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INSTORE : A PC-Based Database Program for Occupational Radiation Exposure of a Nuclear Power Plant

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Abstract

Ensuring occupational radiation exposure(ORE) as low as is reasonably achievable(ALARA) has been one of very important requirements in a nuclear power plant. It is well known that about 70 percent of occupational dose has incurred from maintenance jobs in the outage period. To reduce occupational dose effectively, the high-dose jobs in the outage period should be identified with their dose reduction potentials and methods. In this study, a PC-based ORE database program, INSTORE, is developed to evaluate ORE doses in individual jobs, and the ORE data of Kori Units 3 and 4 are assembled to the database. Based on customary job classification, radiation work is classified into 26 main jobs which comprise 61 detailed jobs, and occupational doses are assessed according to each detailed job. As a result, high-dose jobs are identified with dose reduction priority in terms of collective ORE dose. It is recommended that adeqaute dose reduction methods for these jobs should be prepared to improve their working conditions and procedures.

1. Introduction

The reduction of occupational radiation exposure(ORE) has always been and continues to be one of key issues in the design and operation of a nuclear power plant. In particular, it is true in most advanced concepts of nuclear power system under development, and substantial reductions of ORE are imposed on their design requirements. Their design objectives are specifically set for ORE reduction, and the compliance with their objectives will ask for a comprehensive and systematic assessment of the existing structure of ORE composition in order to avoid a huge financial penalty which could be arisen in meeting the objectives through corrective actions in the operating stage.

Information relevant to ensuring the ORE as low as is reasonably achievable(ALARA) could be effectively derived by analyzing existing ORE data accumulated in each operating plant. Each nuclear power plant keeps a record of ORE which is generally composed of raw data of collective and individual doses year by year, which cannot be directly utilized for design improvements in future plants. The raw data should be analyzed in such a way that individual job constituents be identified in detail, which eventually form the basic database. Using the database, we can ascertain if doses could be lowered further in an economical and sensible way in accordance with ALARA.[2] In order to maximize the benefit of the database, the data need to be appropriately and compatibly formulated. The data should be job-specific as in detail as possible, and the coded job specifications should be compatible with those used in other plants, in order to facilitate data exchange and intercomparisons.[1],[2],[7]

This paper mainly deals with two topics: development of the PC-based ORE database program, INSTORE(Information Storage of Occupational Radiation Exposure), and identification of important radiation jobs with high potential for dose reduction using INSTORE. The ORE data of Kori Units 3 and 4 are used for this database.

2. ORE Database Program

A major portion of ORE is received during maintenance & repair, radwaste handling, inservice inspection, refueling and non-routine operations. In particular, the contribution by the operation of maintenance & repair jobs is identified most dominant. Existing ORE data of each job description are composed of collective and individual doses. It is clear that the use of ORE database program offers to analyze the existing data and to give the opportunity of achieving an effective dose reduction in accordance with overall ALARA program.[1]

2.1. Program Structure and Operation

The structure of INSTORE is summarized in Figure 1. START FORM is the first screen which the user meets when the database program is started. The user now can shift to any of four different modules: DATA MANAGER FORM, DATABASE VIEW FORM, DATA SEARCH FORM or DATA STATISTICS FORM. As shown in Figure 2, the user can select next operation using six different buttons named as DATA MANAGER, DATABASE VIEW, DATA SEARCH, DATA STATISTICS, CLOSE and QUIT. In DATA MANAGER FORM, the user can manage data operation such as entering, deleting and updating. In DATABASE VIEW FORM, the user can view all the data in the database. In DATA SEARCH FORM, the user can search data according to plant unit, job year, main job code and detailed job code. The searched data set is available in the forms of column type and datasheet type. Figure 3 shows an example screen of searched data set in the form of column type. In DATA STATISTICS FORM, the user can pick up the data statistics, such as maximum, minimum, mean and standard deviation according to plant unit, job year, main job code and detailed job code. All the operations described above are performed using the data stored in RADWORK TABLE, and the results can be printed out at each step if necessary.

INSTORE is set up on a PC compatible microcomputer and composed of easy-to-use program modules. The edition of searched data and their statistics, and the exchange of data between INSTORE and other utilities are always possible.

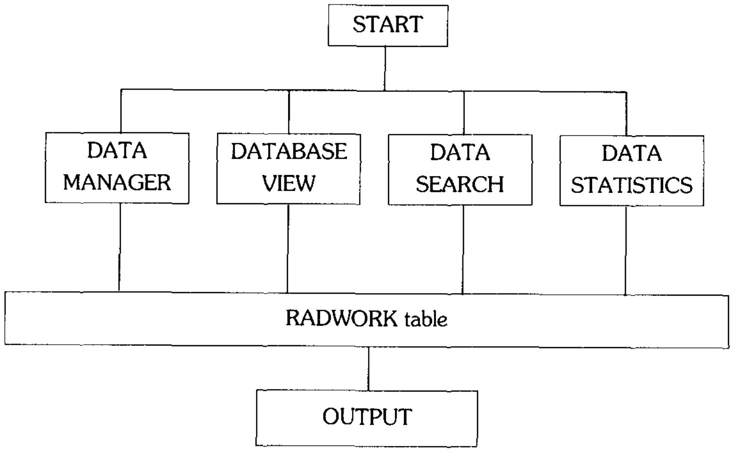

Figure 1. Structure of INSTORE

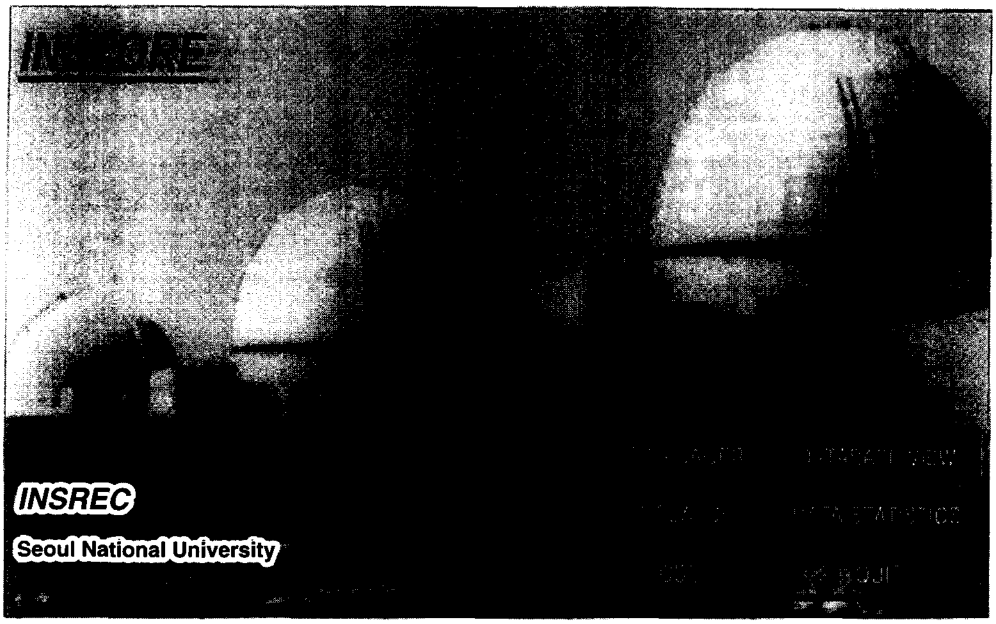

Fig. 2. Screen of START FORM

2.2. Radiation Job Classification

In a database program, it is very important to be easily and efficiently able to manage and utilize the collected data. In this aspect, the key parameters are required to categorize and make access to the collected data.[9] In this paper, main and detailed job codes were selected as key parameters. They are classified by the customary job classification scheme used in operating nuclear power plants.[1],[3],[4],[5],[6] The radiation jobs are classified into 26 main jobs in alphabet, and each main job is subdivided into detailed jobs in numerical number.[5],[6] They are summarized in

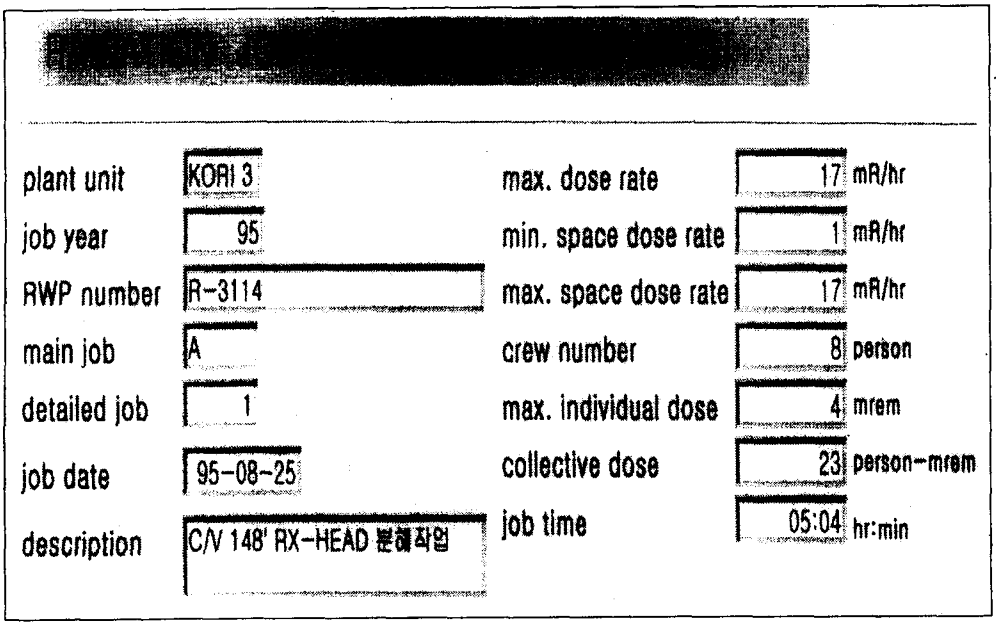

Fig. 3. Example Screen of Searched Data Set of Column Type

Table 1.

2.3. Data Specialization

To provide the user with readily accessible information, the considerations are taken into account in INSTORE as follows:[1]

1) Radiation exposure information should be in detail enough to describe what an individual was doing when the exposure incurred and what the working environment was like then.
2) It is possible to record and track exposure information by Radiation Work Permit(RWP). A well defined and structured RWP form offers an efficient means for collecting the details of exposure on jobs.
3) To the extent practicable, doses should be recorded by job classification. This information should be utilized in identifying areas in which ORE reduction efforts should be directed and where improvements be provided.

Data entry into the database program could be achieved by; plant unit, job date, RWP number, main job code and its title, detailed job code and its title, full description of each job, dose rate, job time, crew number, collective dose and maximum individual dose. Collective dose is not expected value by past experience but recorded value by individual dose-measuring device.

The collective dose of ORE is given by

$$S = \dot{H} T C \tag{1}$$

where S = collective dose [person-Sv],
$\dot{H}$ = effective dose equivalent rate [Sv/hr],
T = job operation time [hr],
C = number of crew [persons].

Hence, the average dose rate due to detailed job i per person is

Table 1. Radiation Job Classification

Main Job Code and Title	Detailed Job Code and Title
A Reactor Job	A1 Preparatory Job, A2 Reactor Disassembling, A3 Fuel Withdrawal, A4 Fuel Inspection, A5 Fuel Loading, A6 Reactor Assembling, A7 Reactor Inspection, A8 Others
B SG Manway Job	B1 Manway open, B2 Manway close, B3 Others
C SG ECT Job	C1 Preparatory Job, C2 Inspection, C3 Template Construction & Removal, C4 Equipment Installation & Movement, C5 ECT, C6 Others
D SG Tube Job	D1 Preparatory Job, D2 Inspection, D3 Template Construction & Removal, D4 Equipment Installation & Movement, D5 Plugging, D6 Sleeving, D7 Equipment Decontamination, D8 Others
E SG Nozzle Dam Job	E1 Dam Construction, E2 Dam Removal, E3 Others
	F SG Lancing Job F1 Preparatory Job, F2 H/H Job, F3 Lancing, F4 Equipment Removal & Decontamination, F5 Others
G SG Related Other Jobs	
H RCP Check & Maintenance Job	H1 Preparatory Job, H2 RCP Motor Job, H3 RCP Seal and MFB Job, H4 RCP TVCS Job, H5 RCP DACS Replacement, H6 Others
I PZR Check & Maintenance Job J RHR Check & Maintenance Job	
K In-Service Inspection	
L Containment Leak Test	
M In-Core Job	M1 Thimble Job, M2 DFMS System Job, M3 Thermocouple Job, M4 Detector Job
N RTD Check & Maintenance Job	
O Snubber Check & Maintenance Job	
P Valve Check & Maintenance Job	
Q P/P Check & Maintenance Job	
R Heat Exchanger Check & Maintenance Job	
S Filter Job	
T Evaporator Job	
U Decontamination & Laundry Job	
V Waste Related Job	
W Radiation Safety Control	
X System Operation	
Y Waste Drum Deposit Job	
Z Others	

$$\overline{\dot{H}_i} = \sum_{j=1}^{N_i} S_{ij} / \sum_{j=1}^{N_i} C_{ij} T_{ij} \qquad (2)$$

where $\dot{H}_i$ = average dose rate of detailed job i per person [Sv/hr],

S_{ij} = collective dose of detailed job i at the jth time period [person-Sv],

C_{ij} = number of crew of detailed job i at the jth time period [persons],

T_{ij} = job operation time of detailed job i at the jth time period [hr],

N_i = total frequency of detailed job i,

i = detailed job i,

j = time period of the jth job.

And the average individual dose is given by

$$I_{av} = S/C \qquad (3)$$

where I_{av} = average individual dose [Sv].

3. Results

The occupational dose assessment should be based on the data accumulated at least for 5 years of operation or four effective full power years of operation.[8] It is well known that about 70 percent of occupational radiation exposure has incurred from maintenance jobs in the outage period.[1],[3],[6] With these requirements, there have to be sufficient data for maintenance jobs. Hence, Kori Units 3 and 4 were selected for this assessment since they have been operating since 1985 and 1986, respectively.[6] The data collected in the database are over the past 10 years from 1986 through 1995. As shown in Table 1, maintenance jobs are classified into 61 detailed job specifications. Among these specifications, however, there are some nominal jobs which have not been performed during maintenance period in Kori Units 3 and 4, while there are other jobs which hardly contain adequate data to evaluate the collective dose.[5] These job specifications have been excluded in this study. For example, nominal jobs are "D1, D8, F5, H6,", and data insufficient jobs are "C2, D6, T0, X0,".

Figure 4 shows the year-by-year variation of annual collective dose for Kori Units 3 and 4, which has been deduced using INSTORE. The collective ORE dose versus calendar year provides designers and operators with a useful information to keep the occupational dose as low as is reasonably achievable. It is encouraging to notice in Figure 4 that the collective ORE dose has recently decreased in both Kori Units 3 and 4, even though Kori Unit 4 still shows high ORE doses. The reason why collective ORE dose of Kori Unit 4 is higher than that of Kori Unit 3 is that collective ORE dose from main jobs such as refueling, steam generator jobs, RCP jobs and valve jobs is relatively high in case of Kori Unit 4. In addition, collective ORE dose in 1993 yr increased because of collective dose increment of steam generator jobs and in-service inspection.

The breakdown of collective ORE dose according to each detailed job specification was evaluated. Several major jobs were found to contribute to the greater part of the total collective ORE dose, and the other minor jobs were found to individually contribute to less than 1 percent to the total collective ORE dose. It was also found that major portions of collective ORE dose have resulted from the jobs related to steam generator and reactor coolant pump. Table 2 summarizes top five detailed job specifications that give the highest collective doses for Kori Units 3 and 4.

For effective reduction of collective ORE dose, first, the repetitive jobs which cause high collective dose should be identified and then their dose-reduction potentials should be determined.[4],[7] Table 3 summarizes top five job specifications of high dose reduction potential in collective ORE dose for Kori Units 3 and 4. The difference

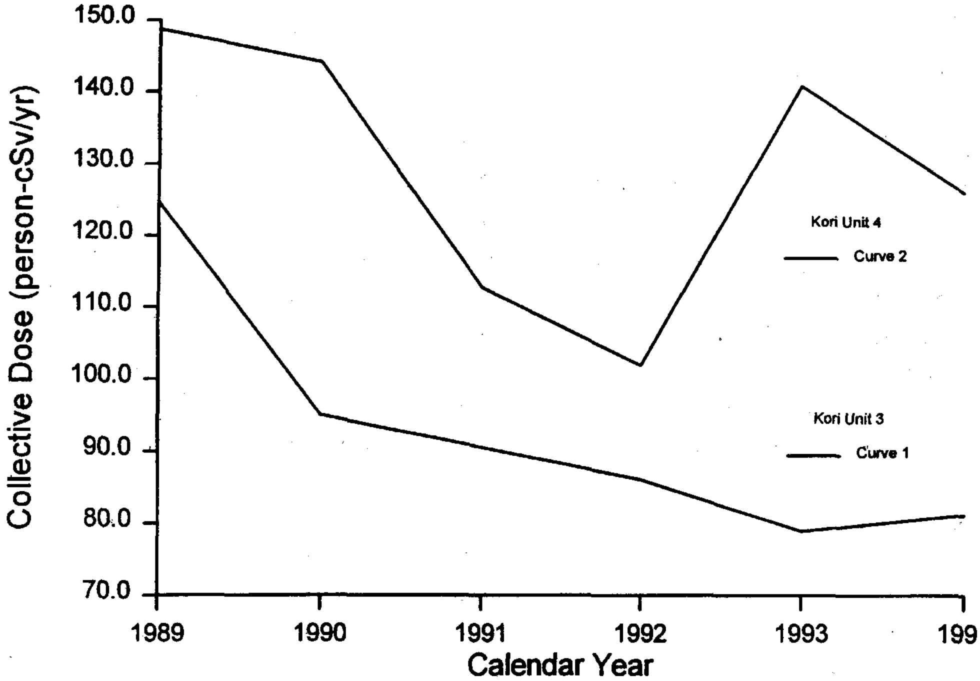

Fig. 4. Annual Collective Dose of Kori Unit 3 and 4

Table 2. Top 5 Detailed Jobs Highest in Collective Dose for Kori Units 3 and 4

Plant	Code	Title	Average Collective Dose (person-mSv)	Fraction (%)
Kori Unit 3	E1	SG Nozzle Dam Construction	40.8	17.8
	D5	SG Tube Plugging	37.1	16.2
	E2	SG Nozzle Dam Removal	21.7	9.6
	D3	SG Tube Job-Template Construction & Removal	14.0	6.3
	H4	RCP TVCS Jobs	12.2	5.6
		Subtotal	125.8	55.5
		Total	228.7	100.0
Kori Unit 4	E1	SG Nozzle Dam Construction	81.9	28.8
	D5	SG Tube Plugging	49.1	17.2
	E2	SG Nozzle Dam Removal	29.3	10.3
	C3	SG ECT Job-Template Construction & Removal	18.6	6.5
	D3	SG Tube Job-Template Construction & Removal	12.1	4.3
		Subtotal	191.0	67.1
		Total	284.6	100.0

Table 3. Collective Dose Summaries of Top 5 Jobs with Highest Dose-Reduction Potentials for Kori Units 3 and 4

Plant	Code	Collective Dose (person-mSv)				Population Size
		Minimum	Maximum	Difference	Average	
Kori Unit 3	D5	4.3	82.9	78.6	37.1	4
	H5	0.7	73.8	73.1	8.8	36
	E1	0.1	73.0	72.9	40.8	4
	H4	0.2	59.8	59.6	12.2	46
	A6	0.1	54.4	54.3	2.5	83
Kori Unit 4	E1	0.1	218.3	218.2	81.9	6
	D5	9.1	89.1	80.0	49.1	2
	B3	0.1	63.3	63.2	10.6	16
	A6	0.1	54.3	54.2	4.3	88
	E2	6.3	48.6	42.3	29.3	3

between maximum and minimum values of each job was analyzed to assess the dose reduction potential of the job. The dose difference is only a rough indication of its relative dose-reduction potential.[4] It should be noted that these dose ranges typify the dose experiences of Kori Units 3 and 4.

The parameters which are required for appropriate assessment of dose reduction potential also include average individual dose rate, number of crew members and job time as well as the difference between maximum and minimum collective ORE dose. Table 4 summarizes these three parameters for 30 detailed job specifications. They are arranged in descending order of average collective ORE dose. In general, we can see that steam generator related jobs have relatively high values of average individual dose rate. Hence, the dose rate, compared with job time and crew number, could be the dominant parameter affecting the collective ORE dose value. The number of crew members seems to have some bearing on collective dose, whereas the job time seems to have little bearing. Steam generator related jobs largely result in very high dose rate as well as involve many crew members, hence, the high collective dose mainly results from these parameters. Reactor coolant pump related jobs do not result in high dose rate but involve relatively many crew members, hence, the high collective dose results from the number of crew members.

4. Discussion and Conclusions

For more reliable assessment of occupational doses, more data from past experience should be available to form a good database. In order to maximize the benefit of these data in designing future nuclear power plants, they need to be appropriately and compatibly formulated. In this study, a PC-based ORE database program is developed and utilized to analyze the ORE data of existing nuclear power plants. Maintenance & repair jobs are divided into 26 main jobs and 61 detailed job specifications. Kori Units 3 and 4 are selected for the database. As a result, high-dose jobs are identified with their relative dose reduction potentials.

The jobs related to steam generator and reactor coolant pump are identified as high-dose jobs in terms of collective ORE dose. By analyzing three parameters which have bearing on collective ORE dose, these jobs were found to need some improvements in their working conditions and

Table 4. Collective ORE Dose and Its Three Variables for Kori Units 3 and 4

Code	Title	Average Individual Dose Rate (mSv/hr)	Job Time (hr)	Crew Number (person)	Average Collective Dose (person-mSv)
E1	SG Nozzle Dam Construction	0.73	4.0	18.9	65.46
D5	SG Tube Plugging	0.44	3.7	19.8	41.10
E2	SG Nozzle Dam Removal	0.87	1.8	13.6	24.56
C3	SG ECT Job-Template Construction & Removal	0.80	2.2	4.5	13.41
D3	SG Tube Job-Template Construction & Removal	1.94	0.9	5.0	12.53
E3	SG Nozzle Dam Other Jobs	1.55	1.5	4.5	10.76
B3	SG Manway Other Jobs	0.21	5.8	6.0	8.81
H5	RCP DACS Replacement	0.14	3.8	12.9	8.14
B2	SG Manway Close	0.23	3.7	8.8	7.19
H4	RCP TVCS Jobs	0.14	3.6	10.4	7.13
B1	SG Manway Open	0.10	4.3	10.6	5.81
C4	SG ECT Job-Equipment Installation & Movement	0.19	4.1	4.5	3.82
A6	Reactor Assembling	0.12	3.3	7.9	3.41
N0	RTD Check & Maintenance	0.19	3.7	4.0	3.14
U0	Decontamination & Laundry Job	0.15	2.4	5.5	2.18
M1	In-Core Thimble Job	0.09	3.6	5.4	1.95
H3	RCP Seal and MFB Job	0.05	4.5	8.2	1.90
A2	Reactor Disassembling	0.06	3.1	9.4	1.86
F1	SG Lancing Preparatory Job	0.16	2.9	4.3	1.77
H2	RCP Motor Job	0.04	3.9	9.6	1.77
H1	RCP Preparatory Job	0.06	3.6	6.7	1.77
F2	SG Lancing H/H Job	0.15	2.8	3.5	1.71
F3	SG Lancing	0.10	3.9	3.8	1.64
C1	SG ECT Preparatory Job	0.10	2.1	5.7	1.38
A3	Fuel Withdrawal	0.02	5.6	10.5	1.36
P0	Valve Check & Maintenance	0.08	2.7	3.8	1.20
K0	In-Service Inspection	0.06	2.4	6.5	1.16
A4	Fuel Inspection	0.03	4.6	8.0	1.13
O0	Snubber Check & Maintenance	0.08	2.1	3.6	1.07
D2	SG Tube Inspection	0.05	8.5	2.5	1.03

procedures, that is, relatively high dose rate and many crew numbers. To reduce occupational dose in compliance with ALARA, adequate dose reduction plans for these jobs should be prepared to improve their working conditions and procedures. Finally, this database along with INSTORE will contribute to optimization of the ORE of the Korea Next Generation Reactor in meeting ALARA requirements. Identification of high dose jobs with dose reduction potential for KNGR as well as operating plants should be feedback information for the KNGR design. In addition, result data through data search and data statistics operation could also be useful information for the KNGR design.

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