EXPOSURE CONTROL DURING HIGH MAINTENANCE JOBS

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ABSTRACT

Occupational radiation doses at U.S. light water cooled reactors (LWRs) have been decreasing every year since 1983. In 1989, the LWR average dose per reactor reached its lowest point since 1973. Historically, maintenance-related activities have accounted for between 70 and 75 percent of the total occupational doses at U.S. LWRs, and most of this maintenance-related dose is accrued during plant outages. This paper will focus on high dose maintenance jobs such as steam generator replacement, recirculation pipe replacement/crack repair, and steam generator tube plugging/sleeving and will discuss how the doses associated with these jobs have declined over the past several years through the implementation of various ALARA techniques.

INTRODUCTION

The NRC (formerly AEC) has been tabulating and analyzing occupational exposure data for over 20 years. In 1969 (the first year for which complete U.S. reactor dose records are available), the average dose for the seven operating light water reactors (LWRs) in the U.S. was 178 person-rems per reactor. In the ensuing years, the average dose per reactor increased as plant size, worker complement, and amount of maintenance work performed increased (1). Average collective doses at U.S. LWRs peaked between the years 1980 and 1983, following the 1979 accident at Three Mile Island (TMI), Unit 2. Since 1983, the average collective doses for both pressurized water reactors (PWRs) and boiling water reactors (BWRs) have been steadily declining. Between 1983 and 1989, the average annual dose per reactor has decreased by an average of 41 person-rems per year (2). The 1989 LWR collective dose per reactor of 343 person-rems was the lowest LWR average collective dose per reactor since 1971 (see Figure 1).

One of the reasons for this downward trend from the peak doses seen in the early 1980s is the completion of a majority of the TMI-mandated fixes instituted after the 1979 accident. Another reason for the decreasing dose trend at LWRs is the increased emphasis being placed by industry, INPO, and the NRC (e.g., through the BNL ALARA Center) on the importance of effectively applying ALARA principles at LWRs. A majority of the plants contacted in recent years have ALARA coordinators on their staff whose job it is to ensure that ALARA principles are integrated into all maintenance/operations work to reduce overall personnel exposures. Maintenance (both normal and special) and operations related doses typically are the major contributors (approximately 70 percent and 12 percent,

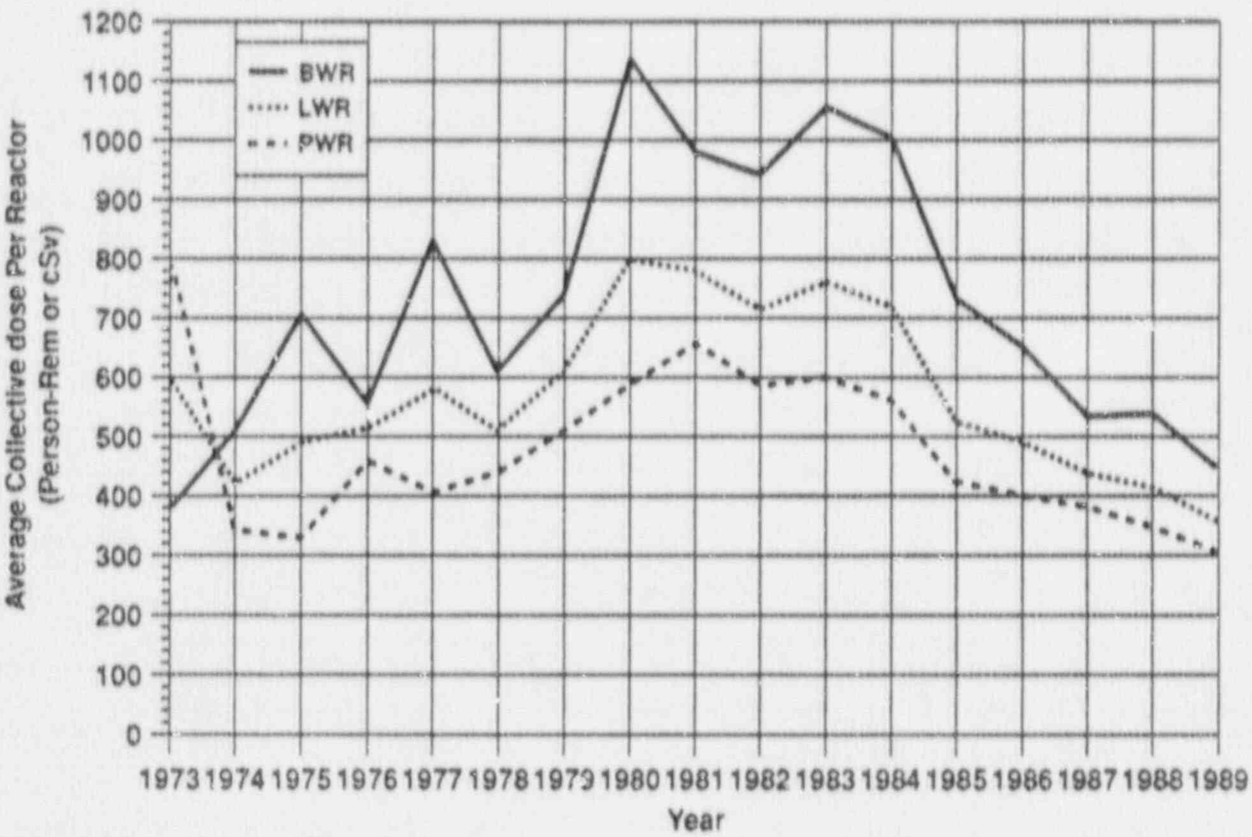


Figure 1
Average Collective Dose Per Reactor

respectively) to the total plant collective dose (see Table I and Figure 2). Therefore, it is very important that ALARA be incorporated into the work plans and procedures during the early planning stages in order to minimize job doses.

OUTAGE VERSUS NON-OUTAGE DOSES

Although plant outage length and collective dose can vary widely depending on the outage work scope, a large percentage of a plant's collective dose is typically accrued during outages. Since a majority of the maintenance and special maintenance work is performed during outage periods, the average outage dose rates to plant personal usually exceed the average non-outage dose rates.

The magnitude of this difference was the subject of an NRC study undertaken in early 1989 (3). As part of this study, approximately two-thirds of the LWRs (62 LWRs - 40 PWRs and 22 BWRs) operating in the U.S. were contacted and asked to provide their average outage and non-outage daily dose rates. On the basis of the data collected, the average collective dose per unit for PWRs was 0.117

Table I
Percentage of Annual Collective Dose
at LWRs by Work Function
1984-1988

Percentage of Collective Dose Each Year					Avg
1984	1985	1986	1987	1988	1984-88
11.4%	12.8%	12.8%	11.9%	16.9%	13.1%
26.9%	34.6%	33.2%	34.9%	36.8%	33.3%
6.3%	8.6%	8.3%	8.0%	13.2%	8.9%
45.4%	32.5%	35.5%	33.2%	20.3%	33.4%
3.6%	5.1%	4.0%	3.9%	5.2%	4.3%
6.4%	6.5%	6.2%	8.1%	7.6%	7.0%

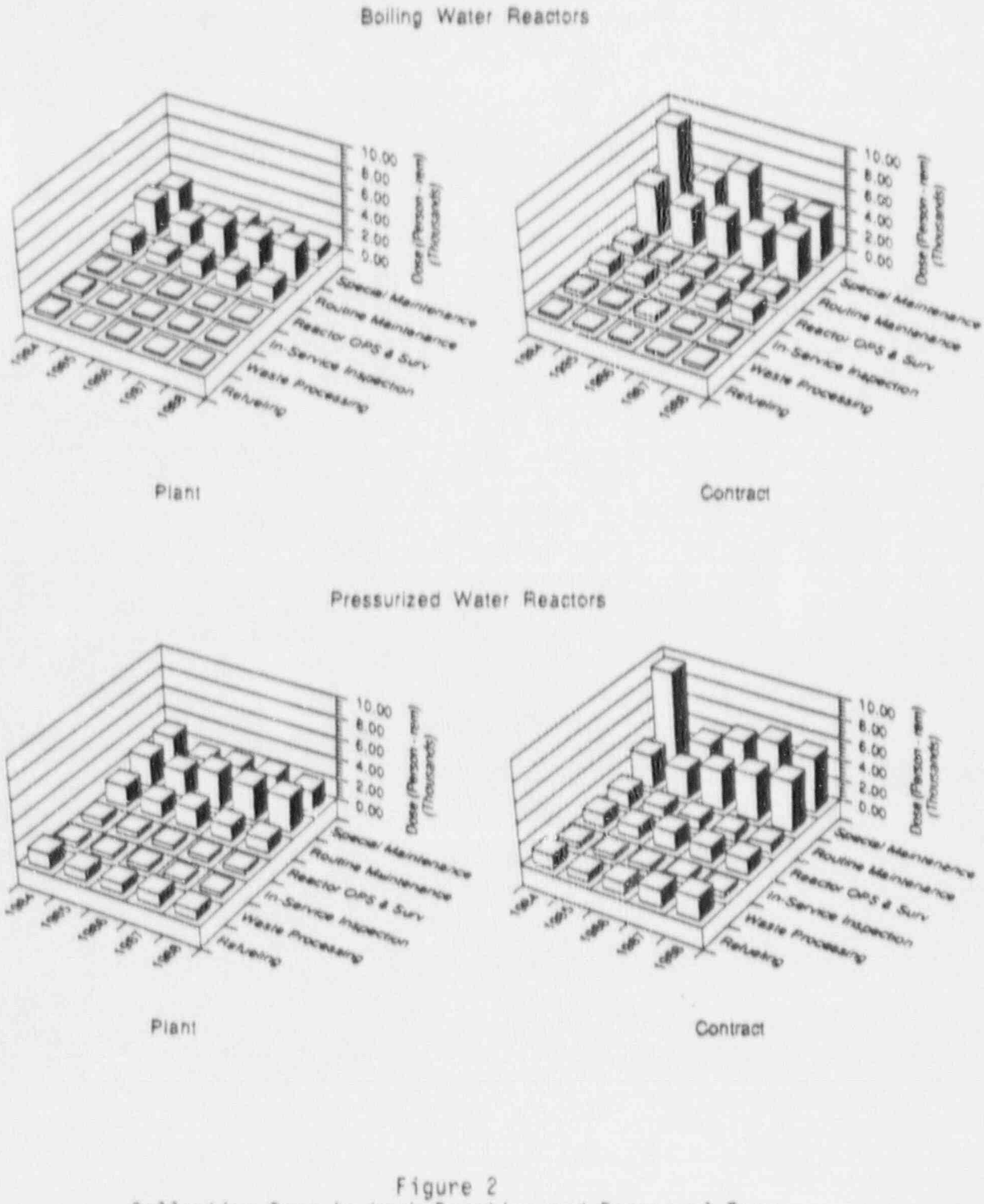


Figure 2
Collective Dose by Work Function and Personnel Type
1984-1988

rem per day during non-outage periods and 3.65 rems per day during outage periods (see Figure 3). This represents a factor of 31 difference between average daily outage and non-outage doses at BWRs. Although the daily doses reported during non-outage periods for PWRs were fairly consistent, the outage dose rates varied from a low of 0.833 rem per day to a high of 10.94 rems per day for the plants surveyed.

This study found that the average collective dose per unit for BWRs was 0.441 rem per day for non-outage periods and 4.00 rems per day during outage periods. This represents a factor of 9 difference between average daily outage and non-outage doses at BWRs. Again, the daily doses reported during non-outage periods for BWRs were fairly consistent, while the outage dose rates varied from a low of 0.3 rem per day to a high of 8.5 rems per day for the plants surveyed.

Because of the magnitude of average daily outage doses relative to non-outage doses, reducing the frequency and duration of plant outages can lead to a lowering of a plant's annual collective dose. Outage doses can be reduced by:

- o Identifying and scheduling outage work well in advance;
- o Preparing comprehensive and detailed work procedures which include ALARA considerations;
- o Performing ALARA reviews of all dose intensive work to be performed;
- o Incorporating adequate radiological controls into outage jobs; and
- o Using experienced and well-trained personnel to perform the outage work.

There are several dose intensive activities which have historically accounted for a large percentage of the annual collective doses at PWRs and BWRs. For PWRs, the replacement of steam generators and steam generator tube plugging/sleeving are two such activities which typically result in large doses. For BWRs, the most dose intensive task has been recirculation pipe replacement. Another activity which has significantly contributed to BWR doses in the past is inspection and repair of pipe cracks caused by intergranular stress corrosion cracking (IGSCC). There are also several potentially high dose jobs which are performed at both PWRs and BWRs. These jobs include erection and breakdown of scaffolding and temporary shielding, snubber removal/replacement, in-service inspection and testing, and refuelings.

STEAM GENERATOR REPLACEMENT

In 1979, Surry, Unit 2 became the world's first PWR to replace its steam generators. The resulting dose of 2141 person-rems for this project was the highest dose experienced to date for any U.S. PWR (with the exception of Indian Point 1 in 1973). This dose was also over four times the 1979 PWR average annual dose of 516 person-rems. The following year, Surry, Unit 1 replaced its steam generators for 1759 person-rems (4).

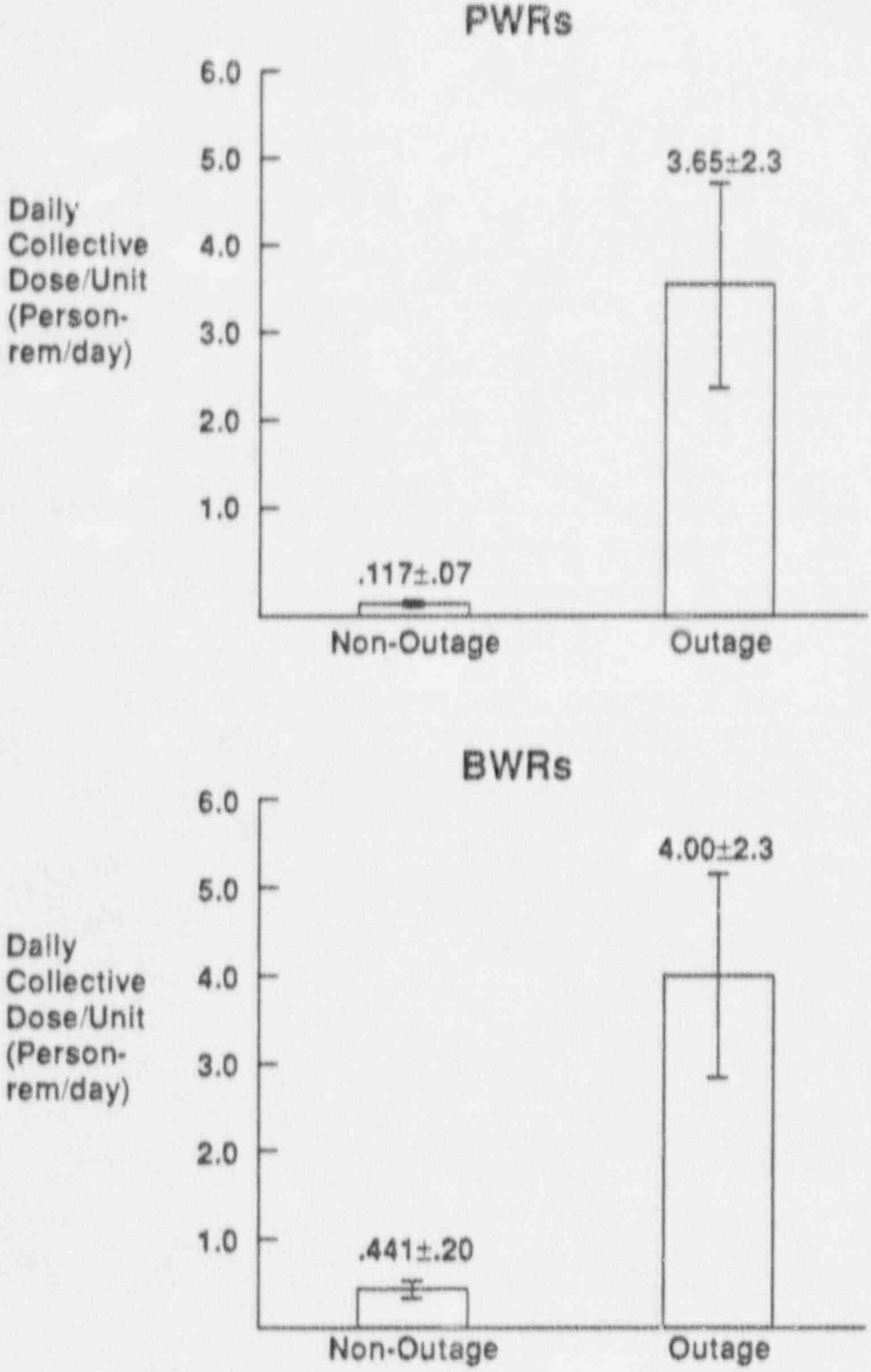


Figure 3
LWR Daily Collective Dose per Unit

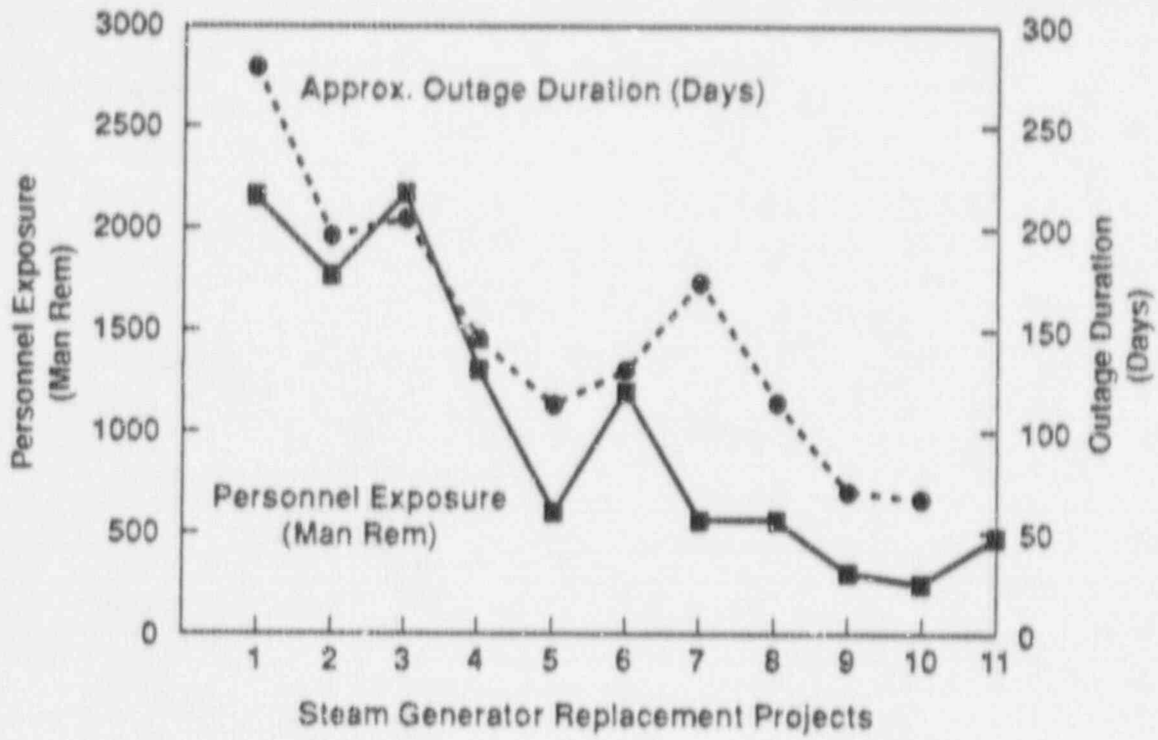
In the ensuing years, six additional U.S. steam generator replacements have been performed at five plants (see Figure 4) and a seventh is now underway at Palisades (5, 6). As can be seen from Figure 6, both the collective dose and outage duration to perform these projects have been decreasing. The most recent U.S. steam generator replacement project to be completed was in 1989 at Indian Point 3. The total collective dose for the project was only 514 person-rems (as compared with 2141 person-rems for Surry 2) and the project outage time of 140 days was approximately half of that required for the Surry 2 replacement project.

Many of the ALARA techniques developed during the first seven U.S. steam generator replacement projects were used during the Indian Point 3 steam generator replacement project (7). All aspects of the Indian Point 3 job received extensive preplanning and the licensee established detailed person-rem estimates prior to initiating the project. The licensee estimates that 100 person-rems were saved by using realistic mock-ups of the steam generator and piping to be replaced. Use of these mock-ups minimized unforeseen problems, permitted the optimization of techniques, and led to time reductions in channel head jumping. The licensee estimates that an additional 50 person-rems were saved by decontaminating the RCS piping. Other dose saving features used at Indian Point 3 included use of automated cutting and welding equipment, closed circuit TV, shielding of RCS nozzles, and ALARA training.

Palisades is currently in the process of replacing its two steam generators. Palisades has relied on lessons learned from previous steam generator replacement projects and has realized significant work place dose rate reductions through RCS piping decontamination. The steam generator replacement project at Palisades is scheduled for completion in March of 1991. The estimated dose goal of 484 person-rems, if realized, would make this the lowest collective dose to date for any U.S. steam generator replacement project.

The first European facility to perform a steam generator replacement was Unit 2 of the Swedish Ringhals plant which, in 1989, replaced its three steam generators in a record 72 days for only 290 person-rems (8). Ringhals 2 utilized many of the ALARA features used at Indian Point 3, such as mock-up training and component decontamination, and also benefited from excellent cooperation between the contractors and the utility. In mid-1990, France's Dampierre-1 became the first French plant to have its steam generators replaced (9). The three steam generators were replaced ahead of schedule for 220 person-rems.

In the 12 years since the world's first steam generator replacement, doses to perform the task have dropped by nearly an order of magnitude. The dramatic drop in the dose required to perform this job is primarily due to careful preplanning (including the setting of person-rem goals), use of lessons learned and ALARA techniques from previous steam generator replacements, and the extensive use of mock-ups.



1. Surry 2 – 1979
   3 Loop Plant
2. Surry 1 – 1981
   3 Loop Plant
3. Turkey Point 3 – 1982
   3 Loop Plant
4. Turkey Point 4 – 1982
   3 Loop Plant
5. Point Beach – 1984
   2 Loop Plant
6. H.B. Robinson – 1984
   3 Loop Plant
7. D.C. Cook - 1988
   4 Loop Plant
   Outage adjusted to deduct
   duration of 10 year ISI
8. Indian Point 3 - 1989
   4 Loop Plant
9. Ringhals 2 – 1989
   3 Loop Plant
10. Dampierre 1 – 1990
    3 Loop Plant
11. Palisades – 1991
    2 Loop Plant

Figure 4
Steam Generator Replacement Project Experience

BWR RECIRCULATION PIPE REPLACEMENT

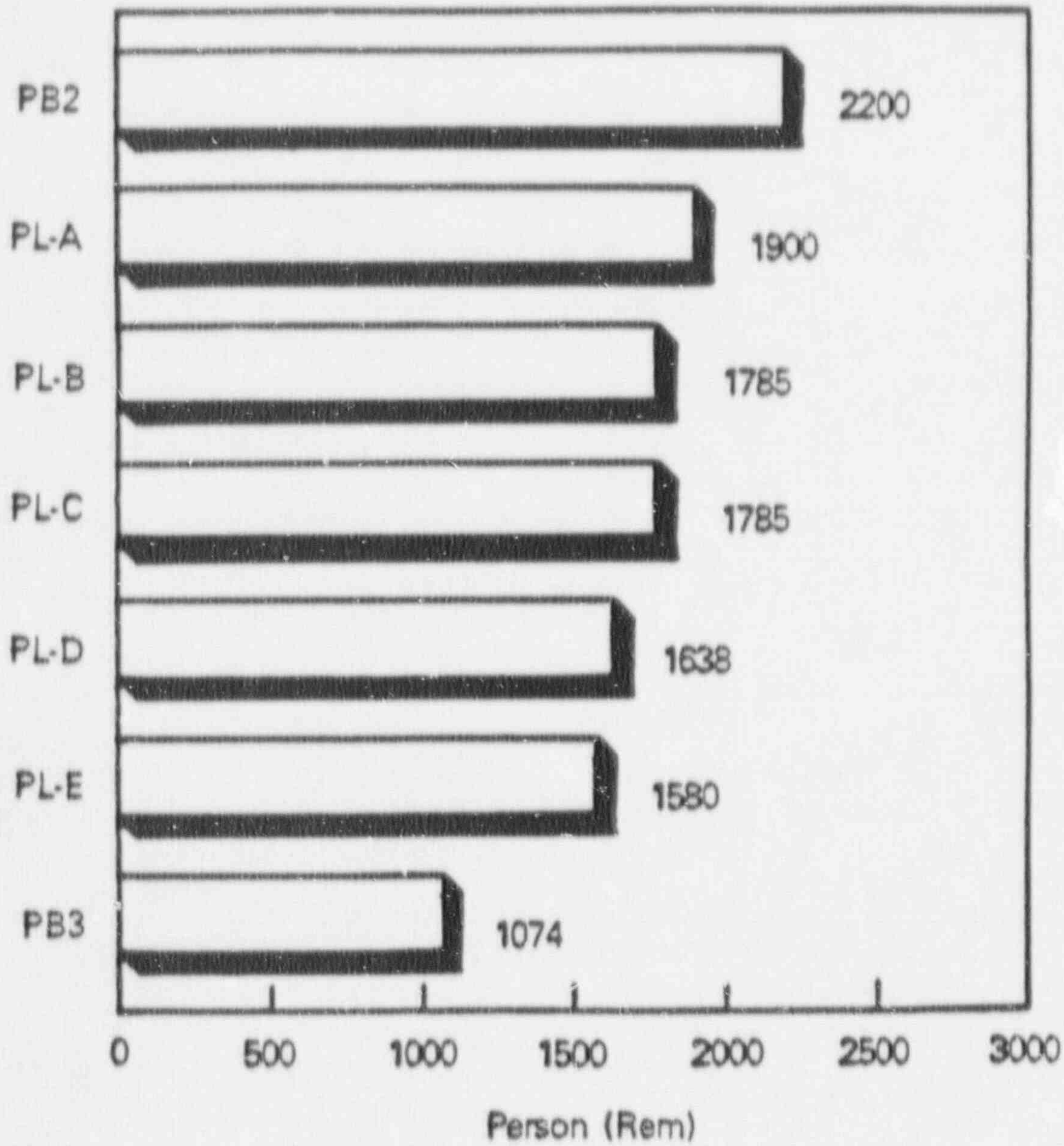
One of the most dose intensive jobs performed at BWRs is the replacement of the primary recirculation system piping. Replacement of all or portions of this piping is often necessary because of the substantial damage done to both the pipe and pipe welds by IGSCC (10).

Nine Mile Point 1 was the first plant to perform a recirculation pipe replacement. This job, performed during 1982-1983, resulted in an 11-month outage and the expenditure of 1464 person-rems. Five additional major pipe replacements have been performed since, with one of the most recent being at Peach Bottom between 1987 and 1988 (see Figure 5). This job was completed in less than four months with the expenditure of only 1074 person-rems (11).

The pipe replacement at Peach Bottom 3 was one of the largest such projects to date in the U.S. nuclear industry and the utility relied heavily on lessons learned from previous pipe replacements. Extensive use of shielding was made and hot spots in the work areas were eliminated or reduced. This served to lower the general area exposures rates. The pipe sections to be replaced were chemically decontaminated prior to pipe cutting. Forty-two field welds were eliminated on the new piping, resulting in fewer weld joints at which crud traps can form. The licensee used various ventilation controls to minimize the generation of airborne activity. This permitted much of the work to be performed without the use of respirators. The use of mock-up training for major tasks helped to familiarize the workers with both the radiological and mechanical aspects of the job. This training, which was videotaped for future use, also resulted in the development of a rapport between the health physics technicians and the construction work force. This rapport resulted in a more efficient working team. Finally, the implementation of a successful ALARA awareness program, including special training, use of signs identifying components, ALARA briefings, and use of good on-the-job communication devices helped to lower overall worker dose. The dose reduction steps which were used at Peach Bottom 3 resulted in a total job dose which was less than half of the dose required (2200 person-rems) for the recirculation pipe replacement performed at Peach Bottom 2 three years earlier.

STEAM GENERATOR PLUGGING/SLEEVING

The plugging/sleeving of steam generator tubes is another job which can result in high collective doses. Denting, IGSCC, and pitting are some of the forms of tube degradation which may necessitate tube plugging and/or sleeving. Since manual tube plugging and sleeving both require entry into the steam generator channel heads, where general area dose rates can exceed 10 rem/hour, this task can be very dose intensive and good ALARA controls are necessary to minimize the potentially high doses involved. The steam generator sleeving project conducted at San Onofre 1 in 1980-1981 resulted in the expenditure of nearly 3500 person-rems, about six times the initial dose estimate for the job. Although some of this dose was due to equipment malfunction caused by use of new, untested sleeving equipment, most of the dose was accrued during the actual tube honing and sleeving operations (12).



PB2 = Peach Bottom-2 project
PB3 = Peach Bottom-3 project
PL-A through PL-E = Other U.S. plants.

Figure 5
Comparison of Radiation Exposure at
BWR Major Pipe Replacement Projects

The development and use of remote tube plugging/sleeving capabilities over the last 10 years has resulted in a marked decrease in the doses associated with performance of this work. Robotic devices which can perform tube plugging/sleeving operations have eliminated the need for personnel entry into the steam generator channel heads. The average dose per sleeve expended during tube sleeving operations has been reduced by a factor of 10 since 1981 (13). The average dose per plug for steam generator tube plugging has also been reduced by a similar factor in the last 10 years. Most of this reduction has been realized through the use of more sophisticated robots to perform these tasks. Although robots have been instrumental in greatly reducing the collective doses required for plugging or sleeving large numbers of steam generator tubes, they may not be cost effective for work on small numbers of tubes or tubes located in peripheral areas of the steam generator tube sheet.

OUTAGE EXPOSURE CONTROL METHODS

There are several exposure control methods which can result in lower outage doses. Doses associated with scaffolding erection/tear-down can account for between 10 and 15 percent of the total outage dose. The use of permanent scaffolding in high dose rate areas would eliminate the personnel doses associated with scaffolding erection/tear-down each outage. Another means of reducing outage doses is to improve the use of shielding. Use of permanent shielding versus temporary shielding in high dose rate areas would reduce the doses associated with the installation/removal of temporary shielding during outages. In instances where it is not feasible to install permanent shielding, the installation of temporary shielding could be facilitated by installing permanent hooks/hangers in areas where this temporary shielding is required. Use of these hooks/hangers would reduce the time needed to hang this shielding. Some other measures of reducing doses during outages are; (1) scheduling jobs to be performed on the same component or in the same areas so that they are performed at the same time to eliminate duplication of setup preparations, (2) using skilled workers to perform difficult jobs, and (3) using the minimum number of personnel necessary to perform the job.

CONCLUSION

In addition to the downward trend of collective doses at U.S. LWRs since the early 1980s there has also been a gradual decrease in the overall percentage of collective dose attributed to maintenance related jobs. This is evidenced by the dramatic decrease in the collective doses required to perform many dose intensive jobs at U.S. LWRs. As the current generation of U.S. LWRs ages, plant components will require increased levels of maintenance and surveillance to ensure that plant safety is maintained and doses are minimized. A strong health physics program which emphasizes ALARA during the planning and execution stages of maintenance work is necessary to prevent LWR doses from increasing as the maintenance work required at these plants increases over the years.

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