A Radiological Approach to Increasing the Radiation Level Standard of a Package

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INTRODUCTION

Among the revised points in the 1985 edition of the IAEA Regulations, the acceptance criteria for shielding integrity after testing at normal conditions of transport is one of the most important points in designing and testing package. The sentence " It would prevent any increase of the maximum radiation level" that appears in the 1973 edition has been changed to "It would prevent more than a 20% increase in the radiation level at any external surface". With respect to the new requirements in the 1985 edition, the necessity of considering any external surface and the meaning of a 20% increase are being discussed worldwide. In this paper we discuss the radiological meaning of this requirement through a radiological approach and propose an alternative concept.

IAEA REGULATIONS

The acceptance criteria for shielding integrity after testing at normal conditions of transport is specified in paragraph 537 of the 1985 edition of the IAEA Regulations.

537. A package shall be so designed that if it were subjected to the tests specified in paras. 619–624, it would prevent:
(a) Loss or dispersal of the radioactive contents; and
(b) Loss of shielding integrity which would result in more than a 20% increase in the radiation level at any external surface of the package.

Paragraph 225 of the 1973 edition of the IAEA Regulations corresponds to paragraph 537 of the 1985 edition.

225. Type A packaging shall be so designed that, if it were subjecte to the tests specified in Section VII, paras. 709–714, it would prevent:
(a) loss or dispersal of the radioactive contents, and
(b) any increase of the maximum radiation level recorded or calculated at the external surface for the condition before the test.

The words "20 % increase in the radiation level at any external surface of the package" specified in paragraph 537 (b) of 1985 edition is a revision of the words "No increase of the maximum radiation level". As it is imposible to prevent packaging from deforming after testing at normal conditions of transport, it appears that this requirement has been changed to a more practical one. The merits of restricting radiation level by a relative value, and not an absolute value is the following.

- o It is possible to make packages have a uniform shielding integrity even though the radiation levels of each package may be very different.
- o As the exposure control of the package under transportation depends on the normal radiation level, it is not a good idea to permit an increase in the radiation level of the package to any large extent even though the radiation level after the tests is lower than the maximum permissible radiation level.

Therefore the requirement to restrict radiation level relatively is useful. But we think it is not reasonable to restrict the radiation level at the external surface of a package and the meaning of 20% not clear.
For example, radiation level increase after the testing may easily 20% at the external surface of a package that has a considerably damagable body such as fiber board boxes or steel drums. It is not practical to reinforce the package to satisfy this requirement because the radiation level around the package will not increase very much after the testing is completed.
There is a large difference between the radiation level ratio at the external surface of the package before testing and after testing depending on whether the package is large or small. But the radiation level ratio at some distance from the package is expected not to depend on the size of package.
It would be more reasonable to restrict the radiation level at some given distance from the package rather than at the external surface of the package.
In the following chapter, we discuss the influence of package deformation on the radiation field by using simplified package models and the exposure situation of transport workers.

INFLUENCES ON THE RADIATION FIELD

Simplified package models, as shown in Figs. 1 to 3, are used to calculate the radiation level around packaging in order to examine the influence of package deformation on the radiation field around the packages by testing at normal conditions of transport.

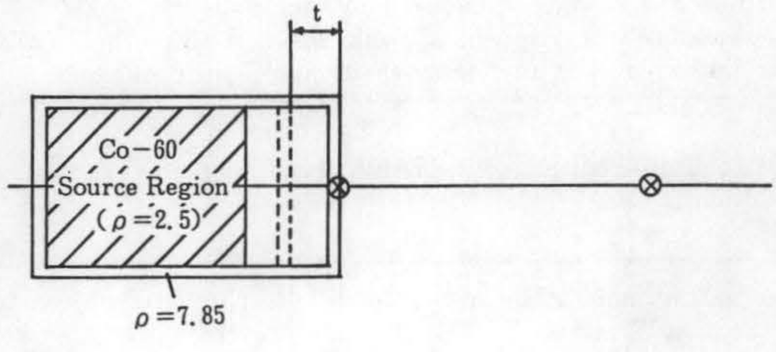


Fig. 1 Deformation Model of Void Region

The package shown in Fig. 1 will be used to simulate the deformation of a steel drum with a large void region. Figure 2 shows deformation after a horizontal drop test and Fig. 3 shows deformation after a penetration test with a 3.2 cm ϕ bar. There are two kinds of packages in Fig. 2 and Fig. 3, a large and small one, to discuss the differences caused by package size. Calculations are performed using QAD code and asuming a Co−60 source.

Influence of Deforming the Void Region

Figure 4 shows the radiation distribution on the axial direction of the package shown in Fig. 1. As the external surface of the package moves close to the source with the deformation, the radiation level at the external surface of the package will increased to a large degree, but the radiation field around the package never changes. It is not necessary to restrict this kind of deformation. In this case when the radiation level at surface of package increases a 20% the radiation level at 1 m from

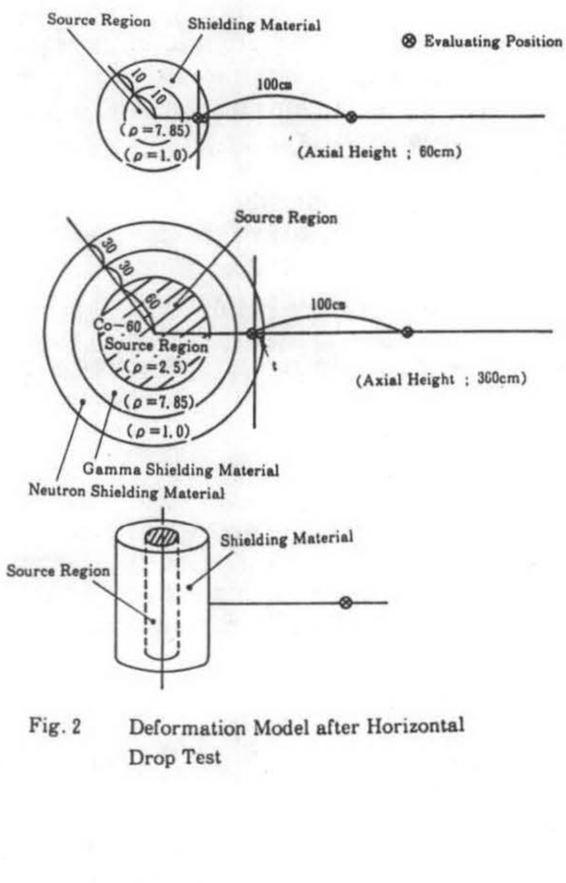


Fig. 2 Deformation Model after Horizontal Drop Test

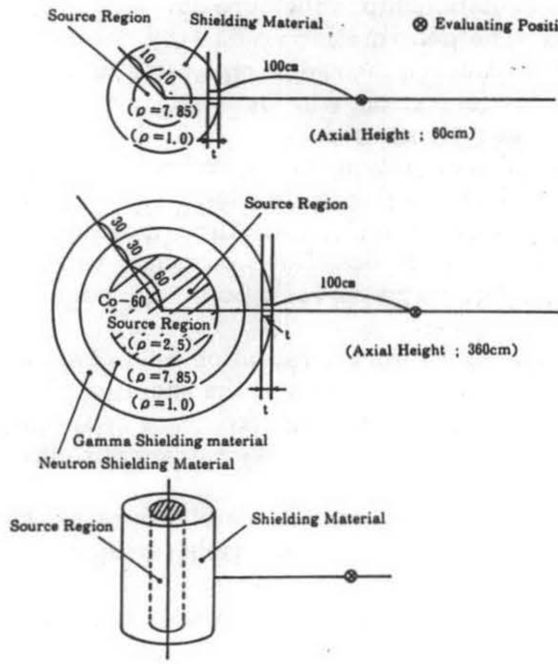


Fig. 3 Deformation Model after Penetration Test

package increases about 10% and 5 % at 2 m.
If you have to restrict the radiation level in this case, it is better to restrict it at some distance from the package not at the external surface.

Influence of Decreased Shielding Thickness

The radiation level increase at the surface of the package and at 1 m from the surface caused by deformation after a horizontal drop test and by deformation after a penetration test are shown in Fig. 5 and Fig. 6 , respectively.
We can ascertain the following.

① The radiation level increase at the surface of the package is larger than that 1 m from the surface.
② At the surface of a package the radiation level increase in small packages is larger than that of large packages. On the other hand at 1 m from the surface, this relationship is the opposite.
③ The deformation caused by the penetration test is very local and doesn't make influence the radiation level 1 m from the surface. Nevertheless this kind of deformation will be restricted if the 1985 edition of the IAEA Regulations is strictly applied.
④ The radiation level increase at 1 m from the surface of large and small packages show similar tendencies. This means that this radiation level increase may represent a change in the radiation field around the package caused by deformation. The radiation level increase at the surface of the package can not represent changes in the radiation field around the package.

Figure 7 shows the radiation field of a small package when the radiation level increase at the surface is 20% and the radiation field of a large package when the radiation level increase at the surface, from one or two meters reached the same radiation level at the same position. We can surmise the following from this figure.

① When the radiation level values at the surface are the same, the radiation fields away from the package becomes different depending on the size of the package.
② When the values at 1 m from the surface are the same, radiation fields of both large and small packages are almost the same except at locations very close to the surface of the package.
③ When the values at 2 m from the surface are the same, the radiation field beyond 2 m both large and small packages converge.

Discussion

Judging from these calculations, we propose that the acceptance criteria for shielding integrity after testing at normal conditions of transport should be revised to restrict radiation level increase at some given distance from the package such as at 1m instead of at the external surface as regulated in the 1985 edition of the IAEA Regulations.

EXPOSURE SITUATION OF TRANSPORT WORKERS

The influence of the radiation level increase by pacakge deformation on the exposure of transport workers can be estimated by the mean exposure distance.

Assumption

Three transport route patterns were selected in order to estimate mean exposure distance.

Pattern 1 : Driver of a road vehicle
Pattern 2 : Package handlers
Pattern 3 : Cabin crew of airplane

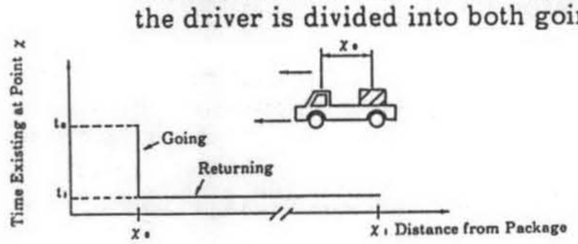
Non-routine work such as monitoring, repair and recovery of packages which have suffered minor damage is not considered because this work is not very severe. It is assumed that the transport workers work without noticing damage to the package in the evaluation of the mean exposure distance.

Transport Worker Movement

Relative location of the package and the transport worker for each pattern can be modeled as follows.

Pattern 1 : Driver of a road vehicle

The distance between the driver of a road vehicle hauling radioactive packages and the packages can be modeled easily as shown in Fig. 8. The rest time of the driver is ignored in this pattern. The movement of the driver is divided into both going and returning.



Pattern 1 : Driver of Road Vehicle

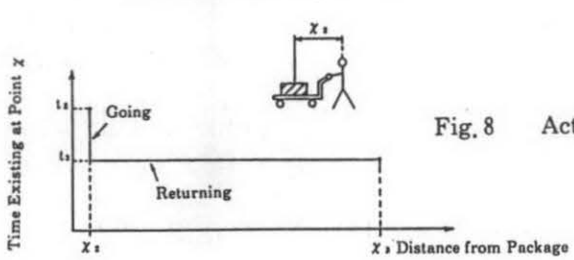
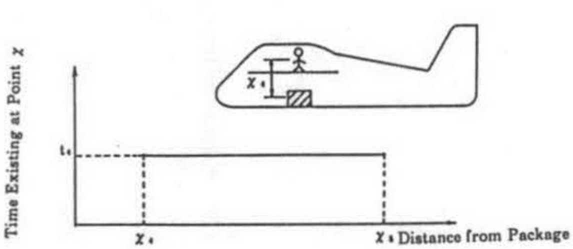


Fig. 8 Action Model of Transport Workers

Pattern 2 : Package Handler



Pattern 3 : Cabin Crew of Airplane

Pattern 2 : Package handlers

The movement of a package handlers depends on the package and the handling location. It is assumed that the worker carries a small package using a handcart because this situation corresponds to the minimum distance between the package handler and the package.

The movement of the worker may be classified into moving the radioactive package and moving non-radioactive materials or other work. The time spent carrying radioactive packages corresponds to its frequency against the total cartage.

Pattern 3 : Cabin crew of airplane

The cabin crew of an airplane moves around in space located above the packages in the cargo compartment. The crew is assumed to move uniformly on the plane as shown in Fig. 8.

Evaluation of Effective Mean Exposure Distance

The effective mean exposure distances of patterns 1, 2 and 3 are estimated using some typical figures.

Pattern 1 : Driver of a road vehicle

As shown in Fig. 9, the data used in this evaluation is as follows.

χ_0: 2 m: Distance between driver's seat and center of the package
χ_1: 500 m: Transport distance of package
V : 36km/h: Speed of vehicle(constant speed)
TI : 10 : Transport index

The vehicle moves at a constant speed both going and returning and the time of loading and unloading the packages is ignored in this evaluation. The package is regarded as a point source in order to simplify the calculation.

The effective exposure distance is evaluated by the following equation:

$$\overline{\chi} = \frac{\int x(t)R(t)dt}{\int R(t)dt}$$

$$= \int_0^{t_2} x(t)R(t)dt \Big/ \int_0^{t_2} R(t)dt$$

$$= \left(\int_0^{t_2} x(t)R(t)dt + \int_{t_2}^{t_2} x(t)R(t)dt\right) \Big/ \left(\int_0^{t_1} R(t)dt + \int_{t_1}^{t_2} R(t)dt\right)$$

$$= \frac{0.06944 + 1.535\times10^{-3}}{0.03472 + 1.383\times10^{-4}}$$

$$= 2.04(m)$$

(Note) The distance between the transport worker and a package varies during work. The effective exposure distance is defined as follows.

$$\overline{\chi} = \frac{\int x(t)R(t)dt}{\int R(t)dt}$$

Where,

$\chi(t)$: Distance between the worker and the package
R (t) : Exposure dose on time t

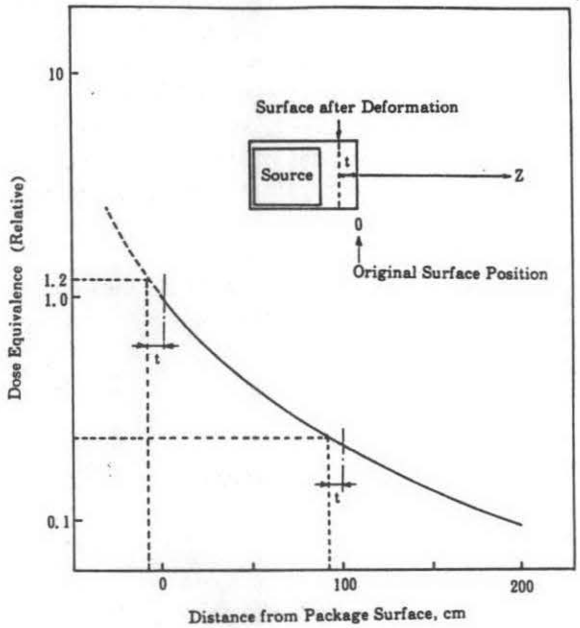


Fig. 4 Effect of Deforming the Package Void Region

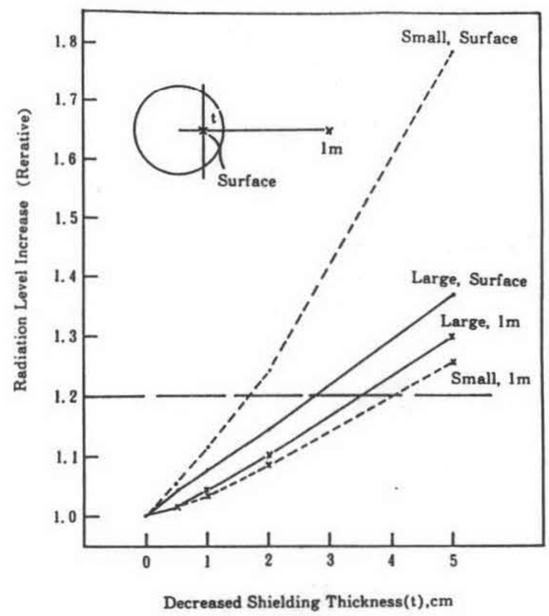


Fig. 5 Relationship between Radiation Level and Decreased Shielding

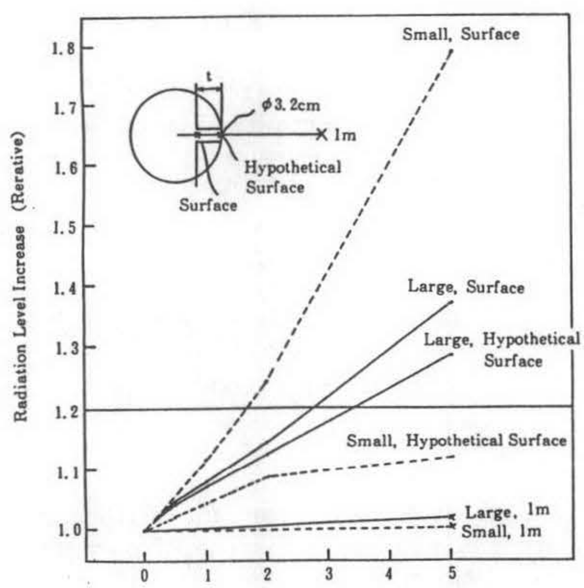


Fig. 6 Relationship between Radiation Level and Decreased

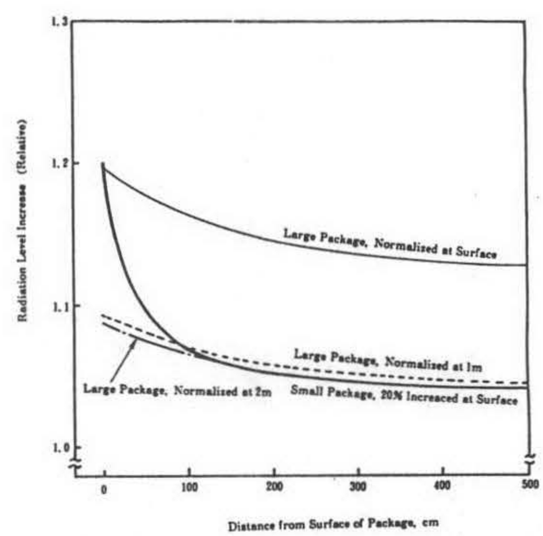


Fig. 7 Comparison between Radiation Field around Large and Small Packages

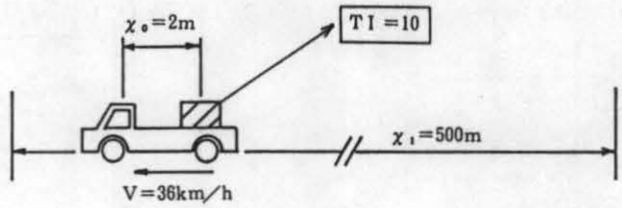


Fig. 9 Calculation Model(Pattern 1)

Pattern 2 : Package handlers

χ_2: 0.5 m: Distance between the worker and the package
χ_3: 50 m: Carrying distance of package
V : 6 km/h: Speed of worker

When transporting radioactive packages at a rate of one to twenty the result is

$\overline{\chi} = 1.00$ m

and at a rate of one to ten

$\overline{\chi} = 0.78$ m

Pattern 3 : Cabin crew of airplane

χ_4: 4 m: Minimum distance between the crew and the package
χ_5: 30 m: Maximum distance between the crew and the package
V : 6 km/h: Speed of crew

Then,

$\overline{\chi} = 9.70$ m

As calculated above, the effective exposure distance of a transport worker is in the range of about 1 m to 10 m. Therefore it is important to observe the radiation level a few meters from surface if the exposure of transport workers is in consideration.

CONCLUSION AND PROPOSAL

It has become clear that the radiation level at a given distance from the surface is more important than that at the surface when considering the influence of package deformation on the radiation field and the exposure situation for transport workers. We would then like to propose the following.

Since exposure protection is the principal purpose of this new transport regulation, the requirements for shielding integrity of packaging after testing at normal conditions of transport should be considered in relation with the exposure of transport workers and the public. For this purpose the requirement for shielding integrity is proposed to be modified by controlling the increase in the radiation level at some given distance from the package rather than at any external surface.