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Occupational Dose Reduction Developments and Data Collected at Nuclear Power Plants*

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Introduction

Brookhaven National Laboratory has been contracted by the Occupational Radiation Protection Branch of the Nuclear Regulatory Commission to study occupational dose reduction at nuclear power plants. This project is entitled "Technical Assistance: Occupational Dose Reduction at Nuclear Power Plants". Its purpose is to provide information to industry which will be useful in preplanning for radiation protection during maintenance, operations and inspections. The objectives of this project are to:

- Identify repetitive high dose jobs, their collective dose range, and their respective dose reduction techniques,
- Investigate the use of low maintenance and high reliability equipment,
- Recommend improved radioactive waste handling equipment and procedures,
- Examine current ALARA incentives and recommend new positive steps to provide additional dose reduction incentives,
- Compile a NUREG Report, and
- Compile an ALARA Handbook.

The NUREG Report will summarize our findings on the above objectives. The ALARA Handbook, which will be utilized mainly by utility Health Physicist and ALARA Coordinators, will be a loose leaf type handbook which will contain:

- Data and techniques for high exposure jobs,
- Cost-benefit calculations for dose reduction modifications,
- ALARA procedures,
- Listing of ALARA equipment,
- Case histories of innovative ALARA techniques,
- A glossary of dose reduction references, and
- A list of persons interested in ALARA at power reactors.

Prior to publication of these reports, the information will be reviewed by the power plant personnel whom we interviewed, our BNL-Industry Dose Reduction Advisory Committee and the NRC. The Dose Reduction Advisory Committee is made up of a representative from AIF, EEI, EPRI, INPO, Bechtel, G.E., Westinghouse, Commonwealth Edison, Northeast Utilities and T.V.A. The information presented here is preliminary and has not yet been reviewed; therefore, it may be subject to change in our final report. The NUREG report should be available in the beginning of 1985 and the ALARA Handbook in late 1985.

Plants Visited

Ten nuclear sites were visited by two Brookhaven health physicists with past nuclear power plant experience to collect the needed information. This encompassed 19 nuclear units, which were selected based on the availability of several years of computerized job-specific data on occupational doses.

Table 1 shows the plants 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 28 plant-years of man-rem data, the six General Electric units had 12 plant-years, the three Combustion Engineering units had 15 plant-years and the three Babcock and Wilcox units had 9 plant-years.

Table 1
Nuclear Plants Visited

Westinghouse Plants

Plant Name	Power Rating (MWe)	Years of Operation	Plant-Years of Data
Zion 1 & 2	1040	10	10
Turkey Point 3 & 4	666	11	3
Haddam Neck	600	17	7
Kewaunee	535	10	8
6 Units	-	-	28 Total
General Electric Plants			
Quad Cities 1 & 2	789	12	6
Milstone 1	660	14	2
Browns Ferry 1,2 & 3	1076	9	4
6 Units	-	-	12 Total
Combustion Engineering Plants			
St. Lucie 1	777	7	6
Milstone 1	870	8	4
Maine Yankee 1	825	11	5
3 Units	-	-	15 Total
Babcock and Wilcox Plants			
Oconee 1, 2 & 3	860	10	9
3 Units	-	-	9 Total

High-Dose Jobs and Dose-Reduction Techniques

The first objective of this project has been the identification of repetitive high-dose jobs, their collective dose equivalent range, and dose reduction techniques applicable to each job. This information will enable industry and the NRC to focus on these major dose-reduction targets. Fifty high-dose jobs were identified and studied.

To reduce the total station collective dose equivalent, the logical approach is to identify the repetitive jobs which cause the highest collective dose equivalent, determine their relative dose-reduction potential and then implement the most cost beneficial 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 important to reducing total station dose equivalent.

The collective dose equivalent for repetitive high-dose jobs were obtained by preparing a generic description of each job prior to the plant visits. These descriptions of the high-dose jobs were modified by station personnel to better define the work associated with these doses. The station ALARA coordinator retrieved computer printouts, ALARA reports and/or letters which contained the needed data on high dose jobs. The Collective Dose Summaries for High Dose Jobs for General Electric and Westinghouse plants are shown in Tables 2 & 3. The dose range per job is indicative of the dose-reduction potential for that job.

Table 2
General Electric Boiling Water Reactors
Collective Dose Summaries for High Dose Jobs

Job Title	Integrated Dose (Man-Rem) Minimum	Maximum	Average	Population Size
Reactor Assembly/Disassembly	7.8	51.0	18.6	11
Fuel Shuffle/Sipping & Inspection	3.8	58.4	17.3	11
CRD Removal/Rebuild & Replacement	6.3	229.0	74.2	11
Recirculation Pump Seal Repair	1.5	22.7	8.1	11
*Torus Repair Inspection and Modification	125.1	597.9	313.0	11
*Reactor Water Cleanup System Repair	9.3	195.6	83.2	9
Turbine Overhaul	0.5	14.6	6.0	8

* Dose Per Cycle = Outage + Routine Operations

Table 3

Westinghouse Pressurized Water Reactors
Collective Dose Summaries For High Dose Jobs

Job Title	Integrated Dose (Man-Rem) Minimum	Maximum	Average	Population Size
Reactor Assembly/Disassembly	12.2	120.6	50.1	19
Fuel Shuffle & Inspections	3.6	15.5	9.4	12
Steam Generator Manway Removal/Replacement	5.7	51.1	18.3	14
Eddy Current Testing (Steam Generators)	5.9	117.6	42.1	16
Reactor Coolant Pump Seal Repair	4.3	31.3	16.6	13
Secondary Steam Generator Inspection & Repair	2.3	40.8	12.3	15
*Chemical Volume & Control System Repair	0.8	22.2	10.5	16

* Dose Per Cycle = Outage + Routine Operation

The dose-reduction techniques for repetitive high-dose jobs were obtained by questioning maintenance, engineering and the health physics personnel on the "tricks of the trade" to reduce exposures and the spread of contamination. The listing of the consolidated dose-reduction techniques can be used in preplanning for radiation protection during these activities. The Dose Reduction Data Sheet for PWR-Reactor Coolant Pump Seal Repair is given below as an example of the dose-reduction data sheets we are developing.

PWR REPETITIVE HIGH DOSE JOB
DOSE REDUCTION DATA SHEET

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; replace auxiliary piping and replace oil. Excludes: exposures associated with vibration measurements, pump ISI inspections, pump modifications (e.g. fire protection oil drip pans), reinsulation, painting, and motor inspections and repair.

COLLECTIVE DOSE:

REACTOR SUPPLIER	MINIMUM MAN-REM	MAXIMUM MAN-REM	AVERAGE MAN-REM
Westinghouse	4.3	31.3	16.6

DOSE REDUCTION TECHNIQUES (Dose Rate Reduction):

- Steam generator in wet layup
- Evaluate shielding of local "hot spots"
- Lead blankets on grating over "hot" pipes

DOSE REDUCTION TECHNIQUES (Timesaving):

- Dedicated RCP tool boxes
- RCP seal replacement video tape
- Temporary deck between grating and flange gap
- Pneumatic torque wrench for flange
- Four ultra-small tracked chainfalls to replace seal lift rig

DOSE REDUCTION TECHNIQUES (Contamination Reduction):

- Periodically mop plastic covered grating
- Hang plastic sheet walls from rails and erect walls around contaminated parts storage area
- Portable doghouse enclosure with vacuum cleaner for ventillation to clean small parts
- Large contaminated parts cleaned over blotter paper in parts storage area
- Restrict access to area

High Reliability and Low Maintenance Equipment

The second objective has been to investigate the use of equipment reliability data, including dose received in component repair, and to determine if this data is used by maintenance and engineering personnel for purposes of dose reduction during equipment selection.

Knowing which components contribute to high maintenance or repair dose will make it possible to evaluate the value of reliability improvements to dose-reduction actions. Since routine and non-routine maintenance activities at nuclear power plants contribute about 70 to 80% of the total station exposure, reducing the amount of maintenance and repair via the use of higher reliability and low maintenance equipment may be important.

In order to accomplish this objective we questioned engineers to determine to what extent the repair dose is considered in making component selection. Also feedback between maintenance and engineering on component reliability was investigated. Lastly, the extent to which station personnel have modified or replaced components which had high maintenance or repair dose was investigated. This was accomplished by questioning the station health physics, maintenance and engineering personnel and architect engineers on the:

- Availability of nuclear plant reliability data (NPRD),
- Availability of component repair dose data,
- Application of NPRD and repair dose data to equipment replacement and selection,
- Application of NPRD and repair dose data to preventative maintenance programs,
- Methodology used to identify unreliable equipment, and
- Nature of the feedback loop on equipment reliability from maintenance worker to architect-engineers.

In regards to whether repair and maintenance dose is considered during the component selection we found that it is of secondary concern. Equipment selection is somewhat subjective. The major considerations are 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 equipment 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 is a secondary benefit along with labor savings. These benefits are rarely quantified for purposes of equipment selection.

In regards to the transfer of component failure information and repair dose data from maintenance and health physics respectively, to engineering, and the transfer of this information from the utility engineers to the nuclear steam system suppliers (NSSS) and architect-engineers (A/Es), we found that this information flows informally within the utility but primarily gets to the A/E-NSSS if they obtain it from plant visits or from informal conversation.

The component repair dose data is available from some health physics computerized job dose tracking programs and is verbally transmitted to maintenance and engineering staff if requested. A few utilities have published selected component dose data in ALARA reports. However, the volume of individual component repair data and the lack of corresponding details of the repair preclude the use of this data by engineers.

The equipment reliability data is available in various forms. Equipment reliability data can be found in: licensee event report (LER) summaries published by the NRC; NPRD summaries published by INPO; computerized listings of equipment work requests being developed by utilities; and equipment failure data bases maintained by NSSS and A/E firms. However, specific component data in the appropriate format is difficult to retrieve. Therefore this data is not being widely used by engineers.

Lastly, unreliable components are being modified and replaced. In general, good communication exists between station maintenance and engineering personnel. In addition the NRC and NSSS send out bulletins on generic failure problems. Examples of unreliable components which were modified or replaced at the stations visited are: pump seals e.g. reactor coolant pumps, recirculation pumps, RWCU pumps, and charging pumps; valves which had repetitive leakage; pressure and level transmitters; and fuel transfer equipment reliability modifications.

Radwaste Handling Improvements

The third objective has been the identification of possible improvements in radioactive waste handling equipment and procedures which could reduce collective dose equivalent. Numerous radwaste packaging improvements were examined.

Radwaste operations contribute about 5-10% of the total station dose. This does not represent a major contribution to the total station dose. However, radwaste handlers and radwaste operators are a critical workgroup in that many approach their administrative dose limits and must be limited from further radiation work. Therefore, radwaste dose-reduction improvements are needed.

The major radwaste improvements were investigated by preparing a pre-selected list of equipment and procedural dose-reduction improvements. The types of waste investigated were bead and powered resins, evaporator bottoms, tank and filter sludge, spent filters/cartridges and dry active waste. Our investigation was restricted to the packaging, prepare-ready-store and truck loading stages of radwaste processing. The radwaste supervisor and ALARA coordinator reviewed the list of dose-reduction improvements and indicated those utilized and whether they considered them successful from a dose reduction standpoint. Table 4 indicates the success rate and the number of plants utilizing the radwaste dose-reduction improvements.

Table 4
Dose-Reduction Improvements

Radwaste Improvement	Success/No. Plants Utilized*
1. Radwaste Handlers	5/5
2. Management Policy and Program	5/5
3. Lead 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 System	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 Filters & Resins	3/5
17. Trash Sorting Area	3/5

* Ten plants surveyed.

ALARA Incentives

The fourth objective has been the examination of current ALARA incentives and the recommendation of new steps to provide additional incentives for dose reduction. This includes identification of the important ALARA incentives, their impact on the plant ALARA programs and what can be done by the NRC and industry to improve them. The relative importance of the ALARA incentives for plant managers and workers were evaluated. In addition, the relative importance of the key components of an ALARA program were examined.

As health physicists we have strong incentives for reducing exposures since this is so basic to our profession. However, the operators of an electric generating plant have very powerful monetary incentives, which at times are in competition with dose-reduction objectives. Since you must have management support to have an effective ALARA program, a determination of managers' ALARA incentives was considered important.

A preselected listing of managers' ALARA incentives was prepared and these incentives were rated by ten plant managers, ten maintenance supervisors and ten radiation protection managers. Table 5 indicates the relative priority and the number of plants which utilized these incentives.

Table 5
Manager's ALARA Incentives

Manager's ALARA Incentives	Priority[a]			No. Plants Utilized[b]
	High	Medium	Low	
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

Table 5 cont'd

Manager's ALARA Incentives

Manager's ALARA Incentives	Priority[a]			No. Plants Utilized[b]
	High	Medium	Low	
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

ALARA is everyones responsibility, and the more minds and hands which are working towards its cause the greater will be a station's dose reduction. Therefore the importance of various worker ALARA awareness techniques was determined.

Again a preselected listing of workers' ALARA awareness techniques was prepared and these techniques were rated by ten plant managers, ten maintenance supervisors and ten radiation protection managers. Table 6 indicates the relative priority and the number of plants which utilized the worker ALARA awareness techniques.

Table 6
Worker ALARA Awareness Techniques

Worker's ALARA Awareness Techniques	Priority[a]			No. Plants Utilized[b]
	High	Medium	Low	
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

Table 6 cont'd
Worker ALARA Awareness Techniques

Worker's ALARA Awareness Techniques	Priority[a] High	Medium	Low	No. Plants Utilized[b]
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 & Pens	7	4	19	3

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

Lastly, the key components of an ALARA program were examined. A listing of the key components was prepared from NUREG CR-3254 entitled "Licensee Programs for Maintaining Occupational Radiation ALARA"(1) and a paper given on the topic at the 1982 Westinghouse REM Seminar.(2) Each component was rated by ten radiation protection managers and ten ALARA coordinators. Table 7 indicates the relative priority and the number of plants which utilized the ALARA program key components.

Table 7
ALARA Program Key Components

ALARA Program Component	Priority[a] High	Medium	Low	No. Plants Utilized[b]
1. ALARA Policy and Management Commitment	19	0	1	10
2. ALARA Data Base 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

Table 7 cont'd

ALARA Program Key Components

ALARA Program Component	Priority[a] High	Medium	Low	No. Plants Utilized[b]
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.

Summary

Occupational dose reduction developments and data collected at nuclear power plants have been described. Written descriptions of repetitive high dose jobs, their collective dose equivalent ranges and list of dose reduction techniques will aid in reducing collective dose equivalents from these dose-reduction targets. Knowing which components contribute to high maintenance or repair dose will aid in reducing routine maintenance collective dose equivalents. The radwaste dose reduction improvements will aid in reducing radwaste operations collective dose equivalent and reduce the number of radwaste workers who exceed their administrative dose limits. The identification and rating of manager's and workers' ALARA incentives will provide the basis for recommendations to improve dose reduction incentives. Lastly, the identification and rating of the key components of an ALARA program will aid in the development and coordination of the nuclear station ALARA programs.

The quality of the information gathered to date would not have been possible, were it not for the cooperation received during our nuclear plant visits and from our BNL-Industry Dose Reduction Advisory Committee. Recent presentation of our finding generated industry interest towards the BNL's ALARA Centers dose reduction efforts.(3-5)

In conclusion, if the good practices for dose reduction in our publications are put to use, this will result in enhanced nuclear safety, reduction of radiological risk and improved reputation of nuclear power in the United States. In addition, this would also represent another example of the NRC/INPO Radiological Protection Coordination.

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