Study on Dose-Equivalent Rate Evaluation System of LLW Packages

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INTRODUCTION

Japanese low level waste disposal facility is located at Rokkasho in Aomori Pref., northern part of Japan. This facility accepts only low level wastes from nuclear power stations. At present, the wastes are limited to the homogeneous wastes which are solidified in 200L open drums. Before the transport, some inspections on waste drums are executed such as the surface dose equivalent rate and an axial compressive strength, etc., in order to ensure that those are conformed to the acceptance criteria of the disposal.
In the transport, waste drums are loaded to LLW packaging. The packages are classified to IP-2 package of IAEA regulation. The packages are transported using trucks from the power station storage facility to the harbor. Then the packages are loaded onto a dedicated vessel named Seiei-maru, and transported to Rokkasho Facility.

Just before leaving power stations, the dose equivalent rate around the packages and trucks should be ensured to conform to the transport regulation. In this confirmation, maximum dose equivalent rate around packages and trucks are needed to compare to the standard value. If the confirmation is accomplished by actual dose rate measurement, many workers have to measure all around the packages and the trucks, and consequently the radiation exposure to the workers could not be ignored.

The purpose of this study was to decrease the workers radiation exposure under measurement by using easy to use personal computer programs. "The Dose Equivalent Rate Evaluation System", which can evaluate the dose equivalent rate around packages and trucks from surface dose equivalent rate of the waste drums which were measured before transport, was developed. This work was performed as a joint research by The Japan Atomic Power Co., Nuclear Fuel Transport Co. Ltd., and nine Japanese utilities.

CALCULATION PRINCIPLE

The low level waste transport package is illustrated in Figure 1. The size and weight are also shown in Figure 1.
This packaging can be loaded with eight waste drums which contain radioactive nuclide, mainly Co60. In order to estimate the dose equivalent rate distribution around the package and truck, the point kernel calculation method was used. Gamma ray from waste drum attenuates according to the distance and through the other drums as shown in Figure 2. If the size, materials, and nuclides contained in the drum are determined, the dose equivalent rate attenuation distribution around the drum can be calculated as shown in Figure 2.

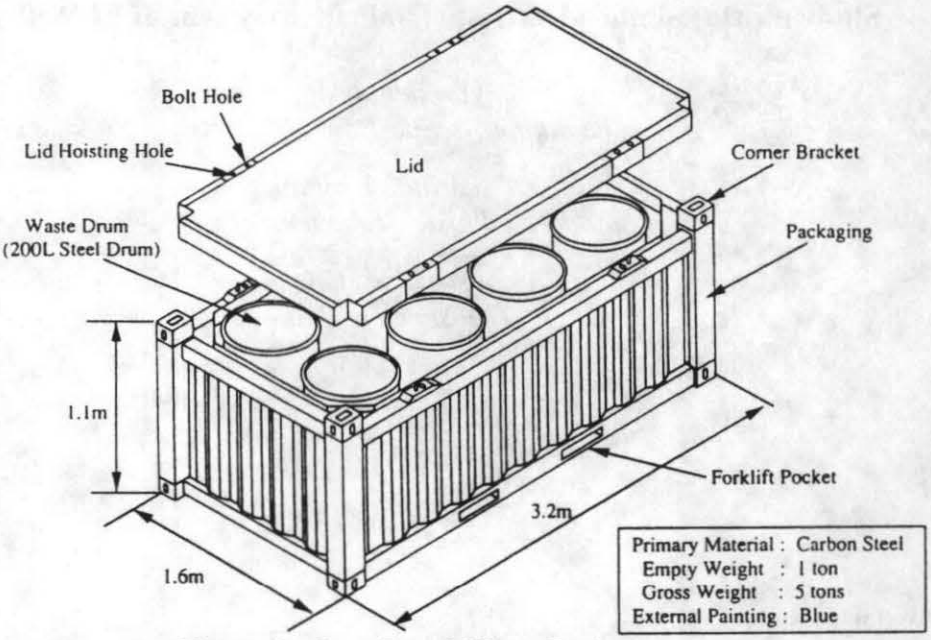


Figure 1 Low Level Waste Package

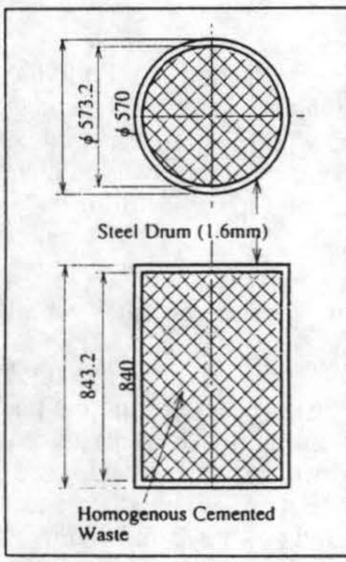
This distribution profile depends on the shielding conditions, and the value is in proportion to the dose equivalent rate of the drum surface. The dose equivalent rates of the evaluation points which are located around the package as Ev1 shown in Figure 2 are calculated as a summation of the radiation from each waste drum loaded in the package.
Figure 3 shows the evaluation points around the package. There are 20 points on the side surface, 20 points at 1m from the surface, 21 points on the lid surface, and 21 points at 1m from the lid.

Figure 4 shows the evaluation points around the truck. There are 33 points on the side surface, 33 points at 1m from the surface, and 3 points on the driving seat.

CALCULATION CONDITION

The calculating conditions used in this study are shown in Table 1.

Table 1 Calculating Conditions



Calculation Code	QAD-CGGP2
Nuclide	Co60 1.25MeV Gamma Ray 200%
Materials	- Radiation Source Cement (ρ =1.9g/cm^3) Co60 distributed homogeneously - Drum Carbon Steel (ρ =7.8g/cm^3)
Conversion Factor	ICRP pub.51 Recommended Value
Build Up Factor	Concrete

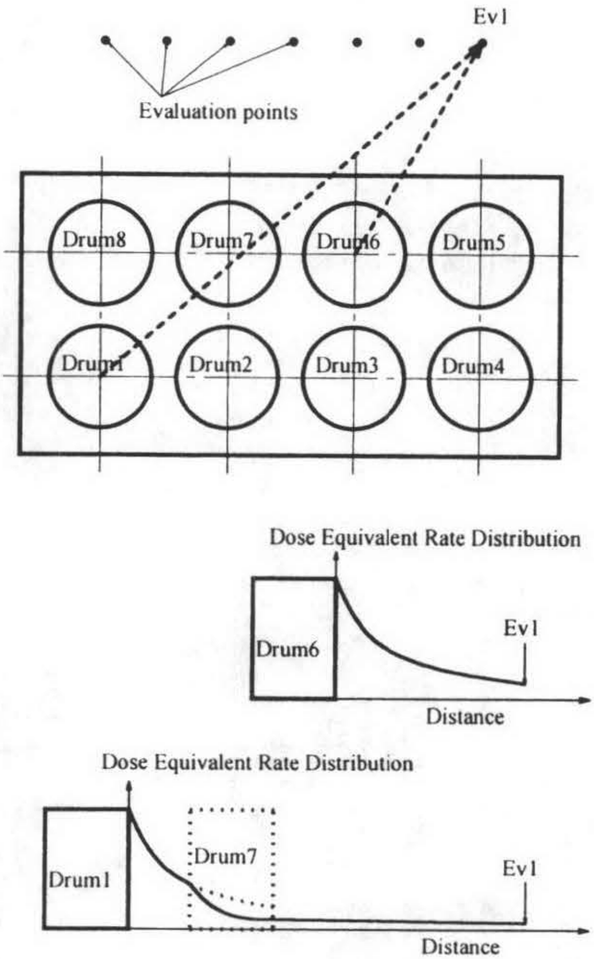


Figure 2 Calculation Principle

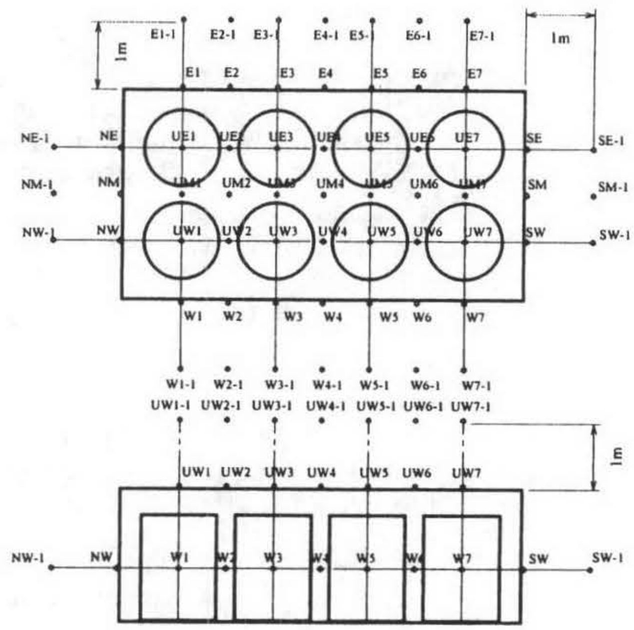


Figure 3 Evaluation Points Around the Package

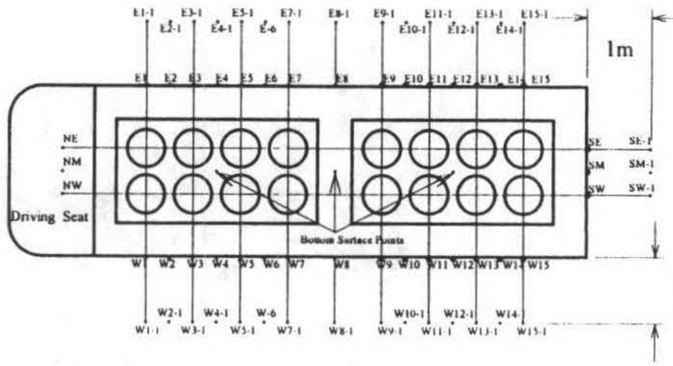


Figure 4 Evaluation Points Around the Truck

To calculate the dose equivalent rate distributions, the reliable shielding computer code QAD-CGGP2 was used.

In the calculation, the following conditions were used:

- The radioactive nuclide contained in drum waste is 100% Co60.
- Co60 is distributed homogeneously in the cemented waste.
- The Co60 emits two 1.25Mev Gamma rays per a decay(200%).
- The material of the drum is carbon steel ,whose density is 7.8g/cm^3.
- The material of the waste is concrete ,whose density is 1.9g/cm^3.

Appropriate calculating conditions were selected to evaluate for all transport cases and made conservative estimation.

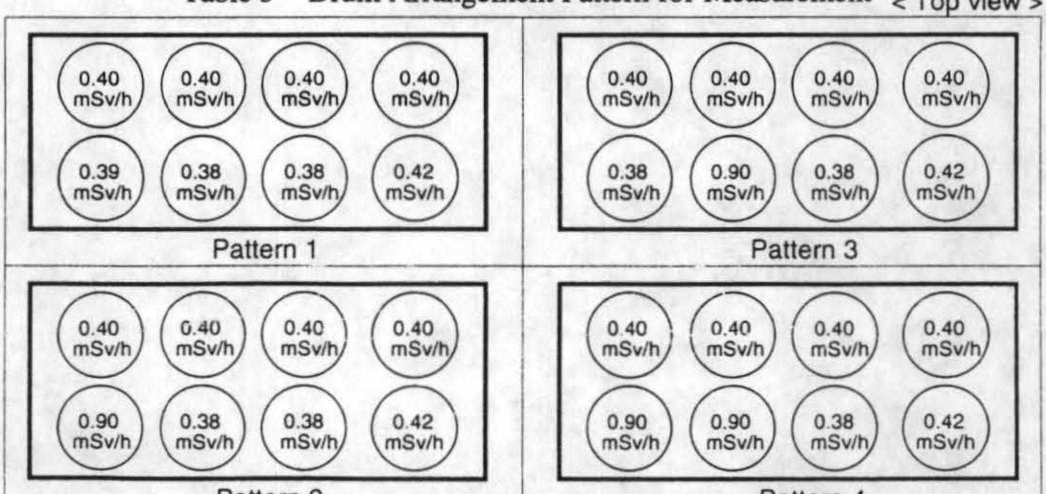
CALCULATION VALIDITY

To determine the calculating conditions, real waste drums stored in the power stations were surveyed. To confirm the validity of the calculation method, the values calculated under some conditions were compared with the measured ones. Table 2 shows a part of the results. In Table 2, "Pattern" means different dose rate drums arrangement into LLW packaging as shown in Table 3.

Table 2 Comparison of Measured Value With Calculated Value

Evaluation Points	Pattern 1			Pattern 2			Pattern 3			Pattern 4		
	Cal. mSv/h	Meas. mSv/h	Rate %	Cal. mSv/h	Meas. mSv/h	Rate %	Cal. mSv/h	Meas. mSv/h	Rate %	Cal. mSv/h	Meas. mSv/h	Rate %
UW1-1	0.051	0.051	100.3	0.066	0.070	94.1	0.063	0.067	93.8	0.078	0.085	91.7
UW2-1	0.058	0.058	99.4	0.071	0.075	94.4	0.071	0.076	93.3	0.084	0.093	90.6
UW3-1	0.064	0.064	100.4	0.076	0.082	92.7	0.079	0.084	94.2	0.091	0.098	93.0
UW4-1	0.065	0.065	100.2	0.074	0.079	93.6	0.078	0.082	95.6	0.087	0.094	93.0
UW5-1	0.065	0.065	99.3	0.071	0.075	94.0	0.076	0.082	93.3	0.083	0.089	92.7
UW6-1	0.058	0.057	102.1	0.062	0.065	95.5	0.067	0.069	97.3	0.071	0.077	92.3
UW7-1	0.052	0.053	97.8	0.054	0.059	92.2	0.058	0.062	93.3	0.060	0.064	94.4
UM1-1	0.052	0.055	93.7	0.065	0.070	92.6	0.063	0.070	89.9	0.077	0.087	88.0
UM2-1	0.058	0.062	94.3	0.071	0.076	93.4	0.071	0.078	91.1	0.084	0.094	89.2
UM3-1	0.065	0.069	94.8	0.077	0.085	90.4	0.079	0.086	91.6	0.090	0.098	92.3
UM4-1	0.066	0.069	96.2	0.075	0.082	91.7	0.079	0.083	95.2	0.088	0.096	91.7
UM5-1	0.066	0.069	95.2	0.072	0.078	92.0	0.077	0.084	92.0	0.083	0.093	89.7
UM6-1	0.059	0.062	95.1	0.063	0.067	93.9	0.068	0.073	92.9	0.072	0.080	89.9
UM7-1	0.052	0.054	96.6	0.055	0.058	94.4	0.058	0.062	94.0	0.061	0.068	89.6
UE1-1	0.051	0.053	96.7	0.063	0.066	95.4	0.062	0.067	92.1	0.074	0.080	92.0
UE2-1	0.058	0.058	99.6	0.069	0.067	103.2	0.069	0.073	94.8	0.081	0.086	93.9
UE3-1	0.064	0.065	99.1	0.075	0.079	94.8	0.076	0.077	98.9	0.087	0.089	97.6
UE4-1	0.065	0.066	98.9	0.074	0.077	95.9	0.077	0.077	99.6	0.085	0.087	98.2
UE5-1	0.065	0.065	99.5	0.071	0.074	95.8	0.075	0.078	96.4	0.082	0.086	94.9
UE6-1	0.058	0.058	100.4	0.063	0.064	97.7	0.067	0.070	95.6	0.071	0.076	93.8
UE7-1	0.052	0.050	103.5	0.055	0.055	99.5	0.058	0.058	100.1	0.061	0.062	98.5

Table 3 Drum Arrangement Pattern for Measurement < Top view >



As shown in Table 2, calculated values corresponded to the measured ones within 10% at each point. Therefore, it is concluded that the developed calculation method is very useful.

DOSE EQUIVALENT RATE EVALUATION PROGRAM

The easy to use personal computer program for evaluating the dose rate around the package has been developed. This program has the following four functions:

< First Function >

The first function is to make appropriate drum arrangement into packaging. If the drum surface dose rate is known before loading into packaging, this program enables to know how the drums should be arranged into packaging in order to decrease the dose rate around the package. In this study, the appropriate arrangement is defined to provide the lowest dose rate around package. Figure 5 shows the flow of this function.

Firstly, the drum surface dose rate data should be inputted to the personal computer program to make drum dose rate data base as shown in Figure 5.

Secondly, one selects arbitrary 8 drums from the drum dose rate data base to load into a LLW packaging. Then the most appropriate drum arrangement is determined by the program as shown in Figure 5.

In addition, this program output the position and the values of the maximum dose rate around the package in the case of the most appropriate drum arrangement.

In order to estimate the appropriate arrangement, the "Arrangement Pattern" is used as shown in Figure 5. For example, when 4 high dose rate drums and 4 low ones are loaded into packaging, high ones should be located inner position to optimize for decreasing the dose rate around the package. In Figure 5, black circle means high dose rate drum and white is low one.

< Second Function >

Second function is to know the position and the values of the maximum dose rate around the package after loading.

If one inputs the drum arrangement in the package and the drum surface dose rate, this program makes package dose rate distribution and points out the maximum dose rate position and values as shown in Figure 6.

In addition, this program makes package data base. This data base includes the package ID, drum arrangement data, and dose rate data. Some information from this data base can be picked up by pointing to only the package ID. Before transport, it is necessary to confirm that the package dose rates conform to the transport regulation. For this confirmation, the measured package dose rate is needed. If there is an information of the maximum positions, the maximum dose rate around package can be known by measuring only that point, instead of measuring all around the package. In that case, the radiation exposure to the workers who measure the dose rate can be decreased.

< Third Function >

Third function is to know the positions and the values of the maximum dose rate around the truck. When the LLW package is transported on the road, two packages are loaded on the truck. Just before the transport, a set of packages to load on a truck is decided. If two packages ID from package data base are picked up, this program makes the dose rate distribution around the truck and points out the maximum dose rate positions and values as

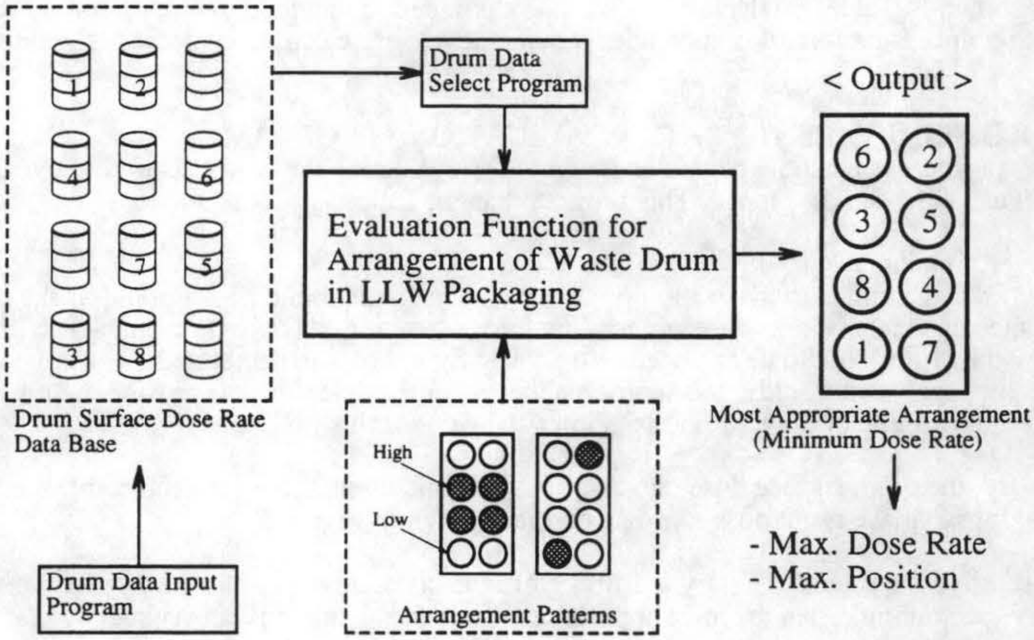


Figure 5 Schematic Flow of First Function

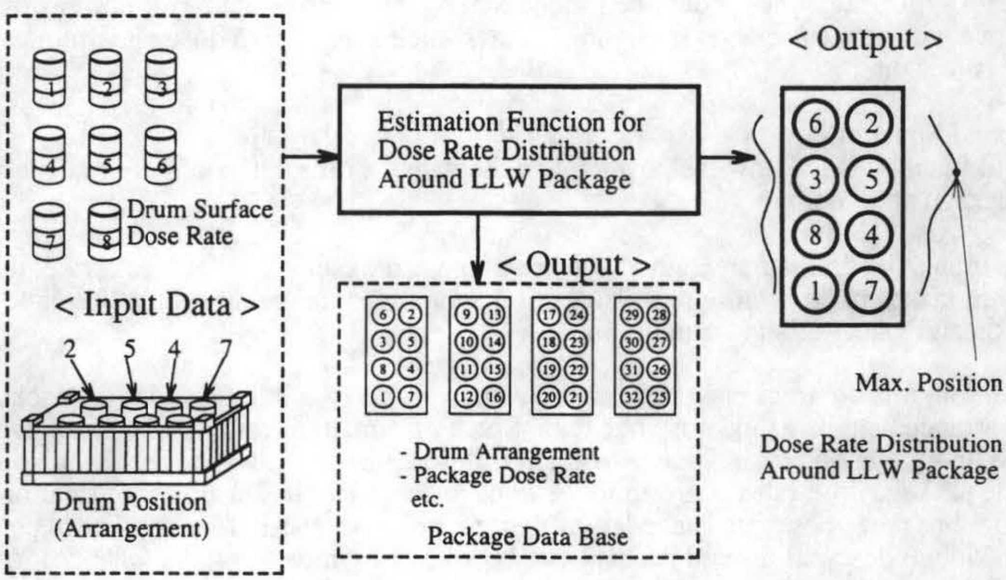


Figure 6 Schematic Flow of Second Function

shown in Figure 7. In addition, this program makes truck loading data base. This data base includes truck ID, a set of package ID, and dose rate data.

< Fourth Function >

Fourth function is to evaluate the radiation exposure to workers. If the entire transportation are realized using the 2nd and 3rd function, all the transport history was recorded as data bases. From this history, the total radiation exposure to the workers can be estimated. This program contains some kind of data of the workers which are the distance between the package and some kind of handling workers such as forklift drivers or crane operators and duration time around the package as shown in Figure 8.

The workers' radiation exposure can be calculated from the defined conditions and the dose rate at this point from dose rate data bases which was mentioned before. This program can output the total exposure of each kind of workers.

CONCLUSION

In order to decrease the workers' exposure under measurement, "The Dose Equivalent Rate Evaluation System" was developed. This system is to evaluate the dose equivalent rate around packages and trucks from surface dose equivalent rate of waste drums which are measured before transport. This system is used practically in many nuclear power stations and is very useful for LLW transports in Japan.

REFERENCE

Sakamoto, Y. and Tanaka, S. QAD-CGGP2 and G33-GP2: *Revised versions of QAD-CGGP and G33-GP (Code with the conversion factors from exposure to ambient and maximum dose equivalents)*, JAERI-M 90-110 (1990)

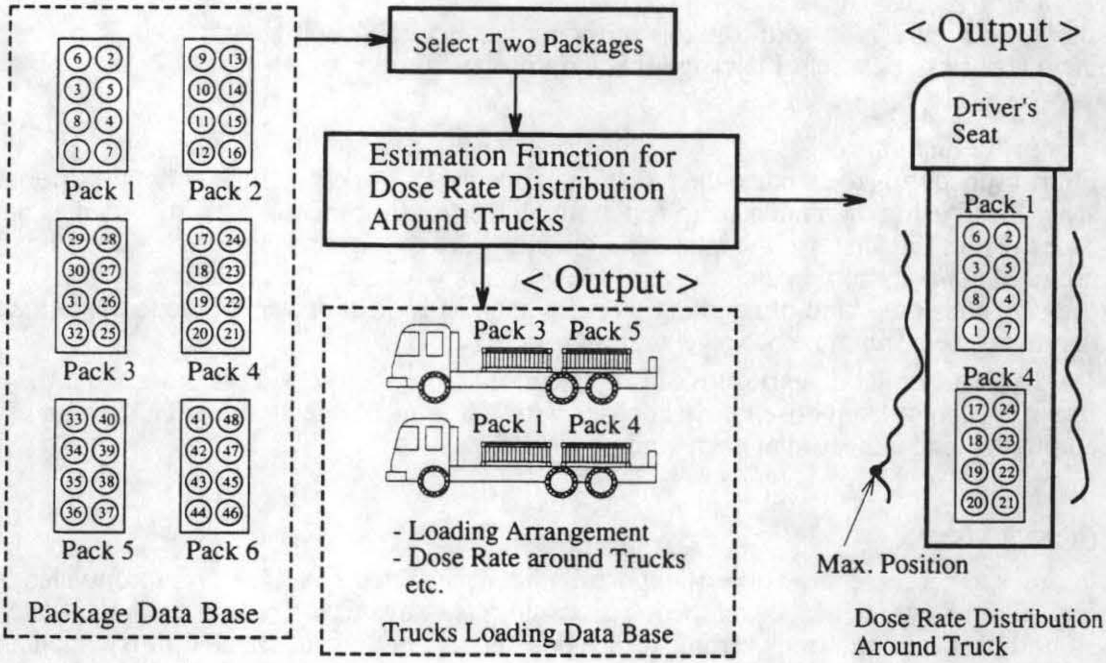


Figure 7 Schematic Flow of Third Function

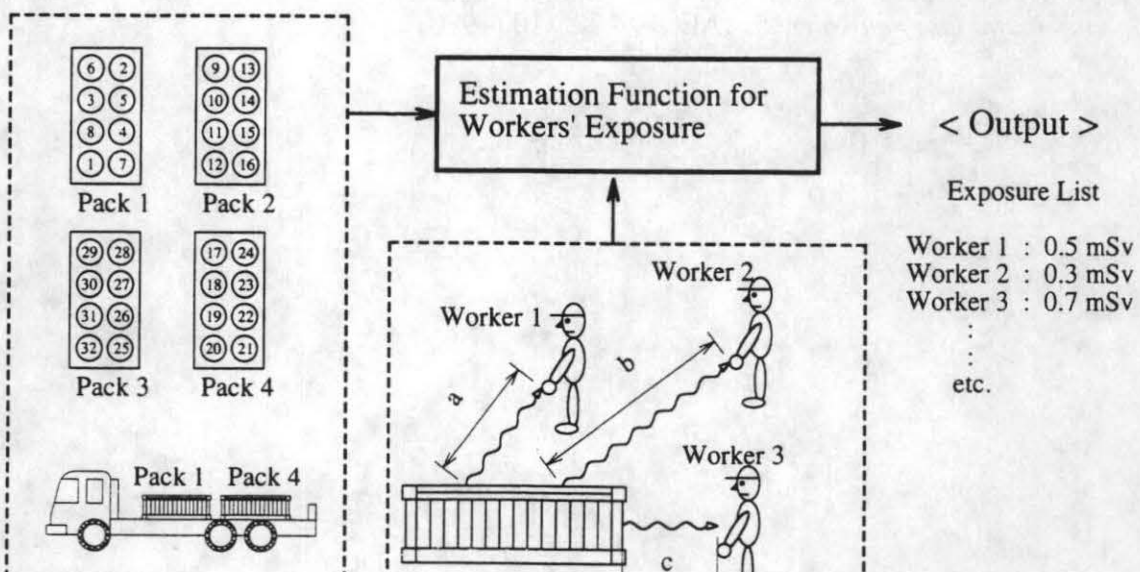


Figure 8 Schematic Flow of Fourth Function