Simulation of Radiation Dose Rate Distributions around Casks in Ships and Vehicles by Using QBF Code for PC-9801 Computer

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INTRODUCTION

It has been believed for a long time that quite a lot of calculation time is unavoidable for the calculation of spatial distribution of radiation dose rate around casks even with high speed computers. Consequently, no such trials have ever been reported to simulate the detailed behavior of radiation dose rate distributions in a wide region of cask shipping vessels.

On the basis of the background mentioned above, a computer code 'QBF' is programmed to simulate spatial distribution of radiation dose rates in a wide region of a cask system composed of steel walls and beams, and radiation shieldings as well as casks. For a typical example of such system, one can enumerate a vessel for shipping casks. In the simulation, the following effects and influences should be taken into account:- (1) Radiation shielding effect by structural materials and shielding materials around the casks. (2) Shadow effect among casks which resembles the partial masking of the sun by the moon. (3) Influence from the difference of the radiation dose rate on each cask surface as well as that from the difference of cask geometries. Consideration of all these effects and influences is necessary to understand the complicated behavior of radiation dose rate distributions.

The QBF code is programmed on the basis of a new calculation principle. Program steps of this code are so short that one can apply this code to the very popular personal computer in Japan: PC-9801, to calculate spatial distribution of radiation dose rates. Required calculation time with this computer is short enough to apply this code to various situations of shipping casks. Validity of calculation method adopted in this code has been confirmed and reported already (H. Yamakoshi (1990)).

As a partner of the QBF code in the present code system, a code 'GRAPH' is programmed and plays an important role. The code GRAPH visualizes the calculated dose rate distributions into a colored contour map, which covers a range of 12 decades of dose rate values with 12 colors. Each decade is covered by 5 lines of the same color, where the 5 lines correspond to the factor of 2, 4, 6, 8 and 10, respectively.

Demonstration of simulating dose rate distributions will be performed for neutrons and gamma rays around a vehicle and a cask shipping vessel.

The main aim of the present report is to show that the behavior of the spatial distribution of the radiation dose rate in a wide region can be easily visualized in various aspects of cask shipment even by personal computers which are very popular today, and that the QBF code system is a useful tool to perform this simulation. A great merit of using this code system is that one can easily analyze, with high reliability, roles of various important factors such as shielding structures and cask positions in the behavior of dose rate distributions.

OUTLINE OF QBF CODE SYSTEM

The QBF code system is developed to simulate behavior of radiation dose rate distribution in a wide spatial region around ships and vehicles for shipping casks. In the following, a brief description will be given on the principle of the calculation method adopted in the QBF code.

CALCULATION PRINCIPLE

The calculation principle of the QBF code can be summarized as follows;

(1) Radiation dose rate contribution from a cylindrical cask to an arbitrarily chosen dose calculation point is formulated into an analytical function of cask geometry, positions of dose calculation points relative to the cask position, and radiation dose rate on the cask surface. This formulation is derived as a result of analytical integration of the dose contribution over the volume source of radiation (H. Yamakoshi (1984)).

(2) Shadow effect among casks is also formulated as shadow distribution function in terms of mutual cask positions, geometry of each cask and coordinates of the dose calculation points. (H. Yamakoshi (1988)).

An example of the shadow distribution function is illustrated in Fig.1.

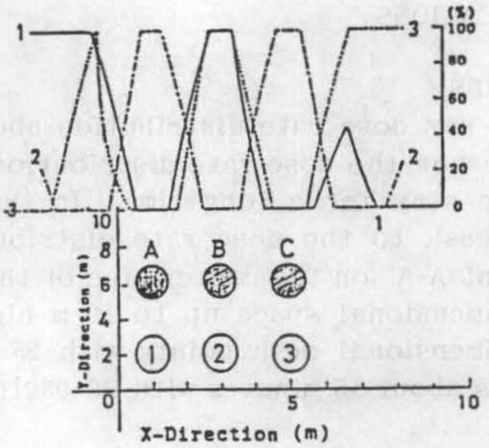
The introduction of the two functions mentioned above is very effective in decreasing both the calculation time and the length of program steps.

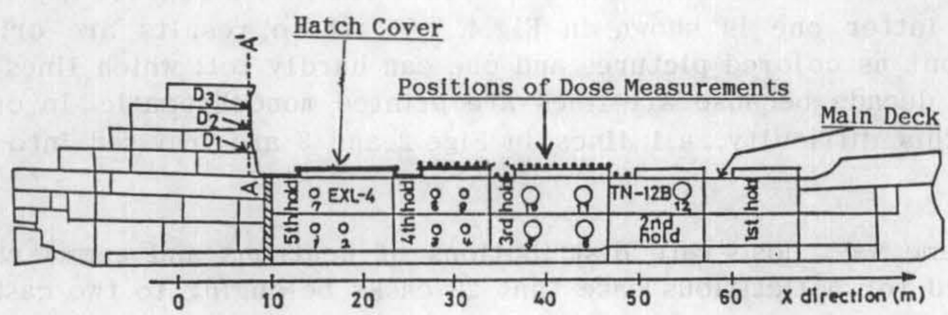
EVIDENCE OF ACCURACY

Accuracy of the calculation method adopted in the QBF code was verified (H. Yamakoshi (1990)) by comparing measured dose rate distributions (K. Ueki (1986)) with calculated ones. As one of input data for the QBF code, surface dose rates for each type of cask are determined by using ANISN code by taking account of volume source data of radiations and cask geometry data. An example of the comparison is shown in Fig.2.

Fig.1 Example of the shadow distribution function for casks 1, 2 and 3

The function describes spatial dependence of cask masking by other casks A, B and C





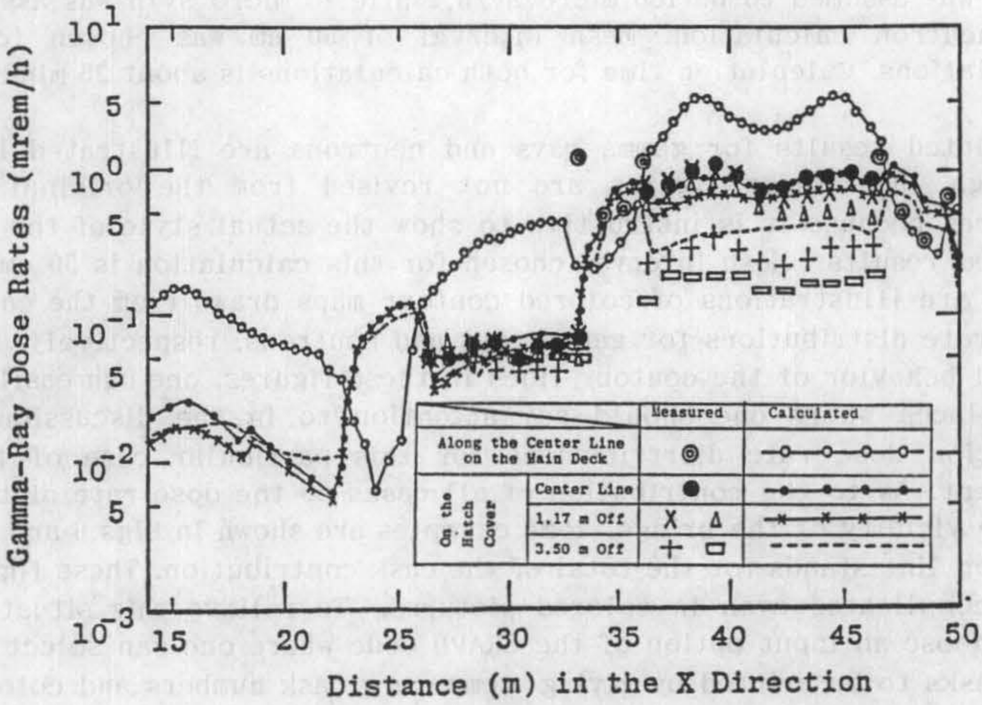


Fig.2 Comparison of dose rate distribution between calculation and measurement

Schematic diagram of the system is shown above.

APPLICATIONS

TO SHIPS

Gamma-ray dose rate distribution above the main deck in Fig.2 is calculated to see how the dose rate distribution behaves around the bridge, where many people stay for a long time. In the same context, cask contribution from each cask to the dose rate distribution is also calculated along the line segment A-A' on the center line of the ship in Fig.2. In this calculation, the two-dimensional space up to 10 m high above the main deck is covered with two-dimensional mesh points with 25 cm intervals. Calculation time for this case is about 15 minutes with PC-9801(VX-21).

Results for the former calculation is visualized into a contour map in Fig.3, and the latter one is shown in Fig.4. All these results are originally printed out as colored pictures and one can hardly tell which lines belong to which decade because all lines are printed monochromatic. In order to relieve this difficulty, all lines in Figs.2 and 3 are revised into marked lines.

In the same way, dose rate distributions of neutrons and gamma rays are calculated for a fictitious case that 20 casks belonging to two cask types are loaded in the same ship mentioned above. Gamma-ray dose rate on all casks was assumed to be 100 micro Sv/h, while 10 micro Sv/h was assumed for the neutron calculation. Mesh interval of 50 cm was chosen for these calculations. Calculation time for both calculations is about 25 minutes.

Calculated results for gamma rays and neutrons are illustrated in Figs.5 through 10. These figures are not revised from the original printed pictures because it is instructive to show the actual style of the original printed results. Mesh interval chosen for this calculation is 50 cm. Figs.5 and 8 are illustrations of colored contour maps drawn from the calculated dose rate distributions for gamma rays and neutrons, respectively. From the global behavior of the contour lines in these figures, one can easily locate the places where one should pay attention to in the discussion of the radiation dose rate disrtributions for this particular case of the cask shipment. As to the contribution of all casks to the dose rate distribution in the vicinity of the bridge, some examples are shown in Figs.6 and 9, where the top line stands for the total of the cask contribution. These figures are too complicated even in colored pictures. To relieve this situation, one can choose an input option of the GRAPH code where one can select a few of the casks to be printed by giving temporary cask numbers and color names. Figs.7 and 10 are results of such selection.

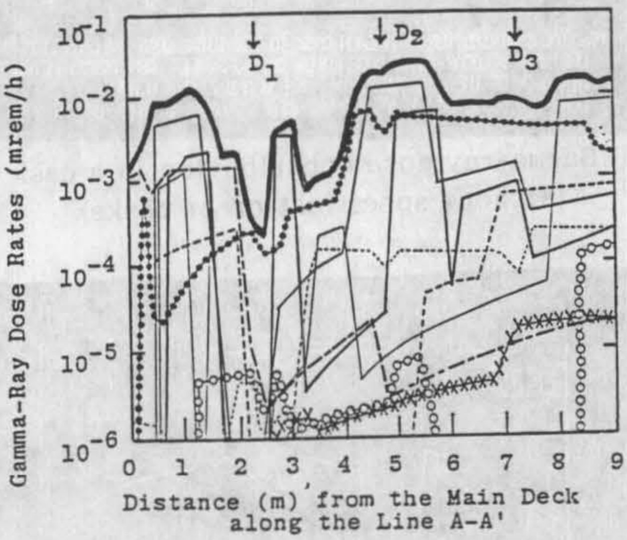
TO VEHICLES

The QBF code system can also be applied to vehicle systems. One of such examples is shown in Fig.11 for gamma-ray dose rate distribution. In this

Steel plates are denoted by the mark [hatched mark], while steel plates with concrete shields are denoted by the mark [striped mark].
Each type of lines corresponds to each range of dose rate values as shown in the following table:

Type of Lines	Factors	Units
	1.0, 1.2, 1.4, ·····	mrem/h
	1.0, 2.0, 4.0, 6.0, 8.0	10^{-1}mrem/h
	1.0, 2.0, 4.0, 6.0, 8.0	10^{-2}mrem/h
	1.0, 2.0, 4.0, 6.0, 8.0	10^{-3}mrem/h
	1.0, 2.0, 4.0, 6.0, 8.0	10^{-4}mrem/h

Fig.3 Analysis of gamma-ray dose distribution for a cask system (Cited from H. Yamakoshi (1990) for old version of QBF code)



············ : from No.1 cask,	——·—·—— : from No.8 cask
—X—X—X— : from No.4 cask,	- - - - - - - : from No.9 cask
-O-O-O-O-O- : from No.5 cask,	———————— : from No. 10 cask
—•—•—•—•— : from No.7 cask,	———————— : from No. 11 cask
	————— - : from No. 12 cask

Fig.4 Analysis of gamma-ray dose contribution for a cask system (Cited from H. Yamakoshi (1990) for old version of QBF code)

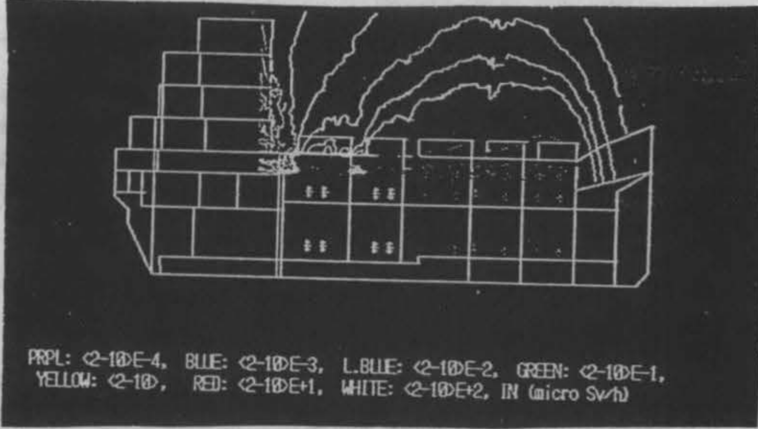


Fig.5 Gamma-ray dose rate distribution in a cask system
(By the present new version of QBF code system)

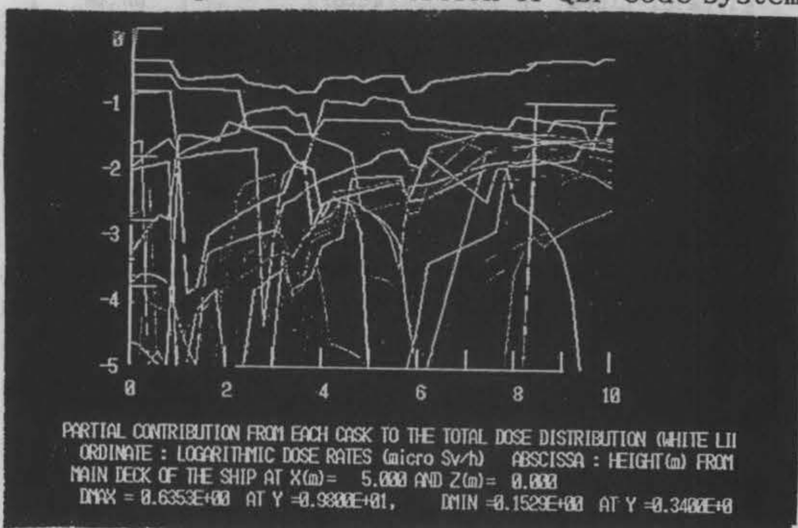


Fig.6 Gamma-ray dose contribution in a cask system
(Without specification of casks)

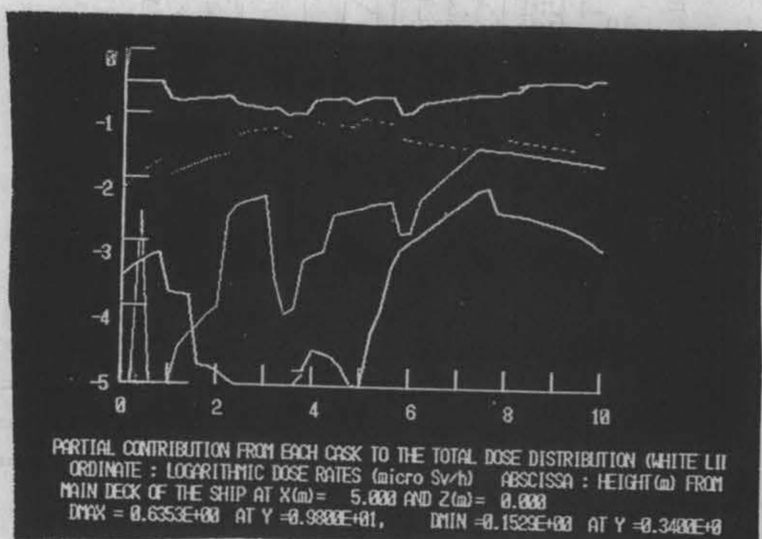


Fig.7 Gamma-ray dose contribution in a cask system
(With a specification of casks)

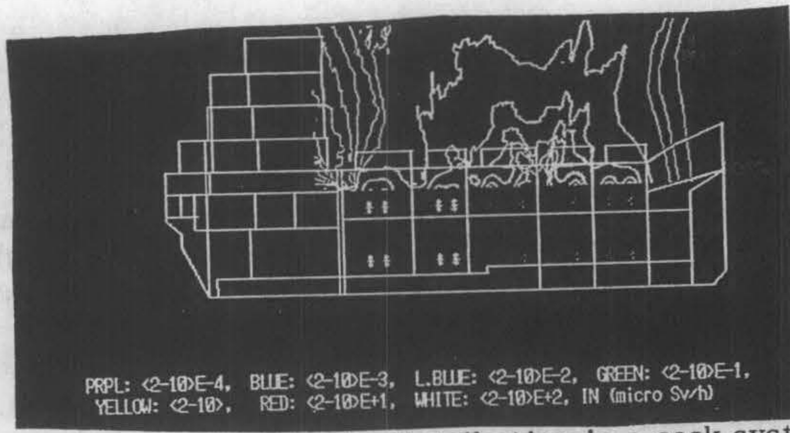


Fig.8 Neutron dose rate distribution in a cask system
(By the present new version of QBF code system)

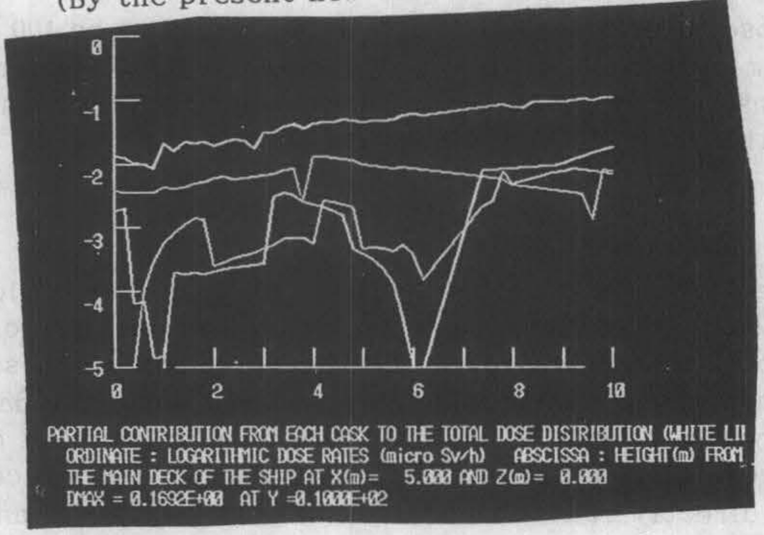


Fig.9 Neutron dose contribution in a cask system
(Without specification of casks)

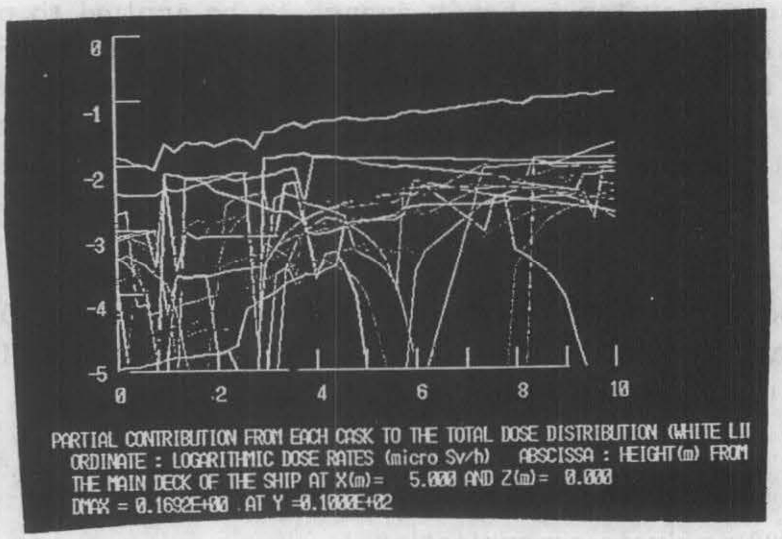


Fig.10 Neutron dose contribution in a cask system
(With a specification of casks)

Fig.11 Gamma-ray dose rate distribution in a cask system

model, the dose rate on the cask surface is assumed to be 100 micro Sv/h. A region of 30 m high and 60 m wide, including the vehicle system, is covered by two-dimensional mesh points with 1 m intervals in this calculation. Calculation time is about 30 seconds with PC-9801.

DISCUSSION

The QBF code system is peculiar because the dose calculation is performed not on the basis of volume type radiation sources but on the basis of surface type radiation sources. In the category of these surface type radiation sources, one can include the measured dose rate data at any place in the cask system as well as the dose rate data measured at cask surfaces. In other words, this code system is convenient and practical in the sense that one can directly utilize the dose rate data measure at any palace in the vicinity of casks.

As the QBF code system is handy enough to be applied to popular personal computers, one can easily analyze, with a short calculation time, the roles of various factors such as source strength of each cask, cask geometry and structures of steel walls and radiation shieldings which influence the spatial distribution of radiation dose rates.

CONCLUSION

The QBF code system can be a useful and handy tool in actual situations of analyzing and predicting behavior of radiation dose rate distributions in a wide space region around casks.

References

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