F]	9.9	140	46	4
Insulation Removal/Replacement	0.60	170	44	8
Safety Valve Repair and Inspection	9.3	80	39	14
Plant Decontamination	9.4	65	37	12
Residual Heat Removal System Repair and Maintenance	11	48	34	5
Operations - Surveillance, Routines, and Valve Lineups	11	53	24	9
Reactor Disassembly/Assembly	7.8	51	24	15
Main Steam Isolation Valve Repair and Inspection[G]	2.7	67	20	13
Fuel Shuffle/Sipping and Inspection	3.8	58	19	15
Radwaste Systems Repair, Operation, and Maintenance	7.7	28	16	4
Instrumentation Repair and Calibration	3.2	41	15	4
TIP/SRM/IRM or PRM Calibration, Repair, and Maintenance	3.5	41	11	14
Recirculation Pump Seal Replacement[H]	1.5	23	7.8	11
Turbine Overhaul and Repair	0.20	21	6.2	14
Refueling Pool Decontamination	3.2	5.6	4.4	2

The wide range in the collective dose is due to the difference in:

A- The number of snubbers, type inspection, extent of repair, and location.
B- The extent of torus repair, inspection, and modification.
C- The scope of the In-Service Inspection program.
D- The number of CRDs rebuilt and replaced.
E- The difference in the number of valves, extent of repair, and location.
F- The scope of the inspection and the jet pump repair.
G- The number of MSIVs and the extent of the inspection and repair.
H- The number of recirculation pump seals replaced and the design of the seals.

TABLE 3-3 WESTINGHOUSE PRESSURIZED WATER REACTORS
COLLECTIVE DOSE SUMMARIES FOR OUTAGE HIGH-DOSE JOBS

Job Title	Collective Dose (man-rem) Minimum	Maximum	Average	Population Size
Snubber, Hanger, and Anchor Bolt Inspection and Repair[A]	0.30	580	110	21
Steam Generator Eddy Current Testing[B]	12	140	50	21
Reactor Disassembly/Assembly	12	120	48	23
Steam Generator Tube Plugging[C]	3.4	180	47	6
In-Service Inspection[D]	1.0	130	46	21
Plant Decontamination	5.0	67	45	15
Primary Valve Maintenance and Repair[E]	1.4	120	30	17
Scaffold Installation/Removal	0.50	62	30	4
Insulation Removal/Replacement	1.2	37	18	5
Reactor Coolant Pump Seal Replacement[F]	1.1	44	17	22
Steam Generator Manway Removal/Replacement[G]	4.4	51	15	18
Instrumentation Repair and Calibration	1.1	31	12	16
Chemical, Volume, and Control System Repair and Maintenance	0.80	37	11	14
Secondary Side of the Steam Generator Inspection and Repair[H]	2.3	41	11	19
Fuel Shuffle/Sipping and Inspections	3.6	16	9.2	15
Operations - Surveillance, Routines, and Valve Lineups	3.0	18	7.4	16
Cavity Decontamination	1.1	16	5.9	8
Pressurizer Valve Inspection, Testing, and Repair	0.30	21	5.5	15
Radwaste System Repair, Operation, and Maintenance	0.50	20	4.9	13
Residual Heat Removal System Repair and Maintenance	0.70	8.8	2.7	16

The wide range in the collective dose is due to the difference in:

- A- The number of snubbers, hangers, and anchor bolts; type inspection; extent of repair; and location.
- B- The number of steam generators entered, the type of ECT equipment used, and the number of tubes to be tested.
- C- The type of plug installed and the number of tubes plugged.
- D- The scope of the In-Service Inspection program.
- E- The number of valves, their location, and extent of repair.
- F- The number of RCP seals replaced and the seal design.
- G- The number of manways opened per steam generator, the number of steam generators, and the method of manway removal/replacement.
- H- The extent of the sludge lance and secondary side inspection program.

TABLE 3-4 COMBUSTION ENGINEERING PRESSURIZED WATER REACTORS
COLLECTIVE DOSE SUMMARIES FOR OUTAGE HIGH-DOSE JOBS

Job Title	Collective Dose (man-rem) Minimum	Maximum	Average	Population Size
Steam Generator Tube Plugging[A]	4.5	580	120	9
Reactor Disassembly/Assembly	20	160	68	13
Snubber, Hanger, and Anchor Bolt Inspection and Repair[B]	0.90	220	34	12
Steam Generator Eddy Current Testing[C]	3.1	140	31	16
In-Service Inspection[D]	0.58	49	24	14
Plant Decontamination	0.70	160	20	12
Reactor Coolant Pump Seal Replacement[E]	5.6	64	18	15
Operations - Surveillance, Routines, and Valve Lineups	7.0	22	13	6
Primary Valve Maintenance and Repair[F]	0.10	34	12	8
Secondary Side of the Steam Generator Inspection and Repair[G]	1.2	48	12	13
Steam Generator Manway Removal/Replacement[H]	1.5	26	9.9	15
Instrumentation Repair and Calibration	1.3	38	9.7	13
Insulation Removal/Replacement	2.6	14	7.6	4
Fuel Shuffle/Sipping and Inspections	2.2	15	7.0	12
Pressurizer Valve Inspection, Testing, and Repair	0.30	17	5.4	11
Cavity Decontamination	1.8	11	5.3	12
Chemical, Volume, and Control System Repair and Maintenance	0.61	8.3	4.8	3
Scaffold Installation/Removal	0.50	4.6	1.6	4
Residual Heat Removal Repairs and Maintenance	0.96	0.96	0.96	1

The wide range in the collective dose is due to the difference in:

- A- The type of plug installed and the number of tubes plugged.
- B- The number of snubbers, hangers, and anchor bolts; type inspection; extent of repair; and location.
- C- The number of steam generators entered, the type of ECT equipment used, and the number of tubes to be tested.
- D- The scope of the In-Service Inspection program.
- E- The number of RCP seals replaced and the seal design.
- F- The number of valves, their location and extent of repair.
- G- The extent of the sludge lance and secondary side inspection program.
- H- The number of manways opened per steam generator, the number of steam generators and the method of manway removal/replacement.

TABLE 3-5 BABCOCK AND WILCOX PRESSURIZED WATER REACTORS
COLLECTIVE DOSE SUMMARIES FOR OUTAGE HIGH-DOSE JOBS

Job Title	Collective Dose (man-rem) Minimum	Maximum	Average	Population Size
Reactor Disassembly/Assembly	14	54	36	8
Snubber, Hanger, and Anchor Bolt Inspection and Repair[A]	4.8	69	33	7
In-Service Inspection[B]	7.6	64	31	7
Steam Generator Eddy Current Testing[C]	7.3	60	24	8
Steam Generator Tube Plugging[D]	4.8	85	23	7
Primary Valve Maintenance and Repair[E]	6.3	27	17	5
Plant Decontamination	1.5	40	17	8
Operations - Surveillance, Routines, and Valve Lineups	5.1	23	15	8
Steam Generator Manway Removal/Replacement[F]	12	15	14	3
Low Pressure Injection Repair and Maintenance	7.4	27	14	5
Reactor Coolant Pump Seal Replacement[G]	3.1	19	11	4
Instrumentation Repair and Calibration	2.9	17	11	4
Fuel Shuffle/Sipping and Inspections	4.4	12	8.1	8
Insulation Removal/Replacement	0.4	18	6.2	4
Pressurizer Valve Inspection, Testing, and Repair	1.4	11	4.9	3
Secondary Steam Generator Inspection and Repair[H]	0.80	3.6	2.4	3

The wide range in the collective dose is due to the difference in:

A- The number of snubbers, hangers, and anchor bolts; type inspection; extent of repair; and location.
B- The scope of the In-Service Inspection program.
C- The number of steam generators entered, the type of ECT equipment used, and the number of tubes tested.
D- The type of plug installed and the number of tubes plugged.
E- The number of valves, their location, and extent of repair.
F- The number of manways opened per steam generator, the number of steam generators and the method of manway removal/replacement.
G- The number of RCP seals replaced and seal design.
H- The extent of the sludge lance and secondary side inspection program.

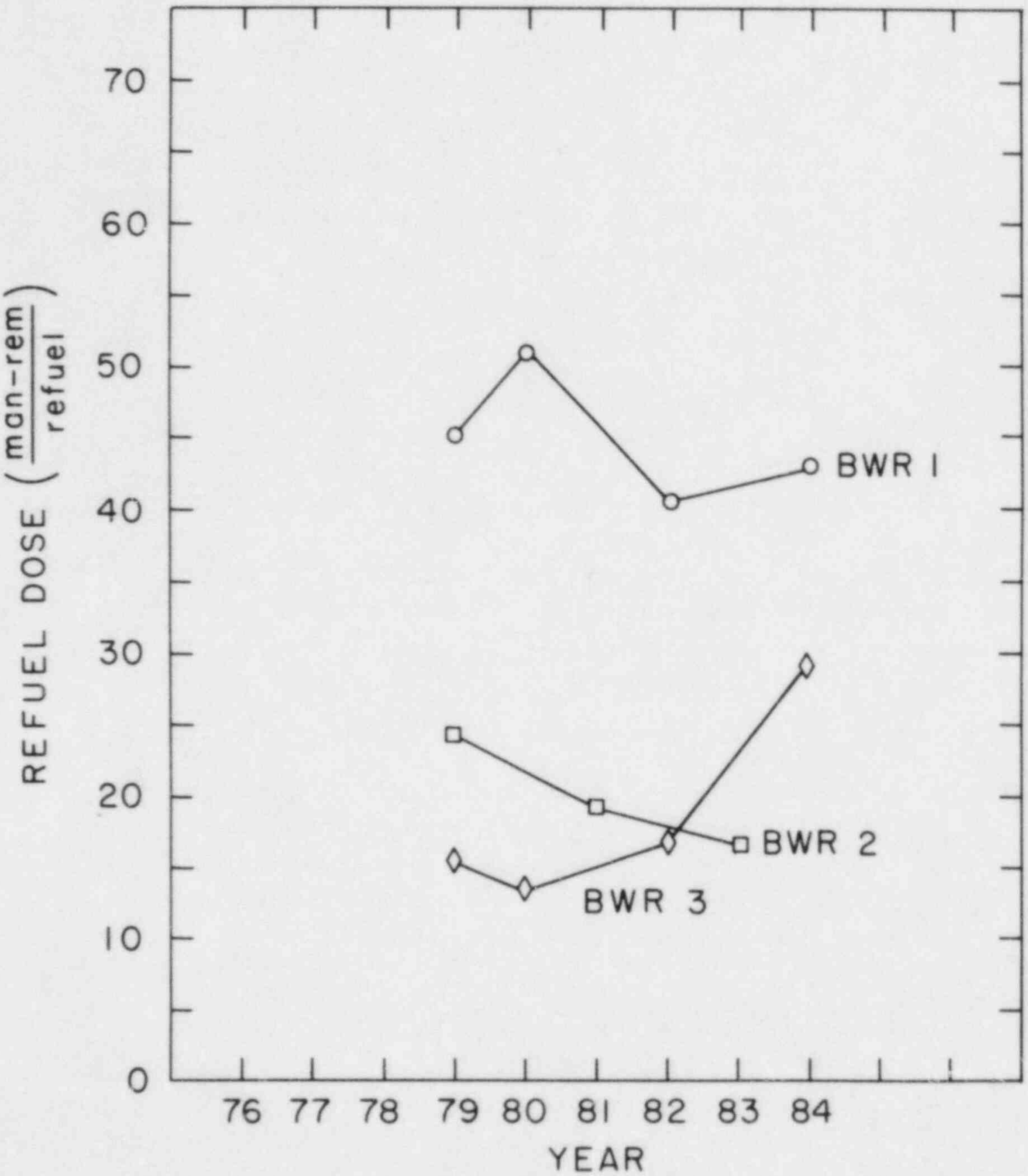

Figure 3-1 BWR Reactor Assembly/Disassembly Collective Dose Trends

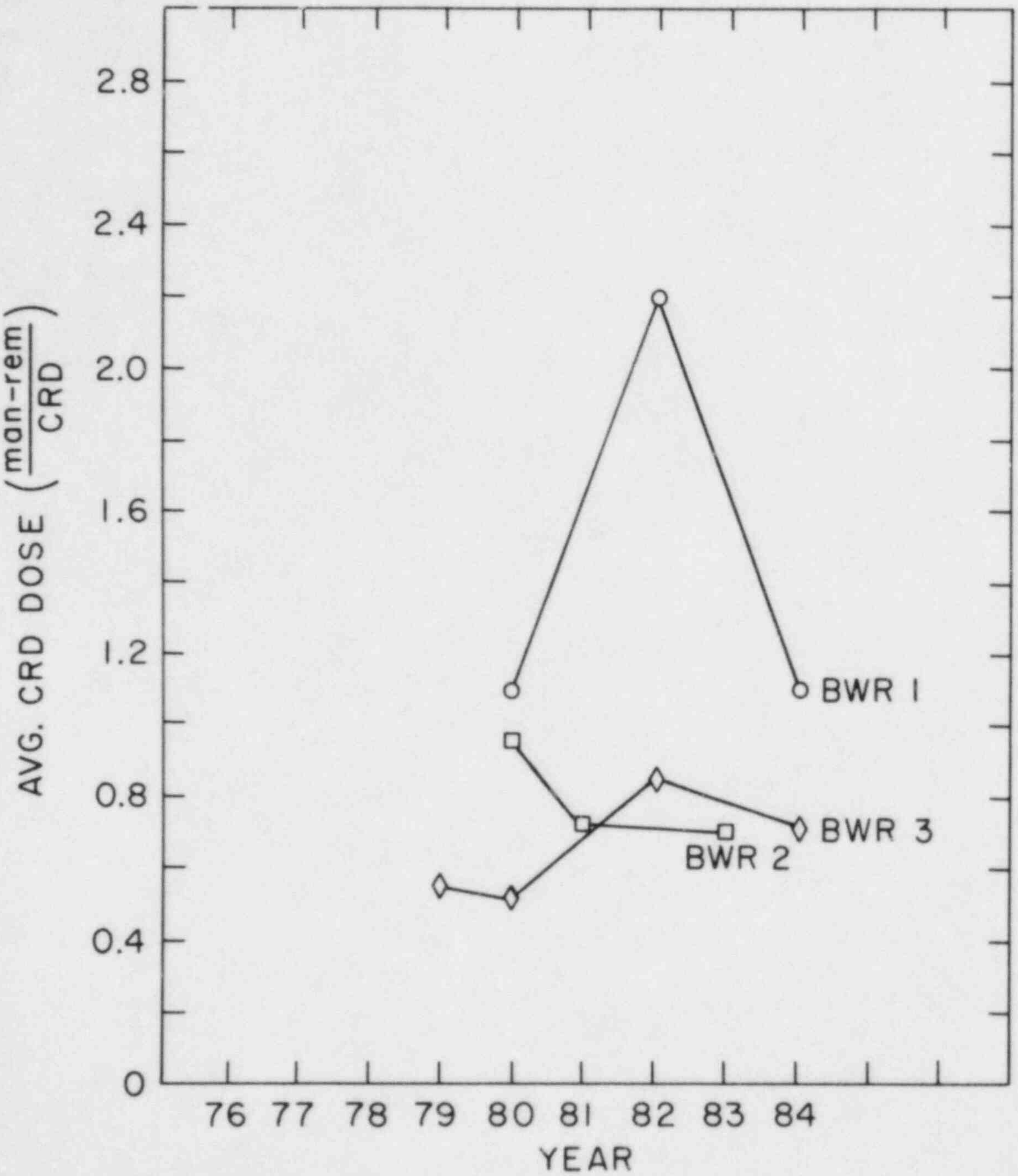

Figure 3-2 BWR CRD Removal, Rebuild and Replacement Collective Dose Trends

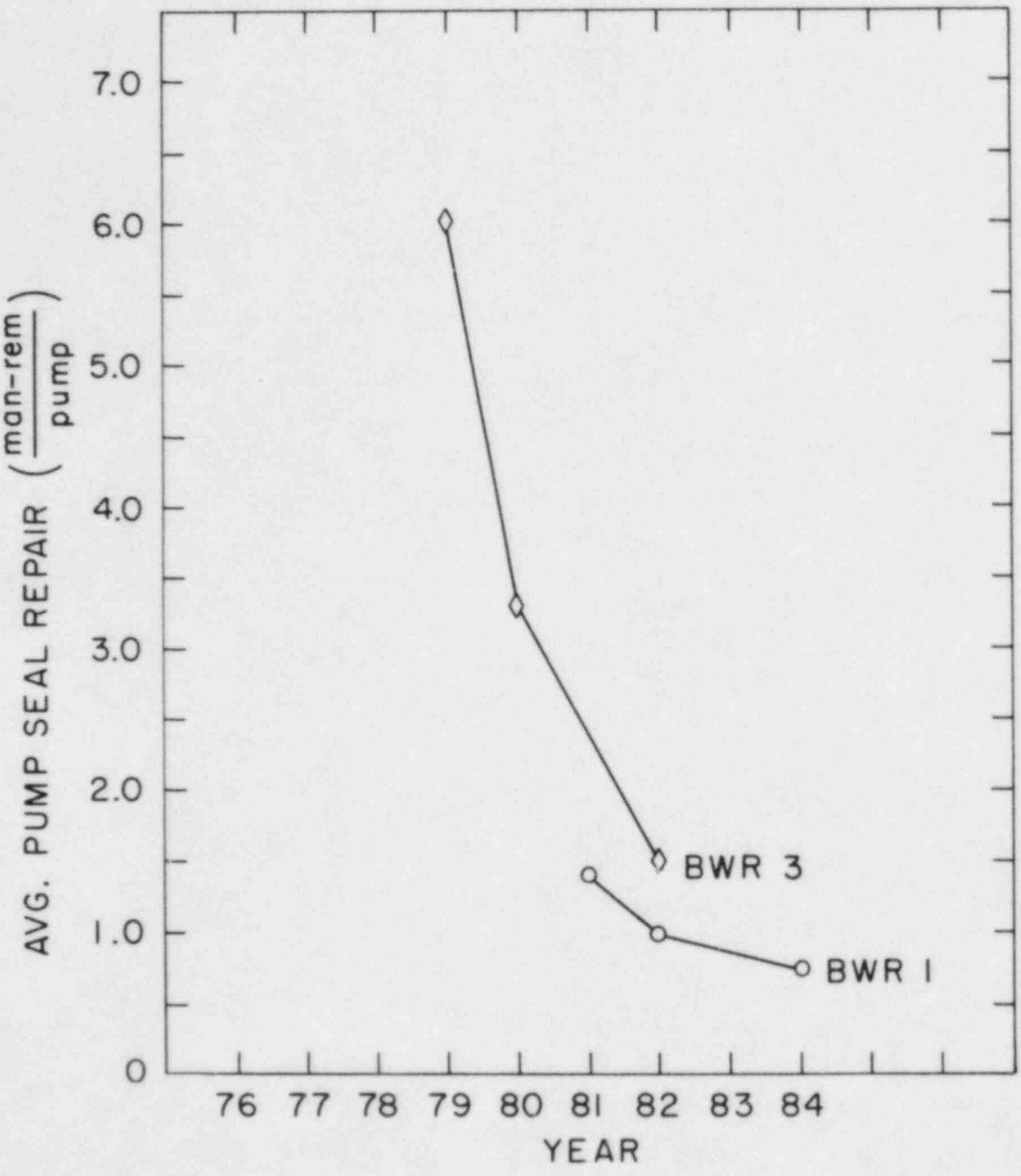

Figure 3-3 BWR Recirculation Pump Seal Replacement Collective Dose Trends

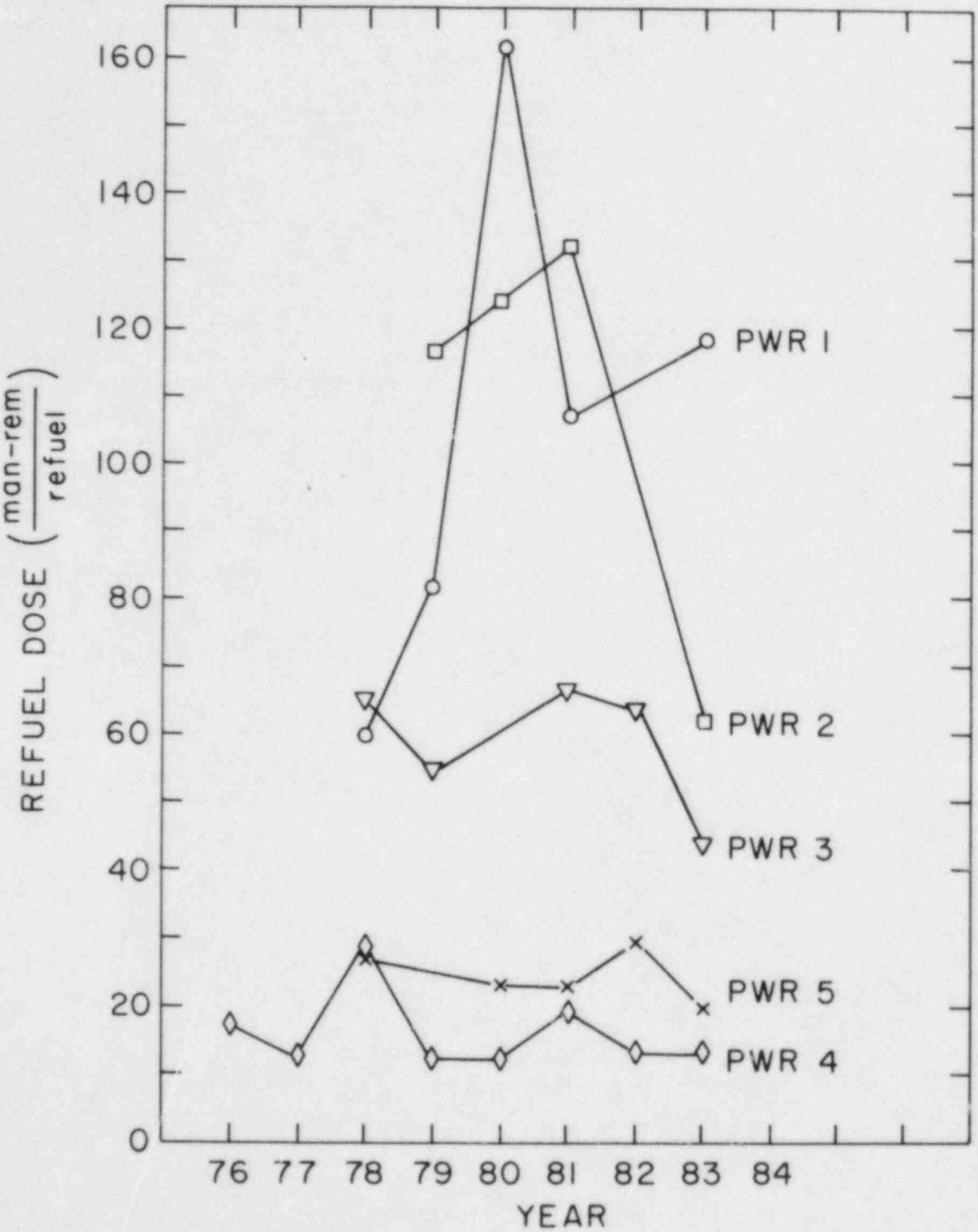

Figure 3-4 PWR Reactor Assembly/Disassembly
Collective Dose Trends

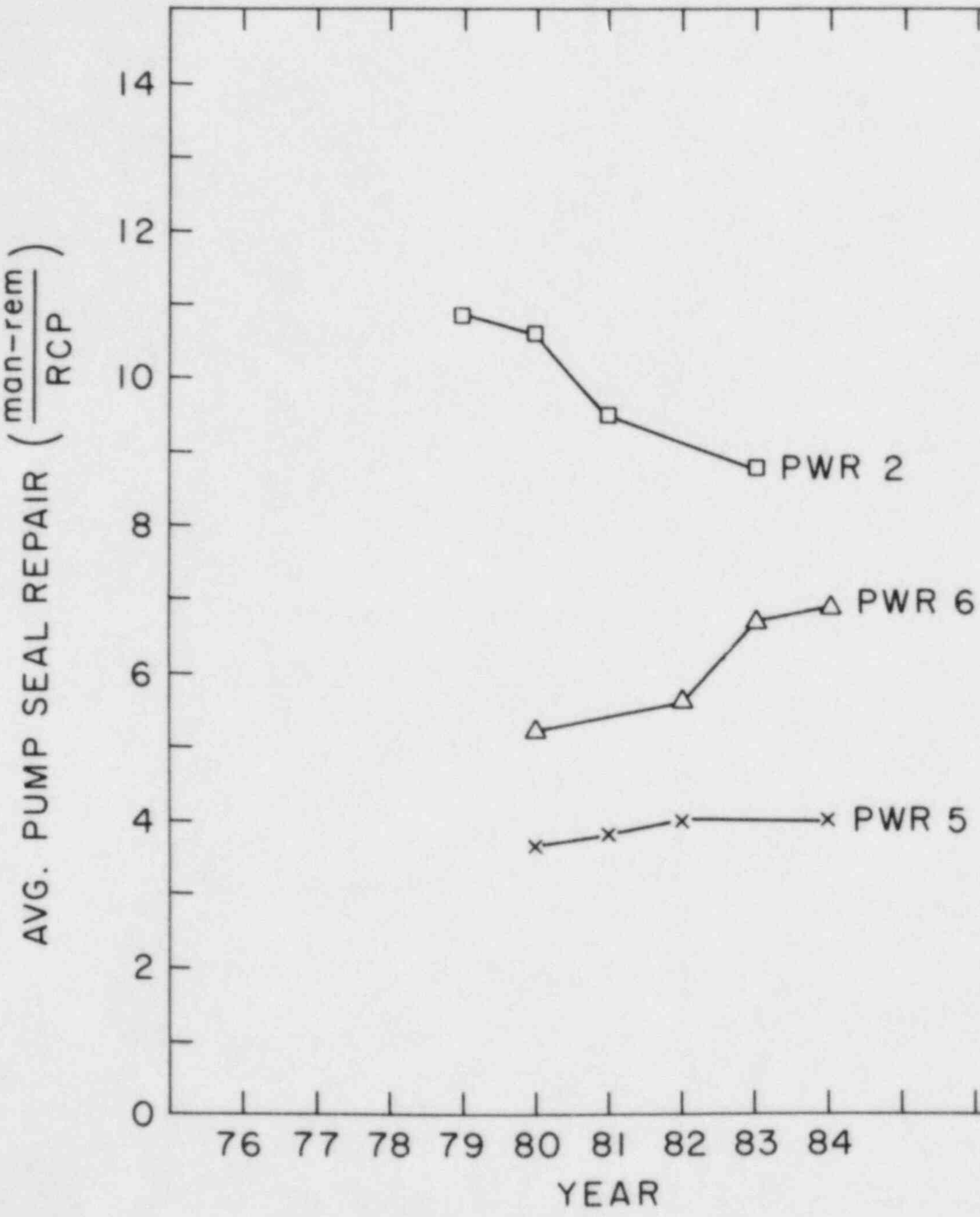

Figure 3-5 PWR Reactor Coolant Pump Seal Replacement Collective Dose Trends

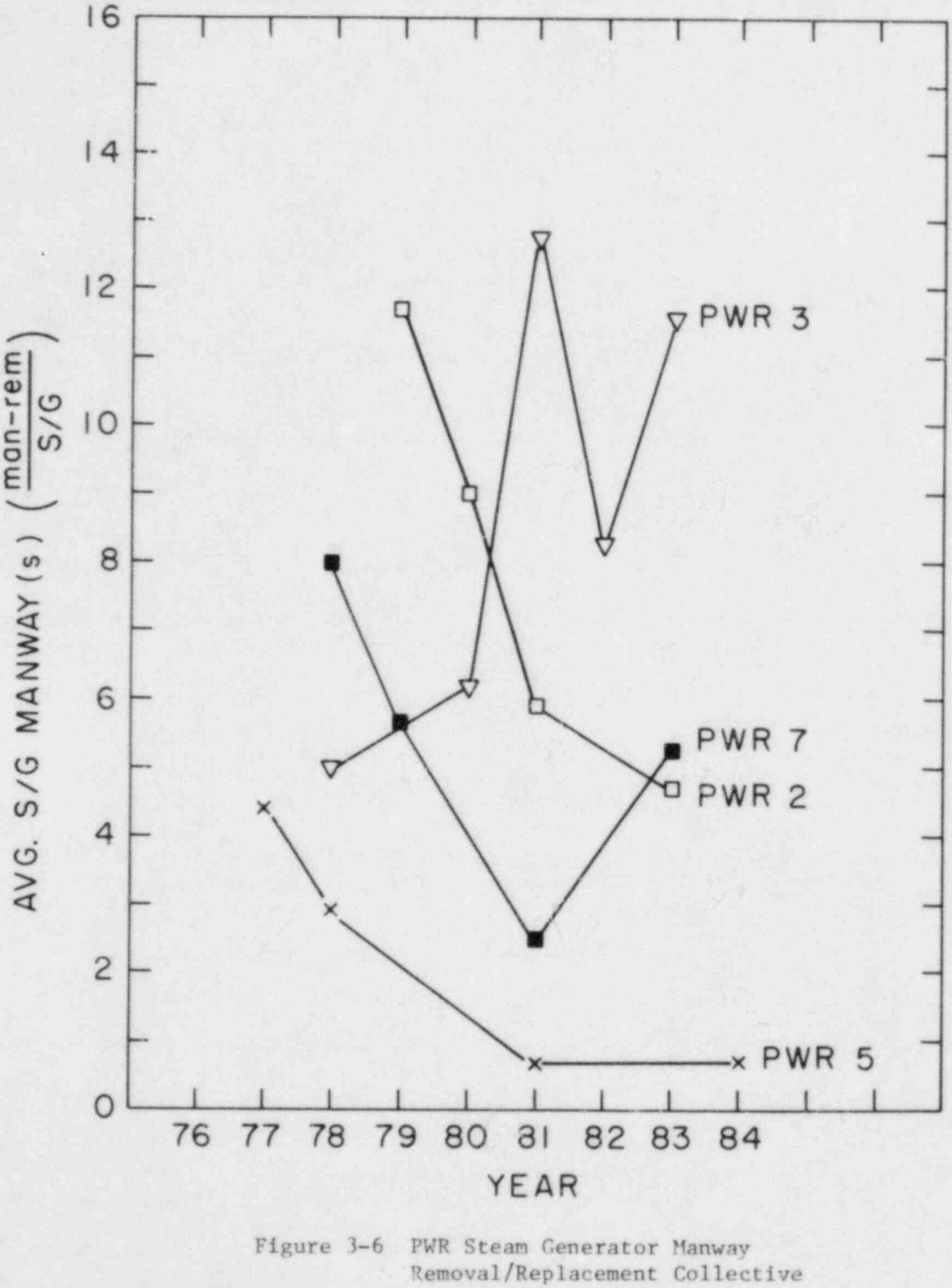

Figure 3-6 PWR Steam Generator Manway Removal/Replacement Collective Dose Trends

4. EQUIPMENT RELIABILITY

4.1 DESCRIPTION

Investigate the extent to which worker dose is factored into decisions as to whether high-reliability, low-maintenance equipment is utilized for initial design and modifications of nuclear power plants. Review nuclear plant reliability data as used in probabilistic risk analysis and determine the extent to which it is utilized in selecting components.

4.2 METHOD

To accomplish this objective, questionnaires were developed to determine to what extent component repair dose and equipment reliability data has been used by engineering and maintenance personnel for purposes of dose reduction during equipment selection. Interviews were performed with six architect engineers, ten utility engineers, ten maintenance supervisors, and ten health physicists.

To determine the extent to which worker dose is considered in equipment selection, the station personnel and architect engineers were questioned on:

- application of dose data during component selection,
- methodology used to collect and disseminate dose data,
- availability of component repair dose data, and
- application of dose data to preventive maintenance.

To determine the extent to which nuclear plant reliability data is utilized in equipment selection, the station personnel and architect engineers were questioned on:

- nature of the feedback loop on equipment reliability information,
- availability of nuclear plant reliability data (NPRD) information,
- application of NPRD to equipment selection, and
- application of NPRD to preventive maintenance.

Lastly, the extent to which station personnel have modified or replaced components which have caused high maintenance or repair doses was investigated.

4.3 FINDINGS

4.3.1 Component Dose Data

With regard to whether dose due to equipment repair and maintenance was considered during component selection, we found that it has been of secondary concern. Equipment selection is somewhat subjective. The major considerations were factors such as cost, availability, qualification to required specifications, past experiences and reputation of manufacturer, and use of equipment similar to existing equipment for purposes of inventory and training consolidation. The use of reliable or low-maintenance components is a general policy for selection of nuclear-grade equipment. However, high reliability is stressed for purposes of plant availability. Related reduction in repair dose along with labor savings is a secondary benefit. These benefits are rarely quantified for purposes of equipment selection.

The basic method which was used to collect dose data on component repair was via the radiation work permit (RWP). Four of the ten sites visited had the computer capability to collect and retrieve collective dose totals by component identification number. The health physics personnel from the ten sites visited could all collect component repair doses by manual retrieval of the associated RWPs. However, because of the large number of RWPs, this was performed only if requested by upper management, or by maintenance or engineering personnel.

One utility disseminated an annual report for each unit to engineering, which listed all component identification numbers and associated collective doses. However, these printouts were rarely used because of the difficulty of locating the desired component in the massive printout. In addition, the accuracy of the dose data was often questionable, since most RWPs do not cover the work associated with a single component. Rather, they are normally written to cover major work efforts.

All sites visited disseminated dose data for major components repair e.g. CRD rebuild, RCP repair, in their outage ALARA reports. The dose data in the Outage ALARA reports were readily available and could be easily extracted by maintenance and engineering personnel.

The application of component dose data to the improvement of preventive maintenance programs has been accomplished indirectly. High repair or maintenance doses caused by components have initiated engineering investigations or maintenance recommendations which have modified the preventive maintenance procedure or frequency. But of the sites visited, only one reviewed its component dose data for the express purpose of modifying its preventive maintenance program.

4.3.2 Equipment Reliability Data

With regard to the transfer of equipment reliability information from maintenance to engineering and the transfer of this information from utility engineers to the nuclear steam system suppliers (NSSS) and architect engineers (A/E), we found that this information flowed informally within the utility, but usually reached the A/E and NSSS only if they obtained it from site visits, resident A/E or NSSS engineer, or informal conversations with the utility personnel. In general, good communication existed on recurring equipment problems within the station. However, the degree of feedback on equipment reliability information between the station and corporate personnel varied greatly from utility to utility depending upon the rapport between corporate and station personnel. Information on equipment reliability was transferred to A/E and NSSS engineers during site visits or via conversations with their resident company engineer. A permanent site A/E or NSSS engineer was considered to be the most dependable source of information on plant equipment problems.

Four of the ten sites visited had NPRD summary reports available to station personnel. Other types of equipment reliability data and information that were available included: licensee event report summaries; NSSS and A/E firms equipment failure rate data; General Electric SILs reports; Westinghouse Technical Bulletins; computerized listings of equipment work request information; bulletins received through Nuclear Operators Maintenance Information Service (NOMIS); and several reports on equipment reliability.[5-7]

The application of NPRD summary report information to the equipment selection process has not yet been fully developed. On rare occasions station engineers have located component failure rate data to assist in the selection process. Two of the sites visited indicated that their corporate plant reliability and capacity groups did routinely review NPRD data and had on occasion notified the station of unreliable components.

Some problems with the use of NPRD summary report information, cited by the engineers, were: insufficient time to perform failure rate evaluations; overwhelming data base; suspect data base inaccuracies; superfluous information; and failure to report important factors related to equipment failure, e.g., operating environment, method of operation, and preventive maintenance practices.

Some improvements in the NPRD summary reports recommended by the engineers included: organization (by NSSS and vintage), production of periodic lists of problem components, improvement in the structure of the data, and transmittal of the data to the appropriate supervisor or engineer.

One out of the ten sites visited had used information from the NPRD summary report to improve its preventive maintenance program. Preventive maintenance procedures and frequency were developed from Technical Specification requirements and manufacturer recommendations or warranty requirements. Improvements in the preventive maintenance programs were based on: reports from mechanics, electricians, and instrumentation technicians; foremen's "gut feelings"; computerized work request repair and failure rate printouts; and licensee event reports and plant incident report recommendations.[8] Again, lack of time and difficulty in extracting the necessary data were among the reasons given for the failure to apply NPRD to the preventive maintenance programs.

It should be noted that the survey results mentioned above are indicative of the plants sampled and are not necessarily representative of the entire nuclear industry. The sites visited are considered to be progressive in terms of the extent of dose accountability and the degree of NPRD program implementation.

Lastly, a survey of components which were modified or replaced was conducted to determine the extent to which station personnel have modified or replaced unreliable equipment. Examples of some of the unreliable equipment modifications that reduced occupational dose and improved reliability are listed in Table 4-1:

TABLE 4-1 EXAMPLES OF EQUIPMENT MODIFIED OR REPLACED THAT REDUCED DOSE

- Charging Pumps
  - Replaced the variable speed belt drive motor with a DC drive motor
  - Modified plungers, sealers, and seal water supply system
  - Replaced existing pump shaft with a new design
  - Changed to an improved packing material

- Reactor Water Cleanup Pumps
  - Moved pump suction to cold side of heat exchanger
  - Installed inline flush capability, monorail, and special RWCP rebuild room to facilitate repair
  - Added coolers to seal cooling water

- Recirculation and Reactor Coolant Pumps
  - Changed individual seals to seal cartridge
  - Installed quick disconnect connectors on motor electrical feed lines

- Boron Recovery Pumps
  - Changed canned pumps to mechanical seal type
  - Changed seal cooling water to a supply with low boron concentration

- Fuel Transfer Tube Flange
  - Modified flange to improve seal

- Drain Lines
  - Changed from carbon steel to stainless steel
  - Added hydrolase or "snake" flanges

- Valves
  - Changed to an improved packing material
  - Replaced the following valves with a more reliable brand:
  - Pressurizer pilot operator safety relief valves (PORV)
  - Main steam safety relief valves (including target rock)
  - Hot and cold leg isolation valves
  - Main steam isolation valves (MSIV)
  - Pressurizer spray valves

- Transmitter
  - Replaced the following transmitters with a more reliable brand:
  - Incore termocouples
  - Steam generator level transmitters
  - Primary coolant temperature, flow, and pressure

- Heaters
  - Replaced steam heaters with electrical heaters

- Pumps
  - Changed motor from belt to DC drive
  - Changed cooling water source or added coolers to seal water supply
  - Provide inline flushing to clear pump
  - Developed new gaskets, seals, or seal cartridges

4.3.3 Equipment Reliability Summary and Recommendations

Data on dose received during component maintenance is rarely quantified for purposes of equipment selection. Only four of the plants visited could provide automated sorts of radiation work permits to extract component repair dose. These data can be extracted manually, but due to the large number of RWPs it is difficult to extract and therefore rarely performed. Annual and outage ALARA reports containing data on selected component repair dose were considered the best method to disseminate these data for use in the equipment selection process.

Equipment reliability data are rarely quantified for use in the equipment selection process. Equipment reliability data are available but specific component data are difficult to extract. NPRD summary reports were available at four of the plants visited but were rarely used owing to difficulties in extracting the required information for a specific component.

It was found that good communication existed concerning unreliable equipment which contributed to increased dose. Numerous examples of unreliable equipment that were modified or replaced were noted. However, the resulting dose savings associated with the modification or replacement was of secondary concern compared to concerns for system availability and the problems caused by repeated repairs.

To facilitate the use of data on component repair dose and equipment reliability, this information must be made readily available. This can best be accomplished by merging information from maintenance work requests with information from health physics radiation work permits. An automated component-sort capability would allow engineers to extract the needed information for use in equipment selection, e.g., data on component failure frequency, repair times, repair dose, impact on system, plant availability, etc.

In addition it is recommended that the implementation of the NPRD programs at the operating nuclear power plants be strengthened. Improvements are also needed in the NPRD summary reports to facilitate the extraction of data for equipment selection. Improvements that were suggested are organizing equipment by system, vintage, and NSSS; producing periodic lists of problem components; improving the overall structure of the data; and transmitting the information to the appropriate supervisor or engineer.

5. RADIOACTIVE WASTE HANDLING

5.1 DESCRIPTION

Review present procedures and equipment used in handling radwaste packages on site. Make recommendations for improved radwaste handling methods with the objective of reducing occupational dose.

5.2 METHOD

Initially a literature review was performed to identify past efforts in this area. Numerous studies have been reported on radioactive waste volume reduction.[9-12] However, very few of the studies included a review of radwaste dose-reduction techniques at nuclear power plants.[13] Numerous radwaste handling improvements have been implemented at each nuclear facility

over the course of its operation. The objective of this task was to examine these improvements and to recommend the most beneficial radwaste handling equipment and procedure changes which would reduce occupational dose. Areas investigated during the plant visits included administrative policy and practices, radioactive waste management organization, waste handling training and procedures, equipment and facility modifications, dose-reduction improvements, and dose associated with radioactive waste-handling operations.

The types of waste investigated included bead and powdered resins, evaporator bottoms, tank and filter sludge, spent filters/cartridges, and dry active waste. The investigation was restricted to the packaging, the prepare-ready-store, and the truck-loading stages of radwaste processing. The major radwaste improvements were investigated using the preselected list of equipment and procedural dose-reduction improvements shown in Table 5-1. The radwaste supervisor and ALARA coordinator reviewed the list of dose-reduction improvements and indicated those utilized and whether they considered them successful for dose reduction. In addition, innovative and unique dose-reduction improvements not on our radwaste improvement list were collected.

5.3 FINDINGS

5.3.1 Dose-Reduction Improvement Ratings

The success rate and the number of plants which utilized the radwaste dose-reduction improvements are indicated in Table 5-1. The radwaste-handling improvements that were considered the most successful for dose-reduction, i.e., those having a 100% success rate, were radwaste handlers, management policy and program, leaded glass and water windows, shielded fork truck, and remote drum decontamination. The dose-reduction improvements that were considered the most popular, i.e., utilized by eight or more plants, were radwaste foreman, shielded drums and transfer casks, new compactor, and storage segregation by radiation level and waste type.

TABLE 5-1 EXAMPLES OF RADWASTE-HANDLING DOSE-REDUCTION IMPROVEMENTS

Radwaste Improvement		Success/Plants that Utilized*
1.	Radwaste Handlers	5/5
2.	Management Policy and Program	5/5
3.	Leaded Glass or Water Windows	4/4
4.	Shielded Fork Truck	4/4
5.	Remote Drum Decontamination	2/2
6.	Radwaste Foreman	8/9
7.	New Compactor	7/8
8.	Shielded Storage Bays and Doors	6/7
9.	Remote Visual Monitoring	6/7
10.	Mobile Solidification by Radiation & Type	4/5
11.	Shielded Drum or Transfer Cask	7/9
12.	Storage Segregation by Radiation & Type	6/8
13.	Radwaste Engineer	5/7
14.	Remote Level, Radiation, and Contamination Monitoring	5/7
15.	Remote Mixing and Capping Stations	4/6
16.	Optimized Use of Filter & Resins	3/5
17.	Trash-Sorting Area	3/5

*Ten plants surveyed. Fraction indicates the number of plants that reported the improvement as being successful for dose reduction over the total number of plants that utilized it.

5.3.2 Radwaste Dose-Reduction Improvements

Innovative, unique changes in radwaste facilities, procedures or equipment which have reduced occupational dose from radwaste operations are listed below by radwaste processing stage, namely, packaging, prepare/store/ready, and truck loading. The radwaste dose-reduction improvements for the packaging stage have been further subdivided by waste type, namely, resins, evaporator bottoms/sludge, spent filters/cartridges, and dry active waste.

5.3.2.1 Radwaste packaging dose-reduction improvements

Resins:

- Dewatering of resins in a shielded area or shielded container
- Slurrying of resin directly into liner inside truck cask
- Slurry resin directly into liner inside spent resin storage shield
- Solidification in 55-gallon drums with remote-control automated drumming facility
- High pressure water flush to clean or unclog resin slurry lines
- Circular path on resin slurry line to allow for continuous resin movement during interruptions
- Filtered dewatering lines to reduce sludge in liquid waste tanks
- Shield wall near liner or drum fill station
- Transfer shield for high integrity container or high level drums
- Remote TV monitoring of resin level in liner
- Remote radiation detector readout for liner dose rate measurements
- Remote smearing pole to obtain smearable contamination on liner
- Remote digital thermocouple for liner temperature measurements
- Quick disconnect hose and shackle connectors
- Headset communication between personnel involved in slurring and dewatering of liners
- Mock-up training for personnel connecting and disconnecting hoses, shackles, and lids on liner and cask

Evaporator bottoms/sludge:

- Crystallizer, extruder, or louver evaporator instead of evaporators
- Remote-control automated drumming, mixing, capping, and monitoring stations
- Backflushable filters in floor drain lines
- Bulk solidification into high integrity containers

Spent filters/cartridges:

- Removal of entire filter cylinder instead of individual filters
- Bulk packaging into a high integrity container
- Lead or concrete lined drums
- Filter transfer shield for highly radioactive filters
- Underwater handling and loading into cask or transfer shield
- Chute to remotely add filter to shielded 55-gallon drum or high integrity containers
- Chute to remotely add cement to loaded 55-gallon drum
- Spent filter storage area located close to the filter banks

Dry active waste

- o Incinerator
- o Shredder
- o High compression compactor
- o Anti-springback disc for 55-gallon drums
- o Bins or boxes instead of drums
- o Addition of heaters and ventilation to compactor
- o Washable protective clothing instead of disposables
- o Segregation of unpackaged waste by dose rate
- o Underwater cask loading capability for extremely radioactive waste
- o Established a de minimis level for waste

5.3.2.2 Radwaste prepare/store/ready dose-reduction improvements

- o Storage of solidified drums on unipack pallets to reduce drum movement and storage
- o Solidification of waste in high integrity container to reduce number of packages to be moved and stored
- o Shipment of waste upon packaging or prior to storage to reduce movement and storage
- o Storage of waste in shielded bays with movable shield doors
- o Segregated storage based on radwaste type and dose rates
- o Automatic remote drum decon machine
- o Remote banding, labeling, and security seal machine
- o Overhead crane and shielded fork lift to move packages
- o Crane operator shield wall with water or lead glass windows
- o Reduced personnel occupancy in the path of radwaste during movement

5.3.2.3 Radwaste truck-loading dose-reduction improvements

- o Heated truck-loading bay with auxiliary lift platform
- o Storage of drums or pallets on elevated loading platform
- o Truck-loading ramp to allow fork truck entry into truck trailer
- o Reduced personnel occupancy in the vicinity of the truck
- o Higher dose-rate packages loaded in center of pallets or truck bed

5.3.3 Recommended Radwaste Handling Improvements

The most beneficial radwaste handling equipment changes to reduce occupational dose have centered around bulk solidification, waste evaporation improvements, remote-control automated drumming facilities, and dry active waste volume reducing devices.

The resin packaging methods which appeared most effective to the minimization of occupational dose to radwaste handlers were dewatering or solidification in high-integrity containers or solidification in 55-gallon drums via a remote control automated drumming facility. For evaporator bottoms and sludge, the methods which appeared to be the least dose intensive were bulk solidification in high-integrity containers or remote-control automated drumming following crystalization, extrusion or louver evaporation. For spent filters and cartridges, remote and shielded transfer into high-integrity containers appeared to be the best packaging technique. Lastly, for dry active waste, the two methods which showed promise were incineration with solidification of ash in drums, or use of a shredder with high compaction in bins or boxes.

It is important to note that the equipment and methods for packaging which have been recommended above must be designed to be reliable, and to be efficient and easy to operate, maintain, and repair, e.g., well shielded, remotely operated, easily decontaminated, modular easy-to-remove components, and readily accessible. In order to obtain lower doses to radwaste operators and handlers than those now being experienced with conventional equipment and methods, improved radwaste systems must be designed utilizing ALARA considerations.

6. ALARA INCENTIVES AND ALARA PROGRAMS

6.1 DESCRIPTION

Identify, describe and evaluate current incentives for reducing the collective occupational dose in the nuclear industry. Make recommendations for positive steps that NRC or industry organizations could take to provide additional incentives. Describe the present status of ALARA programs and determine the impact of the ALARA incentives on the plant ALARA programs.

6.2 METHOD

An initial list of ALARA incentives was prepared via a literature review. Then several utility managers and health physicists were contacted. Based on their suggestions, changes and additions were made to the list. The items identified formed the list of Manager ALARA Incentives and Worker ALARA Awareness Techniques shown in Table 6-1 and Table 6-2, respectively. Ten plant managers, ten maintenance supervisors, and ten radiation protection managers were asked to rate the relative priorities and to indicate if the incentive or technique was utilized at their plant.

Next, each plant manager and radiation protection manager was asked "What are your major motivators or incentives to reduce occupational doses?", "What would you like to see the NRC do to promote and regulate ALARA?" and "What would you like to see INPO do to promote and evaluate ALARA?"

Lastly, the key components of an ALARA program were examined. A listing of the key components was prepared (see Table 6.3) from NUREG CR-3254 entitled "Licensee Programs for Maintaining Occupational Radiation ALARA", (14) and a paper that was given on the topic at the 1982 Westinghouse REM Seminar.(15) Each component shown in Table 6-3 was rated by ten radiation protection managers and ten ALARA coordinators. They assigned relative priorities and indicated if their plant utilized the ALARA program key component.

6.3 FINDINGS

6.3.1 Alara Incentives

The relative priority and the number of plants which utilized these manager ALARA incentives are indicated in Table 6-1.

TABLE 6-1 MANAGER ALARA INCENTIVES

Manager's ALARA Incentives	Priority[a] High	Medium	Low	Plants that Utilized[b]
1. Increased Usage of Experienced Workers	26	2	2	9
2. Improved Personnel Relations Due to Management's Concern for Health & Safety	25	4	1	10
3. Beneficial Performance Review for Meeting Performance Goal in Dose Reduction	22	7	1	9
4. Monetary Savings from Critical Path & Labor Savings	23	1	6	8
5. Humanitarian Considerations	21	6	3	10
6. Decreased Usage of Contractors	21	2	7	6
7. Avoid Inspection Findings for Not Complying with FSAR ALARA Requirements	18	9	3	8
8. Avoid Probable Causation Liability Suits	15	12	3	5
9. National Reputation for Low Plant Doses	16	7	7	7
10. Good Public Relations	14	8	8	7
11. Recognition for Receiving INPO's Good Practice in ALARA	11	7	12	6

[a] Thirty plant personnel rated the priority of the incentives.
[b] Ten plants visited.

The major motivators for a manager to reduce workers' dose appeared to be based on humanitarian and monetary considerations. The highly rated ALARA incentives which showed concern for the welfare of their fellow workers were:

1. Increased usage of experienced utility or local contractor personnel due to lower accumulated dose per worker,
2. Improved employee attitude and relations due to management's concern for workers' safety, and
3. Fundamental humanitarian consideration for the safety of fellow employees.

The highly rated incentives which reflected monetary concerns were:

1. Beneficial manager performance review, i.e. annual salary adjustment for the successful accomplishment of department or station's goal in dose reduction, and
2. Monetary savings from critical path and labor savings resulting from ALARA preplanning efforts.

With regard to the question "What are your major motivators or incentives to reduce occupational dose?" The two most popular answers received from the plant manager and radiation protection manager were: 1) "It's part of our business (my job)," and 2) "To protect the people that work here." These answers typify managements' posture to this question. They indicated that the major motivator is a basic human desire to protect other people and that the practice of reducing occupational doses to as low as is reasonably achievable levels is inherent to nuclear power as it has been since its inception.

The responses to the question "What would you like to see the NRC do to promote and regulate ALARA?" were: They generally felt that the NRC should require licensees to maintain occupational doses ALARA, but should not regulate this area in a percriptive way. The majority stated that the NRC should continue its research in this area and provide information on good ALARA programs, based on observations at utilities. Utility managers and engineers must be allowed to evaluate these recommended improvements for cost-effectiveness at their plant. Five of the twenty managers stated that to promote ALARA, the NRC should consider occupational dose in their value-impact analysis for backfits and modifications.

The plant managers and radiation protection supervisors responses to the question "What would you like to see INPO do to promote and evaluate ALARA?" were: The majority felt that INPO should collect dose-reduction information during their evaluations at member utilities and disseminate "good ALARA practices".

Suggestions for how INPO could promote ALARA included: 1) provide guidance and assistance, 2) disseminate good ALARA practices via meetings and "good practice listings," 3) conduct meetings with INPO ALARA specialists and station ALARA coordinators, and 4) provide access to a computer data base on job doses and dose-reduction techniques.

The relative priority and the number of plants which utilized these worker ALARA awareness techniques are indicated in Table 6-2.

TABLE 6-2 WORKER ALARA AWARENESS TECHNIQUES

Worker ALARA Awareness Techniques	High	Priority[a] Medium	Low	Plants that Utilized[b]
1. Worker Involvement in ALARA Job Reviews	24	5	1	9
2. Visible ALARA Coordinator	23	3	4	9
3. Publicizing ALARA Suggestion Implementation	19	8	3	7
4. Worker ALARA Suggestion Program and Awards	18	8	4	7
5. Publicize Workers Exposure and Plant Dose vs. Annual Goal	14	9	7	6
6. Visible ALARA Office	7	8	15	3
7. ALARA Posters	6	15	9	7
8. ALARA T-shirts & hats	7	4	19	3

[a] Thirty plant personnel rated the priority of the techniques.
[b] Ten plants visited.

The major motivators for workers to reduce their accumulated dose included: radiation risk, prestige, recognition, sense of involvement, management concern, feedback (both positive and negative) and rewards. The four worker ALARA awareness techniques receiving the highest priority ratings and involving the aforementioned motivators are:

1. Involving workers in performing ALARA job reviews,
2. Having an ALARA coordinator who is visible to the workers,
3. Providing an ALARA suggestion program with awards, and
4. Publicizing the implementation worker ALARA suggestions.

Dose-reduction attitudes are developed by: training workers about radiation risks and the ALARA philosophy, teaching them how to reduce dose and the spread of contamination, and impressing upon them how they will benefit from this. Successful worker benefits (rewards) reported during the plant visits were:

1. Day off with pay;
2. Savings bond;
3. Front row reserved parking space;
4. Picture in the plant newsletter; and
5. ALARA T-shirts, hats, or pens.

6.3.2. Positive Steps for ALARA Awareness

The positive step that industry should take to provide additional dose-reduction incentives is to develop ALARA awareness in managers and workers. The development of ALARA awareness in managers requires ALARA training and the awareness of dose reduction's humanitarian and monetary motivators. Managers and supervisors must support and promote ALARA so that their ALARA attitude can be instilled in the workers. The development of ALARA awareness in workers requires ALARA training, the provision of the aforementioned motivators, and the application of the worker ALARA awareness techniques listed in Table 6-2.

The positive steps that INPO should take to provide additional dose-reduction incentives are to disseminate "good ALARA practices," provide guidance, and lend assistance to station personnel.

The positive steps that the NRC should take are to require licensees to maintain occupational doses ALARA, to continue dose-reduction research, and to provide guidelines and information on beneficial dose-reduction techniques. In addition, the NRC's present effort to improve on value-impact analysis of backfits and modifications should be continued since this will prevent future increases in occupational doses.

6.3.3 ALARA Program Status

The relative priority and the number of plants which utilized the ALARA program key components are indicated on Table 6-3.

It should be noted that the plants surveyed were selected because they could perform computerized retrieval of job-related doses. This capability is indicative of a progressive ALARA program. Therefore, the status of ALARA programs depicted by this survey is not representative of all U.S. nuclear plant ALARA programs, but is more indicative of matured programs.

TABLE 6-3 ALARA PROGRAM KEY COMPONENTS

ALARA Program Component	Priority[a] High	Medium	Low	Plants that Utilized[b]
1. ALARA Policy and Management Commitment	19	0	1	10
2. ALARA Database System	19	0	1	10
3. ALARA Job Review	18	2	0	10
4. ALARA Design Reviews	18	2	0	8
5. ALARA Coordinator	18	0	2	9
6. Goals and Tracking Systems	17	3	0	10
7. H.P. Technician ALARA training	17	3	0	7
8. Craft Job Specific ALARA Training	17	1	2	8
9. Engineer ALARA Training	17	1	2	4
10. Annual or Outage ALARA Report	14	6	0	10
11. General Employee ALARA Training	14	6	0	8
12. ALARA Committee	14	3	3	9
13. ALARA Suggestion Program	14	4	2	7
14. ALARA Organization & Responsibilities	12	4	3	8
15. ALARA Program Evaluation & Audit	11	7	2	7
16. Job Specific ALARA Procedures	11	4	5	3
17. Administrator ALARA Training	9	5	6	5
18. Cost/Benefit Methodology for Man-rem Savings	8	7	5	5

[a] Twenty plant personnel rated priority of components.
[b] Ten plants surveyed.

As indicated in Table 6-3, the majority of the key components were utilized by most of the plants surveyed. Brief review of the programs revealed that the development of ALARA programs has been somewhat coordinated, owing to the similarity of their structures. However, much variation in the degree of implementation of individual components was observed.

For example, some stations stressed ALARA job review, while others stressed goals, data base, and tracking systems. Another station had a strong ALARA committee and ALARA suggestion program but did very little ALARA training. It appeared that the extent of a program's emphasis was based on such factors as the experience and training of the ALARA coordinator; the historical

development of the program; the attitudes and rapport between health physics and station personnel; and the degree of management support.

An industry-funded organization such as the Institute for Nuclear Power Operations (INPO) should assist in properly directing the emphasis of the various components of the ALARA program to reflect the needs of the individual plant. The ALARA program components which were found to require coordination and guidance were ALARA data base systems, ALARA design reviews, radiological goals and tracking system, ALARA program evaluation, high-dose job good practices, and cost-effectiveness methodologies for dose-reduction modifications.

A strong commitment to ALARA was observed during most interviews with managers and supervisors. Maintenance supervisors were the most notable exception due to an apparent need to focus attention on plant availability and outage schedules. In general, the stations surveyed had well-structured ALARA programs, but the degree of implementation of some key components required improvement.

The ALARA Program Key Components which received the highest priority rating from the ten radiation protection managers and ten ALARA coordinators were:

1. ALARA Policy and Management Commitment:
   A policy statement signed by upper management which documents managements policy and commitment to the ALARA philosophy.

2. ALARA Data Base and Goals and Tracking System:
   A system to store radiological data and produce needed ALARA data summaries in a timely fashion. Examples of ALARA goal to be tracked are: station annual collective dose, department annual or quarterly collective dose, outage collective dose, and job dose totals. Examples of other ALARA data summaries are: workgroup internal and external dose; job, system, component, and area dose totals; shielding dose-reduction factors; decontamination factors; and personnel and area external contamination incidents.

3. ALARA Job Review:
   A systematic pre- and post-job review of high-dose jobs to ensure that ALARA controls are exercised and documented.

4. ALARA Design Review:
   A systematic pre-design review of equipment, design, and construction to ensure that ALARA design considerations are incorporated and documented into radiologically significant backfits and modifications.

5. ALARA Coordinator:
   An individual whose responsibility is to coordinate activities and make recommendations which will reduce occupational and population doses to as low as is reasonably achievable levels.

6. Goals and Tracking Systems, see 2 above.

7. H.P. Technician ALARA Training:
   This training should include:
   - Federal regulations and regulatory guides,
   - ALARA concepts,
   - ALARA program components,
   - ALARA responsibilities and incentives,
   - ALARA job review and job coverage, and
   - Dose-reduction techniques and job/craft specific instructions to reduce dose.

8. Craft Job Specific ALARA Training:
   This training should include:
   - ALARA concept,
   - ALARA program overview,
   - ALARA responsibility and incentives,and
   - Job/craft specific instructions to reduce dose and the spread of radioactivity.

9. Engineer ALARA Training:
   This training should include:
   - Federal regulations and regulatory guides,
   - ALARA concept and incentives,
   - ALARA program overview,
   - ALARA design reviews and ALARA design considerations,
   - ALARA job reviews and dose reduction techniques, and
   - Cost-effectiveness evaluations.

With regard to the impact of ALARA incentives on ALARA programs, it was evident that the strength and success of the station ALARA programs were directly related to the attitudes of station personnel towards ALARA, and to the financial and manpower commitment of management to the ALARA cause.

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APPENDIX A

BWR REPETITIVE HIGH-DOSE JOB DOSE-REDUCTION DATA SHEETS

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #1

JOB TITLE: **CRD Removal/Rebuild and Replacement**

JOB DESCRIPTION:

Control rod drive overhaul includes electrical disconnect; unlatching of CRDs in vessel or under vessel; CRD removal, and transfer to rebuild room; control rod drive decon, rebuild, inspection, replacement and reconnection. Excludes CRD friction testing and CRD or hydraulics modifications.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	6.3	230	60

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Use lead pig to shield spud end or shielded transfer cart
- o Use TV monitor for remote HP coverage and supervision under the vessel and in CRD rebuild room
- o Rinse off drive and remove spud filters underwater or with remote tools as soon as possible
- o Shield and periodically hydrolase CRD rebuild room drain line
- o Provide stainless steel sloped drain line in CRD rebuild room
- o Store spud filters and CRD waste in shielded drums or shielded high level storage area
- o Remove CRD waste as soon as possible
- o Decon ultrasonic sinks and CRD flush tanks periodically
- o Flood and shield reactor sump under the vessel
- o Shield CRD storage racks or drives with lead blanket during storage outside rebuild room
- o Transfer drives from undervessel to CRD rebuild room during periods of low traffic

Timesaving Techniques:

- o Unlatch control rods from refuel floor instead of from under the vessel
- o Have mockup of the bottom of the vessel and train on removal and installation of CRDs
- o Perform mockup training of rebuilding using new CRDs
- o Use testing rig to pretest rebuilt CRD before replacing
- o Provide large and efficiently laid out rebuild room
- o Use electric hoist with quick disconnect lifting rigs to transfer CRDs
- o Use pneumatic wrenches to remove drives

- Use two shielded transfer carts ... one for the drywell, the other from drywell to rebuild room
- Install monorail in rebuild room

Contamination-Reduction Techniques:

- Use enclosed and ventilated CRD rebuild room
- Use CRD transfer and containment cart
- Place CRD contamination control bag on spud end
- Put plastic and/or paper along CRD transfer path
- Enclose CRD rebuild room and CRD storage area with plastic or aluminum wall
- Rebuild drives in a CRD "doghouse" containment or in an underwater rebuild tank
- Use glove bags to remove spud filters
- Use ultrasonic sinks or flush tanks to clean drives
- Use long gloves and plastic suit for removing drives from under vessel
- Ventilate disassembly table, spray CRDs, and decon table periodically

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #2

JOB TITLE: **Fuel Shuffle, Sipping, and Inspection**

JOB DESCRIPTION:

Fuel shuffle, fuel sipping, and fuel inspection includes new fuel receipt, inspection and storage, dry and wet checkout of the fuel-handling equipment, unloading fuel from core to spent-fuel pool, fuel sipping, fuel inspection, reloading fuel into core from the spent-fuel pool, replacing spent fuel with new fuel, removal of irradiation specimens, removal and replacement of spacers' control blades, and repair of fuel-handling equipment. Excludes core support plates and internals inspection, LPRM changeouts, spent-fuel shipment, packaging and shipment of irradiation samples, foreign object retrieval, and modifications to fuel-handling equipment.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	3.8	58	19

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Reduce the amount of highly radioactive detector filters and equipment stored along the edges of the spent-fuel pool
- o Assure that fuel bridge operators continuously monitor dose rates and survey all equipment being raised out of the water
- o Operate spent-fuel pool filters to reduce radioactivity in pool water
- o Minimize time on bridge and around edge of pool
- o Assure that fuel bridge operators maintain maximum distance from fuel mast
- o Periodically paint or install plexiglass shield on fuel mast to reduce beta dose
- o Assure that fuel bridge operators minimize time that equipment is raised out of pool water
- o Periodically change or shield filter on sipping equipment
- o Provide skimmers to clear radioactive crud from water surface

Timesaving Techniques:

- o Utilize computerized automatic indexing, fuel latching, and fuel movements
- o Provide high speed mast and bridge
- o Assure water clarity for good visibility
- o Prestage equipment

Contamination-Reduction Techniques:

- o Decontaminate fuel bridge mast, cables, rails, and deck
- o Supply highly polished stainless steel mast
- o Replace braided wire cables with solid fuel mast cables
- o Periodically wipe fuel mast and store underwater whenever possible
- o Apply continuous water spray over cable take-up reel during mast movements

BWR REPETITIVE HIGH-DOSE JOBS
DOSE-REDUCTION DATA SHEET #3

JOB TITLE: **In-Service Inspection**

JOB DESCRIPTION:

All in-service inspection related to pressure-vessel-integrity-testing conducted in accordanace with ASME Codes. In general, this testing consists of, staging erection, insulation removal; surface preparation; weld, component, or cladding testing; insulation replacement; and staging removal. The types of tests include dye penetrant, ultrasonic, eddy current, magnetic particles, radiography, and visual inspection. Excludes generic component inspection required by IE Bulletins and ISI of reactor vessel internals, reactor vessel, and recirculation pump casing welds.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	32	380	150

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Chemically decontaminate recirculation piping
- o Flush lines if practical
- o Evaluate the need for temporary shielding
- o Hydrolase safe end nozzles for nozzle ISI
- o Set up ultrasonic or electronic readout equipment in a low-dose-rate area
- o Establish low-dose waiting areas during dye-penetrant drying times
- o Minimize amount of insulation to be removed
- o Obtain ASME or NRC relief on high collective dose inspection
- o Assure continuous monitoring of dose rates (digital electronic dosimeter) during inspections in high-radiation areas
- o Use mirrors or television monitors for remote visual inspections
- o Provide temporary water or lead shield booths in drywell to await dye penetrant

Timesaving Techniques:

- o Provide preshift briefings for inspectors and insulators
- o Store marked insulation outside drywell
- o Use ladders and skyjackers instead of scaffolding
- o Preplan inspection logistics for insulator and inspector efficiency
- o Tag or label weld location, use 3-layered ribbons to indicate insulation removal, weld prep, and inspection completion
- o Provide weld location maps and photographs
- o Use automatic UT scanners

Contamination-Reduction Techniques:

- o Decontaminate and evaluate need for portable ventilation and/or containments during welding, grinding, and polishing

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #4

JOB TITLE: **Instrumentation Repair and Calibration**

JOB DESCRIPTION:

Repair, testing, and calibration of all instruments which are in radiation control areas. This should include repair and calibration associated with valve timing and position verification; RTDs, pressure, level, flow, and temperature transducers; radiation detectors; and instrument panels. This should exclude work associated with TIP/SRM/IRM calibration and repair and any major instrumentation systems replacement, installation, or modifications.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	3.2	41	15

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Locate instrument readouts and electronics in a low-dose-rate area
- o Remove and decon instruments to allow repair in clean shop
- o Backfill instruments with demineralized water prior to startup
- o Flush lines to remove crud if practical
- o Evaluate need for localized shielding of hot spots
- o Use shadow or personnel shields for instrument rack repairs and calibrations
- o Use a telescoping extension pole to locate radioactive sources near detector

Timesaving Techniques:

- o Prefabricate, precalibrate, and prepare test equipment in a low-dose-rate area
- o Coordinate instrument work with concurrent work in area
- o Use fast-response easy-to-operate digital test equipment
- o Use mockup training on in-core detectors
- o Replace unreliable flow, pressure, temperature, and level transmitters with those that are more reliable
- o Replace fuel-handling control module with removable modular console

Contamination-Reduction Techniques:

- o Wipe instrument external surfaces prior to calibration and repair
- o Install plexiglass protective cover over instrument face
- o Transport instruments in plastic bags
- o Paint or coat external surfaces to facilitate decontamination

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #5

JOB TITLE: **Insulation Removal/Replacement**

JOB DESCRIPTION:

All insulation removal and replacement exclusive of that which is removed for in-service inspection purposes. Should exclude heat tracing and scaffold installation/removal.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	0.60	170	44

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Remove highly contaminated "hot" pads first
- o Dispose of highly contaminated pad upon removal
- o Evaluate need to shield local hot pipes

Timesaving Techniques:

- o Mark insulation with ISI weld number for quick identification
- o Use mirror, pads, or blanket insulation with quick connect tabs
- o Use ladders or skyjackers in lieu of scaffolding
- o Schedule insulation work to minimize interference with concurrent work in the same area
- o Prefab new insulation from old pads or drawing measurements in a low dose-rate-area

Contamination-Reduction Techniques:

- o Bag or contain insulation as soon as possible
- o Wear half-man suits to remove highly contaminated and deteriorated asbestos pads
- o Vacuum floor and equipment periodically and following job completion
- o Wipe down mirror insulation prior to storage
- o Provide a roped-off or segregated used insulation storage area
- o Perform insulation removal during periods of low occupancy and low traffic

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #6

JOB TITLE: **Jet Pump Inspection & Repair**

JOB DESCRIPTION:

Inspection and repair of the eight jet pumps includes underwater ultrasonic inspection of the beam bolts and replacement of the beam, plates, and keepers.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	9.9	140	46

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Use remote underwater tooling
- o Build platform above vessel and flood cavity to platform
- o Filter cavity and vessel water to reduce radioactivity
- o Decon and shield drywell bellows
- o Place shield blocks or personnel shield in front of equipment pit
- o Provide TV surveillance of vessel from refuel floor

Timesaving Techniques:

- o Ensure water clarity for good visibility
- o Use underwater ultrasonic inspection tools

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #7

JOB TITLE: **Main Steam Isolation Valve Repair and Inspection**

JOB DESCRIPTION:

All inspection and repairs of main steam isolation valves and operators. Includes lubricating, packing replacement, backseating, body casing leak repairs, stem and seat repair or replacement, motor repair, and routine valve tests. Excludes NRC-required motor operator or valve replacement, special tests, and major valve modifications.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	2.7	67	20

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Allow several days for decay of short half-life isotope
- o Evaluate need for temporary shielding in the area
- o Repair or inspect valves in a low-dose-rate area

Timesaving Techniques:

- o Provide flanged and labeled ductwork to facilitate removal and replacement
- o Use lifting beams in steam tunnel to facilitate picking out valves
- o Use plates and eyebolts on valve and operator to balance during lift
- o Provide mockup training using spare MSIV
- o Use special wrenches and rachets for stem removal

Contamination-Reduction Techniques:

- o Decontaminate operators prior to repair
- o Clean parts in ultrasonic sink prior to repair
- o Use MSIV transfer and containment cart

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #8

JOB TITLE: **Operations-Surveillance, Routines, and Valve Lineups**

JOB DESCRIPTION:

Routine plant operations including normal activities of shift personnel, operator rounds, routine surveillances, inspections, remote panel operations, and training tours. Valve lineup includes valving operations and lineup of systems, tagging of valves, and supervisory verification of proper lineup. Excludes radwaste processing, waste transfer operations, and other valving associated with radwaste.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	11	53	24

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Use reach rods and "T" handles for high-dose-rate area valves
- o Assure continuous dose-rate monitoring (digital electronic dosimeters) in high-radiation areas
- o Schedule rounds or surveillance when operating conditions yield the lowest dose rate
- o Assure that hot spots and low-dose-rate areas are well posted
- o Move step-off pads close to the operator observation point
- o Locate instrument readouts in a low-dose-rate area
- o Use water windows, TV, and mirrors
- o Flush instrument periodically
- o Reduce surveillance frequency in high-radiation areas if possible

Timesaving Techniques:

- o Attach pictures or drawings of valve locations onto cubicle doors
- o Provide floor and wall markers pointing at valve locations
- o Use highly visible easy-to-read valve tags
- o Provide valve checklist with written description of valve locations
- o Use colored ribbon to identify faulty equipment

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #9

JOB TITLE: **Plant Decontamination**

JOB DESCRIPTION:

General routine decontamination and cleaning of surfaces, equipment, and tools. Includes disposing of contaminated waste, handling and cleaning of protective clothing. Excludes packaging and shipping of dry active waste, special maintenance decon efforts, major spills and refueling-pool decontamination.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	9.4	65	37

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Use lead shielding on fork lift and drum carrier
- o Measure dose rates on all waste bags, drums, and bins prior to transport
- o Use remote control cleaning equipment e.g. robotic hydrolaser
- o Segregate waste by radiation level

Timesaving Techniques:

- o Employ dedicated decontamination technicians
- o Use carts to move laundry and dry active waste
- o Use floor-scrubber and wall-washing machines
- o Use steam-cleaning machines
- o Use air-operated vacuum cleaners
- o Use high pressure freon, glass bead, electropolishing and ultrasonic cleaning equipment
- o Provide judicious planning of areas to be deconned
- o Use the most appropriate decon technique
- o Test all mechanical and electrical equipment before use

Contamination-Reduction Techniques:

- o Repair leaks immediately upon discovery
- o Use mop bucket plastic liners
- o Use dry cleaners to reduce liquid radwaste handling
- o Use strippable decontamination coating

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #10

JOB TITLE: **Primary Valve Maintenance and Repair**

JOB DESCRIPTION:

All maintenance and repairs of valves and operators in the radiation control area. Includes lubrication, packing replacement, backseating, body casing leak repairs, stem and seat replacement, operator repair, and routine valve tests. Excludes NRC-required operator or valve replacement, special tests, and major valve modifications.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	7.0	150	57

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- Flush local pipes and valves if practical
- Remove valve or operator to a low-dose-rate area
- Evaluate need for local shielding
- Establish low-dose-rate waiting areas
- Provide beta protection if required

Timesaving Techniques:

- Place description of all valve locations and/or pictures of valve location on door of cubicle
- Use specialized tools to remove and replace packing and valve seat
- Provide mockup training on valve repair if practical
- Provide lighting and scaffolding if necessary
- Use photographs and drawings of valves to familiarize workers
- Prefabricated packing and parts
- Use of ribbon packing

Contamination-Reduction Techniques:

- Utilize glove bags or catch pans
- Provide local ventilation if practical
- Place plastic or blotter paper under valve
- Decontaminate area under valve periodically
- Contain packing material and valve internal following removal
- Moisten valve internals

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #11

JOB TITLE: **Radwaste System Repair, Operation, and Maintenance**

JOB DESCRIPTION:

Liquid, solid, and gaseous radwaste system operation, maintenance, repair, and inspection. Liquid waste system includes clearing of plugged lines and valves; flushing of resin beds; system operation; filter replacement; tank draining; draining of sumps; insulation removal/replacement; heat trace, valve and pump repair. Excludes filter or resin package handling and shipment; Appendix I modifications; liquid radwaste modifications; major spill cleanups; major desludging efforts; and heat trace replacement work. Solid waste system includes solid waste processing operations, including drumming or liner preparations and dry active waste transfer. Also includes associated equipment maintenance and repair. Excludes drumming or resin liner modifications, handling, and shipment. Gaseous waste system includes maintenance, repair, and operation of the standby gas and offgas treatment systems including HEPA and charcoal filter changeout. Excludes filter packaging and shipment, Apppendix I modifications, and major ga[illegible]eatment modifications.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	7.7	28	16

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Use drum survey shield
- o Evacuate areas along resin piping during resin transfers
- o Flush lines and shield prior to insulation, heat trace, or repair
- o Use overhead crane, fork truck, and remote handling tools
- o Use reach rods on high-dose-rate valves
- o Supply mobile solidification system
- o Provide remote control automated drumming facility
- o Install lead housing over resin transfer pump
- o Use rope pulley and snap hook to remotely move filters and place in drum
- o Survey filters and demineralizer beds remotely through holes bored in walls
- o Use mobile shield racks
- o Provide remote waste-sampling points

Timesaving Techniques:

- o Modify filter cartridge housings to facilitate opening and filter removal
- o Replace unreliable motors, pump, and valves with these which are more reliable
- o Employ dedicated radwaste operators and handlers

Contamination-Reduction Techniques:

- o Decontaminate floor and equipment routinely
- o Provide remote drum decon station
- o Use strippable paint in drum and waste processing areas

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #12

JOB TITLE: **Reactor Assembly/Disassembly**

JOB DESCRIPTION:

Reactor assembly and disassembly includes the dismantling and reassembly of the reactor vessel head excluding cavity decontamination; sparger and in-vessel modifications or repairs; and fuel shuffle, sipping, and fuel or vessel inspections. Removal of cavity shield blocks, head spray and vent piping, head instrumentation (thermocouple), and head insulation. Unbolt and remove drywell head (92-208 nuts). Install and remove head vent ducting. Install 4-6 stud tensioners with carousel, detension studs (92-96 studs), install stud protectors, and store studs. Remove and store RPV head. Unlatch, remove, and store steam dryer and moisture separator. Install fuel chute, steam-line plugs, and pool blocks. Remove and install new head O rings. Replace moisture separator, steam dryer, and reactor vessel. Install tensioner carousel and tension studs on reactor head. Connect head instrumentation (thermocouple), and head spray/vent lines. Replace insulation on RV head. Replace drywell head and tension head bolts. Replace cavity shield blocks. Remove steam plugs, equipment, and blocks from cavity.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	7.8	51	24

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- Shield floor and rails for operator of refuel bridge and overhead crane's cab
- Locate stairs or ladder in a low-dose-rate location of the cavity
- Maintain vessel water level at maximum height
- Provide lead shield gate with air shackles for opening between cavity and equipment storage pool
- Minimize the number of personnel on refuel floor during reactor vessel head, steam dryer, and moisture separator lifts
- Remove sludge and shield crud from drywell bellows
- Use lead or steel booths or shield gates for personnel shields in cavity
- Transfer steam separator underwater
- Provide shielding around the base of the reactor vessel head stand
- Provide high-efficiency filters for the cavity and equipment storage pool water

Timesaving Techniques:

- Use high-torque portable pneumatic wrenches for drywell head bolts

- o Provide eight tensioner carousel with mule hoist control
- o Provide air-operated shackles for pool shield blocks, dams, and gates

Contamination-Reduction Techniques:

- o Vent vessel to standby gas treatment before disconnecting flanges
- o Decontaminate cavity and pool shield blocks
- o Put plastic or paper around and on the head stand
- o Provide prefabricated plastic cover for the reactor head on the head stand
- o Wrap or contain steam line plugs after removal
- o Use reactor vessel stud-cleaning machine for stud cleaning
- o Arrange sprinkler hoses and/or spray nozzles around cavity walls and over the equipment storage pool
- o Use wall-washing machines to decontaminate cavity and equipment storage pool
- o Change underwater lights inside an enclosure or containment
- o Provide ventilation near head during head lift and stud hole cleaning

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #13

JOB TITLE: **Recirculation Pump Seal Replacement**

JOB DESCRIPTION:

Outage or forced outage recirculation pump seal replacement. Includes surface and equipment decontamination; auxiliary piping removal; grating removal; flange spool piece removal; rigging installation; lower coupling removal; seal removal; seal surface cleaning; seal testing, replacement and inspection; replacement of auxiliary piping; set thrust bearing; replacements of spool piece and grating. Excludes work associated with vibration measurements; ISI inspection; pump modification, reinsulation, painting; and motor inspection and repairs.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	1.5	23	7.8

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- Flush seals and seal cooling lines
- Evaluate shielding of local "hot spots"
- Provide shield around grating and inside bowl
- Decon seal surface and bowl and shield with plastic

Timesaving Techniques:

- Erect scaffolding and install temporary lighting
- Use recirculation pump seal replacement video tape
- Use hydraulic jacks and strongbacks to couple shaft
- Split leak-off collar to improve shaft coupling and facilitate thermocouple connection
- Modify shaft shroud to facilitate its removal

Contamination-Reduction Techniques:

- Mop plastic covered grating periodically
- Erect plastic walls around change area and contaminated parts storage area
- Wrap old seals in plastic or transport in sealed transfer cart
- Decon highly contaminated parts in ultrasonic sink or dip tank
- Rebuild seals underwater or in a ventilated doghouse

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #14

JOB TITLE: **Refueling Pool Decontamination**

JOB DESCRIPTION:

Decontamination of the refueling pool floor and walls during refueling operation. Can include wet mop, masslin, hydrolasing, hand scrub, wall-washing machines, electropolishing, glass bead blasting, and strippable paint. Excludes tool decon, equipment decon, decontamination in the pool associated with major modifications and processing, and shipment of any of the associated waste.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	3.2	5.6	4.4

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Perform as much decontamination from above as possible
- o Change mop heads on refuel floor
- o Continuously monitor mop heads, vacuum cleaners, and dryer separator pit opening
- o Maintain distance from vessel opening and dryer/separator pit canal
- o Use underwater vacuum on floor during draindown
- o Use lead on bucket walls and bottom around skiff
- o Use remote control cleaning equipment e.g. robotic hydrolaser

Timesaving Techniques:

- o Use highly polished stainless steel walls
- o Use wall- and floor-washing machines
- o Use strippable decontamination coating
- o Perform electropolishing or wet glass bead blasting
- o Preplan method and logistics of cavity decontamination
- o Employ experienced decontamination technicians

Contamination-Reduction Techniques:

- o Hose down wall and squeegee and brush crud (bathtub) ring from refuel floor during draindown
- o Use strippable decontamination coating
- o Keep walls wet prior to decontaminating

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #15

JOB TITLE: **Residual Heat Removal System Repair and Maintenance**

JOB DESCRIPTION:

All maintenance and repair associated with the residual heat removal system. Includes repair and maintenance of pumps and valves as well as cleaning of the heat exchangers. Excludes any major modifications, instrumentation calibration, and repair or major component replacement.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	11	48	34

DOSE-REDUCTION TECHNIQUES:

- o Evaluate need for temporary shielding
- o Prefabricate pipes
- o Flush lines and pumps
- o Remove pumps and valves and repair in a low dose rate area
- o Remove highly contaminated insulation
- o Provide lighting and scaffolding if necessary

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #16

JOB TITLE: **Safety Valve Repair and Inspection**

JOB DESCRIPTION:

All inspection and repairs of safety valves and operators in the radiation control area. Includes lubrication, packing replacement, seat lapping and machining, body casing leak repairs, stem and seal repair or replacement, operator repair, and valve pressure or timing tests. Excludes NRC-required operator or valve replacement, special tests, and major valve modifications.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	9.3	80	39

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Evaluate need for temporary shielding
- o Allow several days after shutdown for decay of short half-life radioactivity
- o Remove valves to low-dose-rate area

Timesaving Techniques:

- o Optimize area accessibility by scheduling small crew size during period of minimal staging or concurrent work
- o Install temporary work platform under safety valves to improve access
- o Plan rigging points and path
- o Use jib arm to pull valve out

Contamination-Reduction Techniques:

- o Decontaminate externals of valve topworks prior to repair
- o Repair or rebuild valve in ventilated containment, e.g., tent
- o Line valve internals with plastic
- o Decontaminate in an acid bath or ultrasonic sink prior to pressure tests or machining
- o Use valve transfer and containment carts or drums

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #17

JOB TITLE: **Scaffold Installation/Removal**

JOB DESCRIPTION:

All scaffold installation and removal exclusive of that which is used for in-service inspection and special maintenance. Exclude scaffold decontamination, packaging, and shipment.

OUTAGE COLLECTIVE DOSE:	REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
	General Electric	24	120	57

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Evaluate need for shielding localized hot spots
- o Decon scaffolding in low-dose-rate area
- o Provide permanently installed platforms and ladders

Timesaving Techniques:

- o Preplan scaffold layout and indicate exact location
- o Provide prehooked, tube lock, or prefabricated scaffolding
- o Coordinate efficient use of scaffolding amoungst various work groups
- o Provide prehooked planks and handrails
- o Schedule scaffolding work to minimize interference with concurrent work in the same area

Contamination-Reduction Techniques:

- o Store contaminated scaffold in trailers for reuse in contaminated areas
- o Wipe scaffold during disassembly
- o Paint or coat scaffolding to facilitate decontamination
- o Segregate use and storage by contamination level

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #18

JOB TITLE: **Snubber Inspection and Repair**

JOB DESCRIPTION:

All inspections and repairs of snubbers in the radiation control area. Includes removal, testing, repair, replacement, inspection and installation. Excludes installation of new snubbers, painting, and special tests.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	2.6	1400	290

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Evaluate need for providing localized shielding
- o Flush pipes, if practical

Timesaving Techniques:

- o Indentify, paint, or tag snubber for easy location
- o Provide light and staging whenever practical
- o Preplan rigging and removal path
- o Replace snubbers with energy absorbers

Contamination-Reduction Techniques:

- o Decontaminate snubbers before testing
- o Wipe snubber external surfaces following removal
- o Provide containment and transfer cart
- o Transfer snubbers in plastic bags
- o Test in a ventillated enclosure

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #19

JOB TITLE: **TIP/SRM/IRM or PRM Calibration, Repair, and Maintenance**

JOB DESCRIPTION:

TIP/SRM/IRM or PRM repair involves retraction of the detector into shielded storage receptacle, removal of the detector, TIP drive maintenance, replacement of new detector, and transfer and storage of old detector.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	3.5	41	11

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Allow several days for short half-life isotopes to decay
- o Use IRM or TIP lead pig or cask
- o Use remote handling tools
- o Clean, fill, and shield sump
- o Pull detectors down into sump and allow to decay prior to transfer
- o Perform continuous dose-rate monitoring
- o Restrict access to TIP room and place "out of service tag" on TIPs

Timesaving Techniques:

- o Prefabricate, precalibrate and prepare test equipment in a low-dose rate area
- o Use fast-response easy-to-operate digital equipment
- o Build scaffolding for indexer
- o Provide mockup training using new parts or instruments

Contamination-Reduction Techniques:

- o Decontaminate indexer periodically
- o Wipe instrument external surface prior to calibration and repair
- o Transport detectors in a shielded containment

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #20

JOB TITLE: **Torus Repair, Inspection, and Modifications**

JOB DESCRIPTION:

Inspection, repairs, and modification of the torus. Inspection includes downcomer and paint inspection. Repairs include hydrolasing, sand-blasting, and sludge removal; painting; downcomer cleaning and repair; vacuum breaker maintenance; and relamping. Modifications include NUREG 0661 Torus modifications, such as saddle support installation; column replacement or reinforcement; downcomer modifications; safety relief valve T quencher and support reinforcement; vent header deflectors; etc.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	100	600	280

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Hydrolase and/or sandblast torus internals and pump out sludge
- o Evaluate need to shield localized hot spots
- o Flush downcomer headers prior to torus work

Timesaving Techniques:

- o Prefabricate components and equipment
- o Provide lighting and scaffolding

Contamination-Reduction Techniques:

- o Repaint contaminated surfaces and decontaminate inside torus
- o Use high-flow-rate ventilation system to exhaust torus

BWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #21

JOB TITLE: **Turbine Overhaul and Repair**

JOB DESCRIPTION:

Turbine overhaul includes high and low pressure turbine disassembly and assembly; rotor inspection; generator inspection and overhaul; exciter inspection and overhaul; valve maintenance and inspection on turbine stop, control, bypass, and intercept valves; and stator inspection. The disassembly of the turbine includes removal of lagging, steam packing, bearing and coupling housing and guards, missile shield blocks, hoods, bearings, steam leads, diaphragms, and rotor. Inspection includes sandblasting of rotor PT and UT of blades and buckets. Repair may include welding and grinding of rotor, partitions, and bridges of diaphragms and/or rotor, or repair of blades and buckets. The assembly of the turbine includes replacing the diaphragms, rotor, bearings, hoods, missile shield blocks; bearing and coupling alignment; steam lead, coupler guard and bearing housing replacement; and lagging installation.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
General Electric	0.20	21	6.2

DOSE-REDUCTION TECHNIQUES:

- Allow several days for short lived decay prior to lapping or machining of stop and control valves
- Use lapping machine with long handle for stop and control valves
- Sandblast blades or parts to be ground, cut, or welded, if possible
- Reduce number of manhours
- Provide beta shielding for valve repair

APPENDIX B

PWR REPETITIVE HIGH-DOSE JOB DOSE-REDUCTION DATA SHEETS

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #1

JOB TITLE: **Cavity Decontamination**

JOB DESCRIPTION:

Decontamination of the reactor cavity floor and walls during refueling. Can include wet mop, maslin, hydrolasing, hand scrub, wall-washing machines, electropolishing, glass bead blasting, and strippable paint. Excludes tool decon, equipment decon, decontamination in the cavity associated with major modifications, and processing and shipment of any of the cavity decontamination waste.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	1.1	16	5.9
Combustion Engineering	1.8	11	5.3
Babcock & Wilcox	-	-	-

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- Perform as much decontamination from above as possible
- Change mop heads on charging floor
- Continuously monitor mop heads, vacuum cleaners, and maslin
- Maintain distance from vessel opening and transfer canal
- Use underwater vacuum on floor during draindown
- Place lead on skiff or bucket walls and bottom
- Use remote cleaning equipment e.g. robotic hydrolaser

Timesaving Techniques:

- Provide highly polished stainless steel walls
- Provide wall-and floor-washing machines
- Use strippable decontamination coating
- Perform electropolishing or wet glass bead blasting
- Preplan method and logistics of cavity decontamination
- Employ experienced decontamination technicians

Contamination-Reduction Techniques:

- Hose down walls and brush crud (bathtub) ring from the charging floor during draindown
- Use strippable decontamination coating
- Keep walls wet prior to decontaminating

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #2

JOB TITLE: **Chemical, Volume, and Control System Repair and Maintenance**

JOB DESCRIPTION:

All maintenance and repair associated with the Chemical, Volume, and Control System. Includes cleaning of heat exchangers, maintenance and repair of pumps, maintenance and repair of valves, and pipe repairs. Excludes any major modifications, instrumentation calibration and repair, and major component replacement.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	0.80	37	11
Combustion Engineering	0.61	8.3	4.8
Babcock & Wilcox	-	-	-

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Repair pumps and valves in a low-dose-rate area
- o Evaluate need for shielding of local hot spots
- o Core bore hole in volume control tank cubicle to remotely monitor equipment problems and dose rates

Timesaving Techniques:

- o Modify heat tracing to have dedicated power supply, segmented with failure indication and redundant heat trace to initiate upon failure

Contamination-Reduction Techniques:

- o Repair leaks upon identification
- o Decontaminate boron crystals on floors and equipment periodically

PWR REPETITIVE HIGH-DOSE JOB

DOSE-REDUCTION DATA SHEET #3

JOB TITLE: **Fuel Shuffle, Sipping, and Inspections**

JOB DESCRIPTION:

Fuel shuffle, fuel sipping, and fuel inspections includes dry and wet checkout of the fuel-handling equipment, unloading fuel from core to spent-fuel pool, fuel sipping, core mapping (TV), fuel inspection, reloading fuel, replacing fuel, removal of irradiation specimens, removal and replacement of CRDs and spacers, and repair of fuel-handling equipment. Excludes core support plates and internals inspection, fuel shipment, packaging and shipment of irradiation samples, foreign object retrieval, and modifications to fuel handling equipment.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	3.6	16	9.2
Combustion Engineering	2.2	15	7.0
Babcock & Wilcox	4.4	12	8.1

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Provide cavity and spent-fuel-pool water-purification
- o Reduce time on bridge and around edge of pool and cavity
- o Use remote-handling tools
- o Hang lead from rails and cover deck of fuel bridge near operator
- o Provide skimmers to clear radioactive crud off water surface
- o Shield sipping bottles and filters
- o Reduce the amount of highly radioactive tools and equipment stored along the edge of the spent-fuel pool
- o Assure that fuel bridge operator continuously monitors dose rates and surveys all equipment being raised out of water
- o Assure that fuel bridge operator maintains maximum distance from fuel mast
- o Assure that fuel bridge operators minimize the time that equipment is raised out of water

Timesaving Techniques:

- o Prestage equipment
- o Utilize computerized automatic indexing, fuel latching, and fuel movements
- o Provide high speed mast and bridge
- o Assume water clarity for good visibility

Contamination-Reduction Techniques:

- o Decontaminate fuel bridge mast, cables, rails, and deck
- o Provide highly polished stainless steel mast

Fuel Shuffle, Sipping, and Inspections
Sheet #3 (cont.)

- Replace braided wire cable with solid fuel mast cable
- Periodically wipe fuel mast and store underwater whenever possible
- Apply continuous water spray over cable take-up reel during mast movement

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #4

JOB TITLE: **In-Service Inspection**

JOB DESCRIPTION:

All in-service inspection related to pressure-vessel-integrity testing conducted in accordance with ASME Codes. In general this testing consists of staging erection; insulation removal; surface preparation; weld, component, or cladding testing; insulation replacement; and staging removal. The types of tests include dye penetrant, ultrasonic, eddy current, magnetic particle, radiography, and visual inspection. Excludes primary and secondary steam generator tube inspections and generic component inspection required by IE Bulletins. ISI of reactor vessel internals, reactor vessel, and reactor coolant pump casing welds should be listed separately if possible.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	1.0	130	46
Combustion Engineering	0.58	49	24
Babcock & Wilcox	7.6	64	31

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- Verify weld preparation prior to dispatching inspectors
- Evaluate need for temporary shielding
- Flush lines if practical
- Minimize amount of insulation to be removed
- Obtain ASME or NRC relief on high collective dose inspections
- Establish low-dose-rate waiting areas during dye-penetrant drying times
- Set up ultrasonic or electronic equipment readouts in a low-dose-rate area
- Assure continuous monitoring of dose rates (digital electronic dosimeter) during inspections in high-radiation areas
- Use mirrors or television monitors for remote visual inspections
- Provide temporary water or lead shield booths in the containment to await dye-penetrant development

Timesaving Techniques:

- Provide preshift briefings for inspectors and insulators
- Store marked insulation outside drywell
- Use ladders and skyjackers instead of scaffolding
- Preplan inspection logistics for insulator and inspector efficiency
- Tag or label weld location; use 3-layered ribbons to indicate completion of insulation removal, weld prep, and inspection
- Provide map or photographs with weld location

- Plan logistics of inspection program
- Use automatic UT scanner

Contamination-Reduction Techniques:

- Decontaminate and evaluate need for portable ventilation and/or containments during welding, grinding, and polishing

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #5

JOB TITLE: **Instrumentation Repair and Calibration**

JOB DESCRIPTION:

Repair and calibration of all instruments in the radiation controlled area. This should include repair and calibration of source range monitor; low or intermediate power range and high or power range monitors; traversing in-core probes; RTDs; flow, level, pressure, and temperature transducers; radiation detectors; instrument panels; etc. This excludes any work related to major instrumentation system replacement, installation, or modification.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	1.1	31	12
Combustion Engineering	1.3	38	9.7
Babcock & Wilcox	2.9	17	11

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Use a telescoping extension pole to locate radioactive source near detector
- o Locate instrument readouts and electronics in a low-dose-rate area
- o Use lead pigs for flux mapping and in-core detectors
- o Drop in-core detectors through seal table and into containment sump
- o Shield the loop drain and bypass lines during hot and cold leg thermocouple calibration
- o Modify conoseal or in-core instrumentation connector to quick disconnects which can be removed from the top of the reactor vessel head
- o Use shadow shields or personnel shields for instrument rack repairs and calibrations
- o Remove and decon instruments to allow repair in clean shop
- o Backfill instruments with demineralized water prior to start-up
- o Flush lines to remove crud
- o Evaluate need for localized shielding of hot spots

Timesaving Techniques:

- o Practice mockup training on in-core thermocouples and RTDs
- o Precalibrate, prefabricate and do prep work on instruments in a low-dose-rate area
- o Modify rod position indicator and CRDM cables to disconnect via panels instead of individually

Instrumentation Repair and Calibration
Sheet #5 (cont.)

- Replace unreliable flow, pressure, temperature, and level transmitters with those that are more reliable
- Replace fuel-handling control module with removable modular console
- Coordinate instrument work with concurrent work in area
- Provide fast-response easy-to-operate digital test equipment

Contamination-Reduction Techniques:

- Wipe instrument external surfaces prior to repair and calibration
- Provide a plexiglass protective cover over instrument face
- Transport instruments in plastic bags
- Paint or coat external surfaces to facilitate decontamination

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #6

JOB TITLE: **Insulation Removal/Replacement**

JOB DESCRIPTION:

All insulation removal and replacement exclusive of that which is removed for in-service inspection purposes. Excludes associated heat tracing and staging installation/removal.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	1.2	37	18
Combustion Engineering	2.6	14	7.6
Babcock & Wilcox	0.40	18	6.2

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Remove highly contaminated "hot" pads first
- o Dispose of highly contaminated pads upon removal
- o Evaluate need to shield localized hot pipes

Timesaving Techniques:

- o Mark insulation with ISI weld number for quick identification
- o Use mirror, pads, or blanket insulation with quick connect tabs
- o Use ladders or skyjackers in lieu of scaffolding
- o Schedule insulation work to minimize interference with concurrent work in the same area
- o Prefab new insulation from old pads or drawing measurements in a low-dose-rate area

Contamination-Reduction Techniques:

- o Bag or contain insulation as soon as possible
- o Wear half-man suits to remove highly contaminated and deteriorated asbestos pads
- o Vacuum floor and equipment periodically and following job completion
- o Wipe down mirror insulation prior to storage
- o Provide a roped-off or segregated area for used insulation storage
- o Perform insulation removal during periods of low occupancy and low traffic

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #7

JOB TITLE: **Operations-Surveillance, Routines, and Valve Lineups**

JOB DESCRIPTION:

Routine plant operations including normal activities of shift personnel, operator rounds, routine surveillances, inspections, remote panel operations, and training tours. Valve lineup includes valving operations and lineup of systems, tagging of valves, and supervisory verification of proper lineup. Excludes radwaste processing, waste transfer operations, and other valving associated with radwaste.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	3.0	18	7.4
Combustion Engineering	7.0	22	13
Babcock & Wilcox	5.1	23	13

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Use reach rods and "T" handles for high-dose-rate area valves
- o Assure continuous dose-rate monitoring by digital electronic dosimeters in high radiation areas
- o Schedule rounds or surveillances when operating conditions yield the lowest dose rate
- o Assure that hot spots and low-dose-rate areas are well posted
- o Move step-off pads close to the operator observation point
- o Locate instrument readouts in a low-dose-rate area
- o Use water windows, TV, and mirrors
- o Flush instruments periodically
- o Reduce surveillance frequency in high-radiation areas if possible

Timesaving Techniques:

- o Attach pictures or drawings of valve locations onto cubicle doors
- o Provide floor and wall markers pointing at valve locations
- o Use highly visible easy-to-read valve tags
- o Provide valve checklist with written description of valve locations
- o Use colored ribbon to identify faulty equipment

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #8

JOB TITLE: **Plant Decontamination**

JOB DESCRIPTION:

General routine decontamination and cleaning of surfaces, equipment, and tools. Includes disposing of contaminated waste, handling, and cleaning of protective clothing. Excludes packaging and shipping of dry active waste, special maintenance decontamination efforts, major spills, and cavity decontamination.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	5.0	67	45
Combustion Engineering	0.70	160	20
Babcock & Wilcox	1.5	40	17

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Use lead shielding on the back of the forklift and drum carrier
- o Measure dose rates on all waste bags, drums, and bins prior to transport
- o Use remote control cleaning equipment, e.g. robotic hydrolaser
- o Segregate waste by radiation levels

Timesaving Techniques:

- o Employ dedicated decontamination technicians
- o Use carts to move laundry and dry active waste
- o Use floor-scrubber and wall-washing machines
- o Use steam-cleaning machines
- o Use air-operated vacuum cleaners
- o Use high pressure Freon, glass bead, electropolishing, and ultrasonic cleaning equipment
- o Provide judicious planning of areas to be deconned
- o Use the the most appropriate decon technique
- o Test all mechanical and electrical equipment before use

Contamination-Reduction Techniques:

- o Repair leaks immediately upon discovery
- o Use mop bucket plastic liners
- o Use dry cleaners to reduce liquid radwaste handling
- o Use strippable decontamination coatings

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #9

JOB TITLE: **Pressurizer Valve Inspection, Testing, and Repair**

JOB DESCRIPTION:

All inspection, maintenance, and repair of pressurizer valves and their operators. Includes lubrication; electrical inspection; packing replacement; backseating; stem and seat replacement; motor operator repair; and valve timing tests for the pressurizer safeties, pressurizer reliefs, pressurizer drain or surge, and pressurizer spray valves. Excludes any major modifications to the pressurizer and special tests.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	0.3	21	5.5
Combustion Engineering	0.30	17	5.4
Babcock & Wilcox	1.4	11	4.9

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- Evaluate the need to shield local hot spots
- Flush pressurizer spray valves if possible

Timesaving Techniques:

- Modify missile shield block house on top of pressurizer - bored manway for quick access
- Provide additional lighting and work platform
- Reduce temperature in pressurizer block house
- Use special tooling to remove valves in compact area
- Relocate relief and spray valves to allow improved access
- Use 3/4 in. impact wrench for reliefs
- Use polar crane to lift and align valves

Contamination-Reduction Techniques:

- Decon relief valves prior to pressure test
- Bag reliefs or transfer in a contained transfer cart

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #10

JOB TITLE: **Primary Valve Maintenance and Repair**

JOB DESCRIPTION:

All maintenance and repairs of valves and operators in the radiation control area. Includes lubrication, packing replacement, backseating, body casing leak repairs, stem and seat replacement, valve operator repair and routine valve tests. Excludes NRC-required valve operator or valve replacement, special tests, and major valve modifications.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	1.4	120	30
Combustion Engineering	0.10	34	12
Babcock & Wilcox	6.3	27	17

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Flush local pipes and valve if practical
- o Remove valve or operator to a low-dose-rate area
- o Evaluate need for local shielding

Timesaving Techniques:

- o Attach description or pictures of valve locations on door of cubicle
- o Use special tools to remove and replace seats and packing
- o Use ribbon packing
- o Prefabricate packing or parts
- o Provide mockup training on valve repair if practical
- o Provide lighting and scaffolding if necessary
- o Use photographs and drawings of valves to familiarize workers

Contamination Reduction Techniques:

- o Provide local ventilation if practical
- o Utilize glove bags or catch pans
- o Place plastic or blotter paper under valve
- o Decontaminate area under valve periodically
- o Contain packing materials and valve following removal
- o Moisten valve internals

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #11

JOB TITLE: **Radwaste System Repair, Operation, and Maintenance**

JOB DESCRIPTION:

Liquid, solid, and gaseous radwaste system operation, maintenance, repair, and inspection. Liquid waste includes clearing of plugged lines and valves; flushing of resin beds; system operation; filter replacement; tank draining; sump draining; removal/replacement of piping insulation; heat trace, valve and pump repair; and heat exchanger maintenance. Excludes filter or resin package handling and shipment; Appendix I modifications; liquid radwaste modifications; major spill cleanup; major desludging efforts; and heat trace replacement work. Solid waste includes solid waste processing operations, such as drumming of evaporator bottoms and floor drain sludge; resin slurring and dewatering into a liner. Also includes associated equipment maintenance and repair. Excludes drumming; compacting; resin liner loading; solid radwaste modifications; and radwaste handling and shipment. Gaseous waste system includes operation, maintenance, and repair of the gas holdup tanks, ventilation system, and associated filters including replacement of HEPA and charcoal filters. Excludes filter packaging handling, and shipment; Appendix I modifications; and gaseous radwaste modifications.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	0.50	20	4.9
Combustion Engineering	-	-	-
Babcock & Wilcox	-	-	-

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Use drum survey shield
- o Evacuate areas along resin piping during resin transfer
- o Flush lines and shield prior to insulation, heat trace, or repair
- o Use overhead crane, fork truck, and remote handling tools
- o Use reach rods on high-dose-rate valves
- o Supply mobile solidification system
- o Provide remote control automated drumming facility
- o Install lead housing over the resin transfer pump
- o Use rope pulley and snap hook to remove filters and place in drum
- o Survey filter and demineralizer beds remotely through holes bored in walls
- o Use mobile shield racks
- o Provide remote waste-sampling points

Timesaving Techniques:

- o Modify filter cartridge housings to facilitate opening and filter removal
- o Replace unreliable motors, pump, and valves with those which are more reliable
- o Employ dedicated radwaste operators and handlers

Contamination-Reduction Techniques:

- o Routinely decontaminate floor and equipment
- o Provide remote drum decon station
- o Use strippable paint in drum and waste processing area

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #12

JOB TITLE: **Reactor Assembly/Disassembly**

JOB DESCRIPTION:

Reactor assembly and disassembly includes dismantling and reassembly of the reactor vessel head excluding cavity decontamination; fuel shuffle, sipping, and related inspections; and reactor vessel and apparatus modifications and repair. Remove missile shield, seismic restraint, and head insulation. Disconnect head-vent piping, CRDM ventilation ducts, thermocouple flanges and electrical cables. Remove and store fuel transfer tube flange. Install 3 tensioners and detension 48-52 studs. Remove, clean, and store studs. Install stud hold plugs, reactor head guide pins, and reactor vessel lift rig. Install cavity seal ring and test. Lift and store reactor vessel head. Unlatch, remove, and store upper internals. Remove and install head O ring, remove thermocouple baffles, meggar, and cap CRD shafts. Replace reactor vessel head and remove head lift rig. Remove stud hold plugs and guide pins. Replace studs and tension. Remove cavity seal ring. Replace fuel transfer tube flange. Connect CRDM ventilation ducts, thermocouple connectors, electrical cables, and lead vent piping. Replace head insulation, seismic supports, and missile shield.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	12	120	48
Combustion Engineering	20	160	68
Babcock & Wilcox	14	54	36

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- Provide temporary or permanent reactor vessel-head shield
- Place lead blankets over cavity seal plate and vessel flange drip trays
- Use personnel shields in cavity
- Shield floor and railing for operator of manipulator crane
- Place permanent plexiglass shield around manipulator mast
- Use CRDM vent duct flange lead shield plate
- Use thermocouple flange water shield or lead blanket draped around flange
- Use under reactor vessel-head laydown stand shield
- Maintain water to railing level in fuel transfer canal
- Maintain water level in vessel and cavity as high as possible
- Restrict number of people during internals and vessel-head lift
- Restrict number of people around edge of cavity until cavity water level is above upper internals

- Flush crud from cavity seal plate crevices and vessel flange drip tray after draindown
- Operate cavity and spent-fuel-pool cleanup pumps at full capacity
- Perform a hydrogen peroxide flush during cooldown
- Process water in refueling water storage tank
- Use underwater cavity filtration and vacuum cleaner system

Timesaving Techniques:

- Use stud tensioner mockup
- Provide six remotely operated stud tensioners
- Use remote stud hole cleaning tool
- Use stud-cleaning machines and associated ventilation
- Use portable stud spin-out tool
- Use pneumatic drive for tensioner handwheels
- Modify head and upper internals lift rigs to accept air shackles
- Use ring or suitcase clamps on modular CRDM ventilation duct sections
- Use power wrench to remove CRDM vent duct bolts
- Provide CRDM ventilation duct lift rig
- Provide conoseal or in-core instrumentation flange tool box
- Provide conoseal or ICI flange mockup
- Provide conoseal or ICI quick disconnect connectors located at the top of the head
- Provide individual elongation rods for each stud
- Provide additional lifting capability via circular bridge or jib cranes
- Place O ring around reactor vessel-head stand prior to storage of head
- Provide CRDM, rod position indicator, and heated junction thermocouple quick-disconnect connectors and panels
- Provide reactor vessel-head O ring spring clips
- Provide inflatable or permanent cavity seal plate

Contamination-Reduction Techniques:

- Use portable HEPA/charcoal ventilation blower for the cavity
- Place plastic sleeving on reactor-head guide pins prior to removal
- Place plastic on head laydown stand
- Isolate containment ventilation during reactor-head lift
- Attach flexible ventilation suction hose on ICI or conoseal flange during initial head lift
- Use continuous particulate iodine and noble gas monitor
- Place plastic over the top of the fuel-transfer canal during flange removal/replacement
- Use charging floor modular enclosure for refueling equipment and tool decontamination
- Crosstie RHR to CVCS to allow for cleanup during fuel shuffle and cavity drain

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #13

JOB TITLE: **Reactor Coolant Pump Seal Replacement**

JOB DESCRIPTION:

Outage or forced outage reactor coolant pump seal replacement. Includes auxiliary piping and coupling removal; oil pan removal; coupling, runners, seals, and seal housing or seal package removal; seal area cleaning; seal package replacement; heat fit coupling; concentricity alignment; oil pan replacement; auxiliary piping replacement; and oil replacement. Excludes vibration measurements, pump ISI inspections, pump modifications (e.g., fire protection oil drip pans), reinsulation, painting, and motor inspections and repair.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	1.1	44	17
Combustion Engineering	5.6	64	18
Babcock & Wilcox	3.1	19	11

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Assure steam generator in wet layup
- o Evaluate shielding of local "hot spots"
- o Place lead blankets on grating over "hot" pipes

Timesaving Techniques:

- o Provide dedicated RCP tool boxes
- o Use RCP seal replacement video tape
- o Place temporary deck between grating and flange gap
- o Use pneumatic torque wrench for flange
- o Use four ultra small tracked chainfalls to replace seal lift rig

Contamination-Reduction Techniques:

- o Mop plastic covered grating periodically
- o Hang plastic sheet walls from rails and erect walls around contaminated parts storage area
- o Supply portable doghouse enclosure with vacuum cleaner for ventilation to clean small parts
- o Clean large contaminated parts over blotter paper in parts storage area
- o Restrict access to area

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #14

JOB TITLE: **Residual Heat Removal System Repair and Maintenance**

JOB DESCRIPTION:

All maintenance and repair associated with the residual heat removal system. Includes heat exchanger cleaning, valve repair, and pump maintenance and repair. Excludes any major modifications, instrumentation calibration, and repair or major component replacement.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	0.70	8.8	2.7
Combustion Engineering	0.96	0.96	0.96
Babcock & Wilcox	7.4	27	14

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Evaluate need for temporary shielding
- o Flush lines and pumps if practical
- o Remove pump and valve and repair in low-dose-rate area

Timesaving Techniques:

- o Prefabricate pipes
- o Provide lighting and scaffolding if necessary

Contamination Reduction:

- o Utilize catch pans and glove bags for valve repairs
- o Decontaminate parts to be repaired if practical

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #15

JOB TITLE: **Scaffold Installation/Removal**

JOB DESCRIPTION:

All scaffold installation and removal exclusive of that which is used for in-service inspection and special maintenance. Excludes scaffold decontamination, packaging, and shipment.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	0.50	62	30
Combustion Engineering	0.50	4.6	1.6
Babcock & Wilcox	-	-	-

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Evaluate need for shielding localized hot spots
- o Decon scaffolding in low-dose-rate area
- o Install permanent platforms and stairs

Timesaving Techniques:

- o Preplan scaffold layout and indicate exact location
- o Provide pre-hooked, tube lock, or prefabricated scaffolding
- o Coordinate efficient use of scaffolding amoungst various work groups
- o Provide prehooked planks and handrails
- o Schedule scaffolding work to minimize interference with concurrent work in the area

Contamination-Reduction Techniques:

- o Store contaminated scaffold in trailers for reuse in contaminated areas
- o Wipe scaffold during disassembly
- o Paint or coat scaffolding to facilitate decontamination
- o Segregate use and storage by contamination level

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #16

JOB TITLE: **Secondary Side of the Steam Generator Inspection and Repair**

JOB DESCRIPTION:

All inspection and repair work inside the secondary side of the steam generator. Inspection work includes fiber optic, photo flow slot, and TV inspections. Includes transfer and setup of equipment in containment; handhole area insulation removal; handhole covers removal; TV, fiber optic, and/or photographic inspection; tube deposit sampling; foreign objects retrieval; equipment removal; handhole covers and insulation replacement. Repairs include repair of handhole leaks, sludge lancing, and tube supports. Excludes any feedwater or main steam line nozzle modifications or major secondary side tube support modifications. Sludge lancing includes transfer and setup of hoses, pumps, lances, and work station; water balance test; lance transfer; leak repair; filter changeout; sludge lance operation; and removal of lance, pumps and hoses from containment.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	2.3	41	11
Combustion Engineering	1.2	48	12
Babcock & Wilcox	0.80	3.6	2.4

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- Maintain water above tube bundle when working through inspection ports in upper section of steam generator
- Maintain water on secondary side up to handhole opening
- Rope off and post area around handhole beam
- Use remote tooling to minimize amount of time near handhole
- Minimize amount of time hands are in beam and avoid beam
- Locate sludge lancing station in a low-dose-rate area
- Use lead plug with key handled bolts for handhole shields
- Evaluate need for shielding of localized hot spots
- Flood primary side if possible
- Expedite filling of secondary steam generator following handhole replacement
- Use computerized automated wand for sludge lancing

Timesaving Techniques:

- Preoperational test of equipment

Contamination-Reduction Techniques:

- Assure leak-tight sludge lance hoses
- Obtain positive seal on lance fixture
- Sleeve all sludge lance hoses going into a contaminated area
- Place plastic and curbing or drip tray under filter trailer
- Provide plastic laydown area for the sludge filter drums

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #17

JOB TITLE: **Snubber, Hanger, and Anchor Bolt, Inspection and Repair**

JOB DESCRIPTION:

All snubber inspections and repairs in the radiation control area. Includes removal, testing, repair or replacement, inspection, and installation. Excludes installation of new or additional snubbers, painting, and special tests. All seismic inspections of walls, stands, and supports for safety-related equipment to ensure seismic integrity conducted in accordance with the IE Bulletin 79-14 programs. All anchor bolt inspections, repair, and replacement program conducted in accordance with the IE Bulletin 79-02 and 79-14.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	0.30	580	110
Combustion Engineering	0.90	220	34
Babcock & Wilcox	4.8	69	33

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Evaluate need for shielding of local hot spots
- o Test snubber in a low-dose-rate area
- o Eliminate unnecessary replacement
- o Start with easy low-dose-rate components first

Timesaving Techniques:

- o Schedule inspections so as not to interfere with concurrent work in the same area
- o Preplan snubber-support rigging and removal path
- o Preplan logistics of inspection to do all snubbers, anchor bolts, or supports in an area at the same time
- o Provide electric hoist to remove and replace snubbers and supports
- o Clearly identify snubbers, anchor bolts and supports for workers and inspectors
- o Mark location after snubber is removed
- o Provide maps or photographs showing, or listing type, size, elevation, and location of all snubbers, anchor bolts, and supports
- o Improve accessibility with lighting, scaffold, ladders, or skyjackers
- o Test snubbers in a noncontaminated area if possible
- o Replace snubbers with energy absorber

Contamination-Reduction Techniques:

- o Perform quick decontamination before repair, grinding, removal, or welding
- o Use portable ventilation during grinding, welding, or boring
- o Decontaminate snubbers prior to testing
- o Provide containment and transfer cart
- o Transfer snubbers, hangers, and anchor bolts in plastic bags
- o Test snubbers in a ventilated containment

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #18

JOB TITLE: **Steam Generator Eddy Current Testing**

JOB DESCRIPTION:

Eddy current testing includes movement of ECT equipment into containment; setup of equipment at manway and data station; probe change, repair, and calibration; running standards; data collection; and equipment removal.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	12	140	50
Combustion Engineering	3.1	140	31
Babcock & Wilcox	7.3	60	24

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- Delay testing to allow for decay of short half-life radioactivity
- Remove protective clothing in a low-dose-rate area
- Maintain steam generator jumper log including reason for entry
- Provide TV monitor and audio communications for HP technicians and supervisors
- Locate ECT controls, electronics, and readouts in a low-dose-rate area
- Provide remote camera fixture with laser tube pointer
- Perform hydrogen peroxide flush of primary piping with resin cleanup during cooldown
- Shield steam generator manway
- Shield racks between manway and probe drive
- Replace bolted design nozzle dam with inflatable covers
- Shield drain lines near work platform and manway access path
- Shield work platform deck to provide low-dose-rate area underneath
- Shield inside of channel head
- Perform channel head decontamination

Timesaving Techniques:

- Use S/G mockup for training of S/G jumpers
- Tie off equipment going into generators
- Use automated ECT equipment with remote controls and readout
- Use reliable probe pushers, e.g., beltless driver
- Use robotic ECT machine connected to manway flange
- Use video tapes of steam generator jumps for training
- Provide reliable electric and air outlets
- Provide good lighting and large unobstructed work platform
- Minimize number of tubes to be tested

Contamination-Reduction Techniques:

- o Decontaminate steam generator bullpen, tent, or canvas floors periodically
- o Minimize ECT equipment brought into containment
- o Provide steam generator ventilation suction in opposite manway
- o Provide breathing air hose take-up reels
- o Decontaminate or contain equipment removed from inside of generator prior to transfer
- o Restrict traffic through area
- o Provide slight negative pressure on primary side

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #19

JOB TITLE: **Steam Generator Manway Removal/Replacement**

JOB DESCRIPTION:

Steam generator manway removal includes transfer and setup of manway tensioners or tools and manway-handling fixture or chain falls; insulation removal; stud detensioning; manway cover removal; stud cleaning; diaphragm removal; and storage of studs and manway. Replacement includes diaphragm replacement; manway cover replacement, stud tensioning; insulation work; and tools or tensioner removal.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	4.4	51	16
Combustion Engineering	1.5	26	9.9
Babcock & Wilcox	12	15	14

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Move diaphragms to a low-traffic area and cover with shielding or store in shielded drum
- o Shield steam generator manway
- o Shield drain lines near work platform and along manway access path
- o Clean studs in a low-dose-rate area
- o Start with manway at the far end of the work platform
- o Perform hydrogen peroxide flush of primary piping with resin cleanup during cooldown
- o Shield work platform deck to provide low-dose-rate area under platform

Timesaving Techniques:

- o Provide mockup training for manway removal and replacement
- o Install one-piece manway with flexitalic gasket and diaphragm attached
- o Tie off equipment going into generator
- o Use S/G manway diaphragm 1/4-turn fasteners and/or 3-screw diaphragm
- o Use manway handling fixtures such as strongbacks, jackable tilting tables, or hydraulic handling device
- o Use torque multipliers, hydraulic torque wrench or multistud tensioner detensioner
- o Provide permanent ladder, stairs, and spacious work platform
- o Provide tapered guide pins and all-thread studs to facilitate manway alignment
- o Provide tabs near stud holes for alignment of diaphragm

Steam Generator Manway Removal/Replacement
Sheet #19 (cont.)

Contamination-Reduction Techniques:

- Use steam generator manway adapter and ventilation system
- Use steam generator area bullpens or tents or rope-off area with canvas on floor
- Utilize catch pan during diaphragm removal
- Clean manway studs inside a clear plastic bag, underwater, or inside a stud-cleaning machine
- Maintain slight negative pressure on primary side if possible
- Decontaminate or contain equipment removed from inside of generator prior to transfer
- Clean and decontaminate area following manway replacement

PWR REPETITIVE HIGH-DOSE JOB
DOSE-REDUCTION DATA SHEET #20

JOB TITLE: **Steam Generator Tube Plugging/Sleeving**

JOB DESCRIPTION:

Tube plugging or sleeving includes template installation, obtaining photographs, marking of tubes, plug or sleeve installation, plugging or sleeving equipment removal, and final plug or sleeve inspection.

OUTAGE COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM man-rem	MAXIMUM man-rem	AVERAGE man-rem
Westinghouse	3.4	180	47
Combustion Engineering	4.5	580	120
Babcock & Wilcox	4.8	85	23

DOSE-REDUCTION TECHNIQUES:

Dose-Rate-Reduction Techniques:

- o Delay plugging or sleeving to allow for decay of short lived radioactivity
- o Remove protective clothing in a low-dose-rate area
- o Maintain steam generator jumper log including reason for entry
- o Provide TV monitor and audio communications for HP technicians and supervisors
- o Provide tube plugging controls, electronics, and readouts in a low-dose-rate area
- o Provide remote camera fixture with laser tube pointer
- o Perform hydrogen peroxide flush of primary piping with resin cleanup during cooldown
- o Shield steam generator manway
- o Shield drain lines near work platform and manway access path
- o Shield work platform deck to provide low-dose-rate area underneath
- o Shield inside of channel head
- o Decontaminate channel head

Timesaving Techniques:

- o Use S/G mockup for training of S/G jumpers
- o Tie off equipment going into generators
- o Use automated tube plugging equipment with remote controls and readout
- o Use reliable plugs, e.g., mechanical
- o Use robotic tube plugging and sleeving machine attached to manway flange
- o Use video tapes of steam generator jumps for training
- o Provide reliable electric and air outlets
- o Provide good lighting and large unobstructed work platform
- o Minimize number of plugs

Steam Generator Tube Plugging/Sleeving
Sheet #20 (cont.)

Contamination-Reduction Techniques:

- o Decontaminate steam generator bullpen, tent, or canvas floors periodically
- o Minimize equipment brought into containment
- o Provide steam generator ventilation in opposite manway
- o Provide breathing air hose take-up reels
- o Decontaminate or contain equipment removed from inside of generator prior to transfer
- o Restrict traffic through area
- o Provide slight negative pressure on primary side if possible

NRC FORM 335 (2-84) NRCM 1102, 3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

SEE INSTRUCTIONS ON THE REVERSE

1. REPORT NUMBER (Assigned by TIDC, add Vol. No., if any)
NUREG/CR- 4254
BNL-NUREG-51888

2. TITLE AND SUBTITLE
Occupational Dose Reduction and ALARA at Nuclear Power Plants: Study on High-Dose Jobs, Radwaste Handling, and ALARA Incentives

3. LEAVE BLANK

4. DATE REPORT COMPLETED

MONTH	YEAR
April	1985

5. AUTHOR(S)
Bruce J. Dionne and John W. Baum

6. DATE REPORT ISSUED

MONTH	YEAR
May	1985

7. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
Safety and Environmental Protection Division
Building 535A
Brookhaven National Laboratory
Upton, New York 11973

8. PROJECT/TASK/WORK UNIT NUMBER

9. FIN OR GRANT NUMBER
A-3259

10. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
Division of Radiation Programs and Earth Sciences
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

11a. TYPE OF REPORT
Formal

b. PERIOD COVERED (Inclusive dates)
January 1983 - January 1985

12. SUPPLEMENTARY NOTES

13. ABSTRACT (200 words or less)
The purpose of this report is to provide the NRC and the nuclear industry with information and data which will be useful for occupational dose reduction at nuclear power plants. The objectives of this effort were to:

1. identify the repetitive high-dose jobs, related collective dose ranges and applicable dose reduction techniques,
2. investigate and recommend improvements in the selection of high reliability and low maintenance equipment to assure that collective doses received during equipment repair is considered,
3. recommend improved radioactive waste handling procedures and equipment which could reduce collective dose equivalent, and
4. examine current ALARA incentives and recommend new positive steps which will provide additional dose-reduction incentives.

Ten nuclear sites were visited by two Brookhaven health physicists to collect the needed dose-reduction data and information. This report summarizes the findings and recommendations on the above objectives.

14. DOCUMENT ANALYSIS - a. KEYWORDS/DESCRIPTORS
Dose, Dose Reduction,
Nuclear Power Plants,
Radiation Protection,
ALARA

b. IDENTIFIERS/OPEN ENDED TERMS

15. AVAILABILITY STATEMENT
Unlimited

16. SECURITY CLASSIFICATION
(This page) Unclassified
(This report) Unclassified

17. NUMBER OF PAGES
94

18. PRICE

120555078877 1 1AN
US NRC
ADM-DIV OF TIDC
POLICY & PUB MGT BR-PDR NUREG
W-501
WASHINGTON DC 20555