Proposal of the Standard for Dose Rate Increase under Normal Test Conditions

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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 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.
The object of this research is to propose an updated and more justifiable standard for dose rate increase under normal test conditions than that adopted in the IAEA Transport Regulations, the 1985 edition, taking into account the evaluated influence of deformations in the package on the surrounding radiation field and the difference of exposure level according to the method of operation of the transport operator.

IAEA REGULATIONS

The acceptance criteria for shielding integrity after testing at normal conditions of transport are 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.

The words "20% increase in the radiation level at any external surface of the package" specified in paragraph 537 (b) of the 1985 edition is a revision of the words "No increase of the maximum radiation level" of the 1973 edition. 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 and more rational one. The merits of restricting radiation level by a relative value, and not an absolute value is the following;

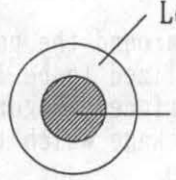
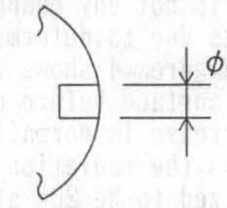
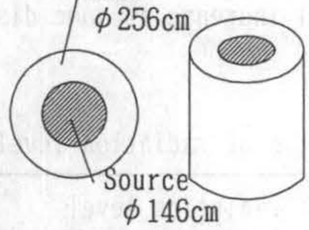
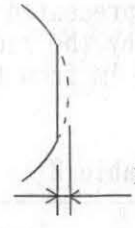
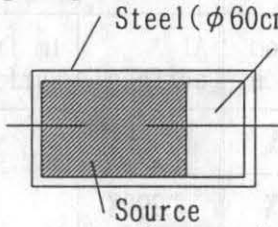
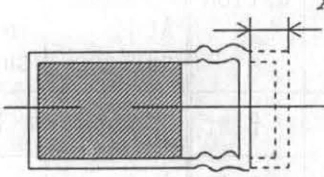
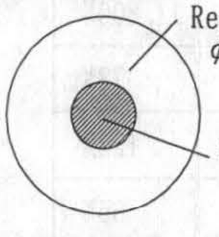
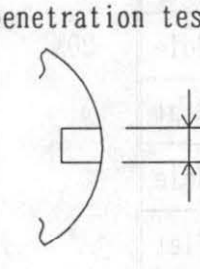
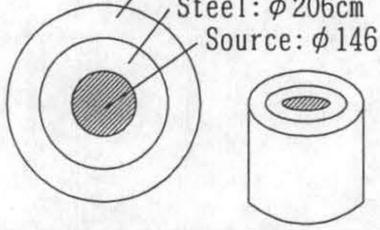
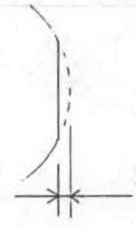
- It is possible to make packages have a uniform shielding integrity even though the radiation levels of each package may be very different.
- As the exposure control of the package under transportation depends on the normal radiation level, it is not a good idea to permit an increase in the radiation 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 increasing level at the external surface of a package.
For example, radiation level increase after the testing may be easily 20% at the external surface of a package that has a considerably damageable body such as fiber board boxes or steel drums.
It is not practical to reinforce the package to satisfy this requirement because the level around the package will not increase very much after the testing is completed.
Increasing ratio of the radiation level at the external surface of the package after testing, depending on the depth of shielding deformation and the change of distance between the surface and the radiation source, will not represent necessarily the change of the radiation field around the package after the test because it will also depend on the size of the package and deformation area.
Then, 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 Table 1, are assumed for the calculations of 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.
The small sphere model represents the package of radioisotopes and the large cylinder model represents the large package such as for radioactive wastes and for spent fuels. Deformation of shielding is assumed after penetration test and horizontal test. Drum model is also assumed for representing the package with void. Such a package will easily deform after drop test and exceed the radiation increasing level over 20%, while the radiation field will not change at all.
Gamma ray calculations are performed using QAD code and assuming a Co-60 source.
Neutron shielding calculations are performed using DOT 3.5 code and assuming a U-235 fission source.

Table. 1 Calculation Models

Source	Model	Deformation
γ-ray (Co-60)	[Small sphere]  Lead φ30cm Source φ15cm	[After penetration test]  φ3.2cm
	[Large cylinder]  Lead φ256cm Source φ146cm	[After horizontal test]  x cm
	[Drum]  Steel(φ60cm) Void Source (Concrete)	[After drop test]  x cm
Neutron (fission)	[Small sphere]  Resin: φ30cm Source: φ15cm	[After penetration test]  φ3.2cm
	[Large cylinder]  Resin: φ256cm Steel: φ206cm Source: φ146	[After horizontal test]  x cm

EFFECT OF DECREASED SHIELDING THICKNESS

The radiation level increase around the package after the test is shown in Figure. 1 through Figure. 8.
Figure 9 shows the radiation field around the drum package. This case is a typical one, because there is not any change in the radiation field if the radiation level at surface increases due to deformation of void part.
Figure. 1 through Figure. 4 showe the radiation field around the package which the radiation level at surface before deformation is normalized to be 1 and the radiation level increase is normalized to be 20% at surface. Figure. 5 through Figure. 8 showe also the radiation field around the package which the radiation level increase is normalized to be 20% at 1m from the surface.
The results are summarized in Table 2.
From these results, we can ascertain that the change of the radiation field around the package cannot be represented by the provision of radiation level increase at the package surface but by the radiation level increase at some distance from the package, for example, at 1m from the surface.

Table 2 Increase ratio of radiation level

Source	Model	Defor-mation	Increse ratio of radiation level					
			Normalize at surface			Normalize at 1m from surface		
			At surface	1m from surface	5m from surface	At surface	1m from surface	5m from surface
γ-ray	small sphere	Flat		8.1%	6.4%	56%		18%
		Hole		1.6%	1.2%	296%		18%
	Large cylinder	Flat		16%	12%	25%		15%
		Hole	20%	0.03%	0.02%	11,800%	20%	13%
Neutron	small sphere	Flat		5.0%	6.8%	78%		28%
		Hole		3.3%	1.2%	123%		6.8%
	Large cylinder	Flat		6.2%	3.6%	65%		12%
		Hole		0.2%	0.6%	1700%		55%

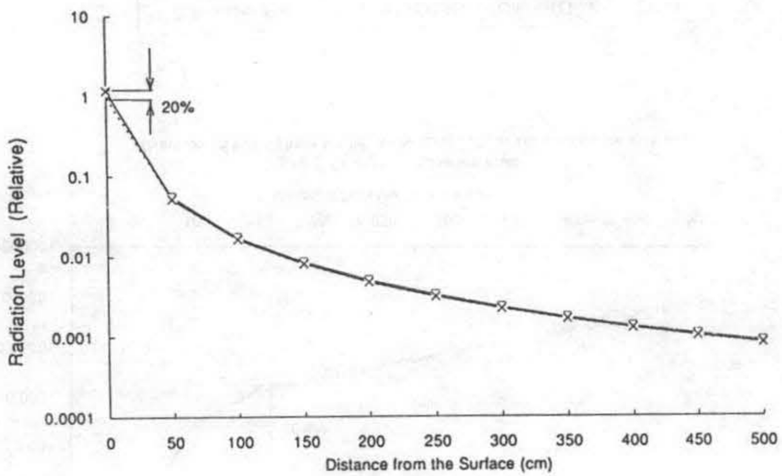


Figure 1 Change of Radiation Field
(Gamma Ray ; Small Sphere Model ; Increasing 20% at Surface)

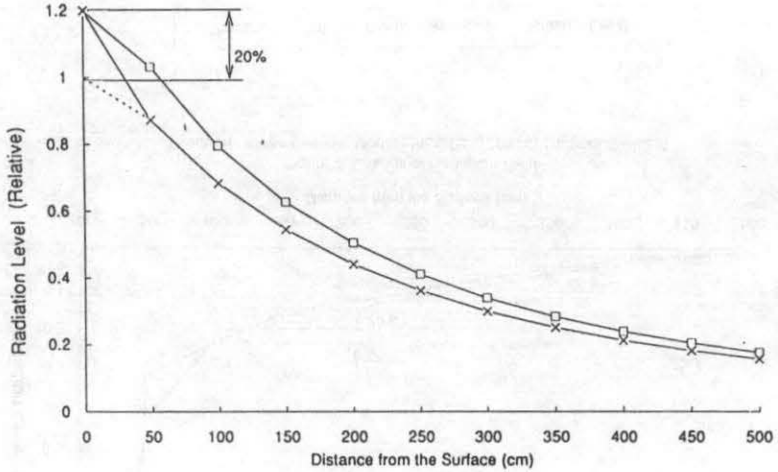


Figure 2 Change of Radiation Field
(Gamma Ray ; Large Cylinder Model ; Increasing 20% at Surface)

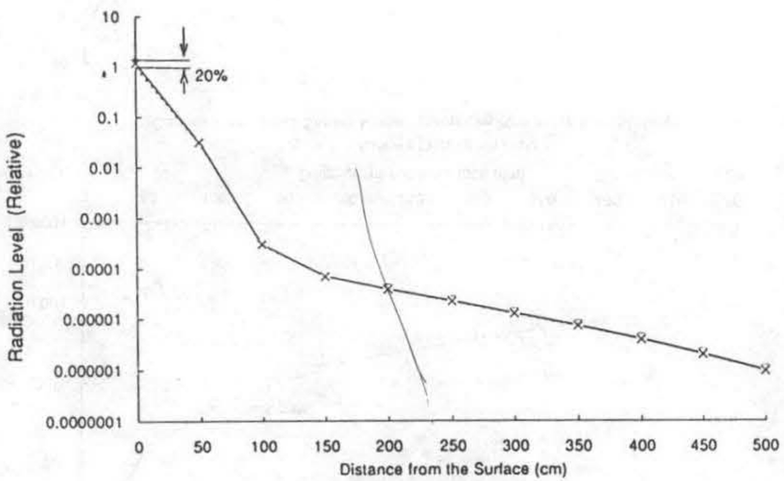


Figure 3 Change of Radiation Field
(Neutron ; Small Sphere Model ; Increasing 20% at Surface)

□ Deformation;Flat × Deformation;Hole ·· Original Level

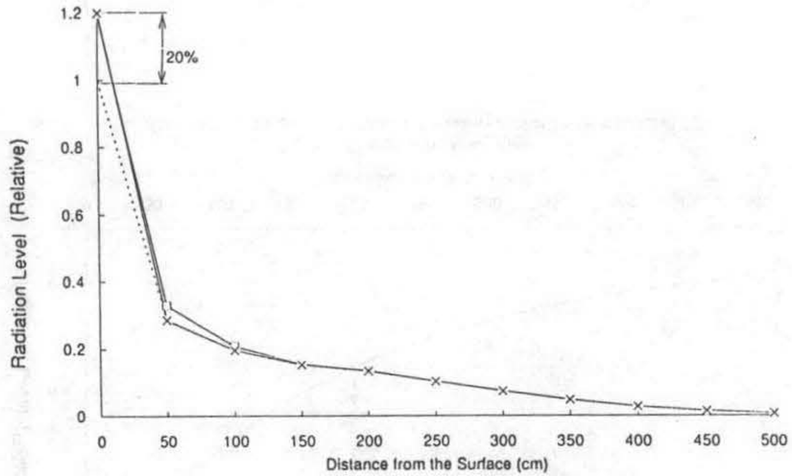


Figure 4 Change of Radiation Field
(Neutron ; Large Cylinder Model ; Increasing 20% at Surface)

□ Deformation;Flat × Deformation;Hole ·· Original Level

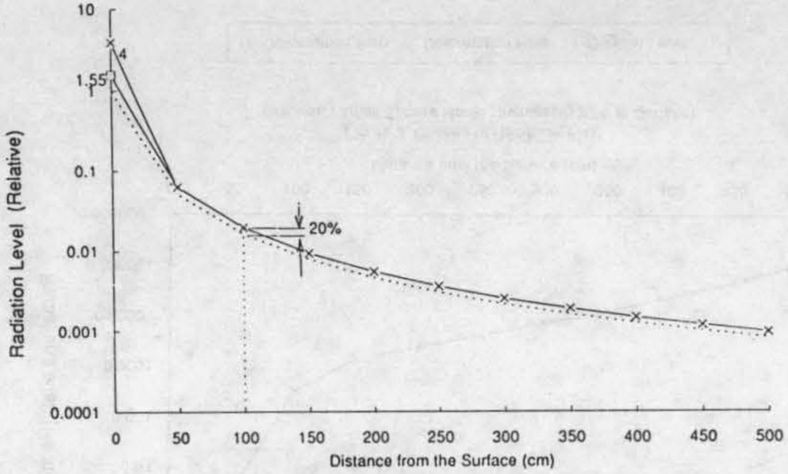


Figure 5 Change of Radiation Field
(Gamma Ray ; Small Sphere Model ; Increasing 20% at 1m from Surface)

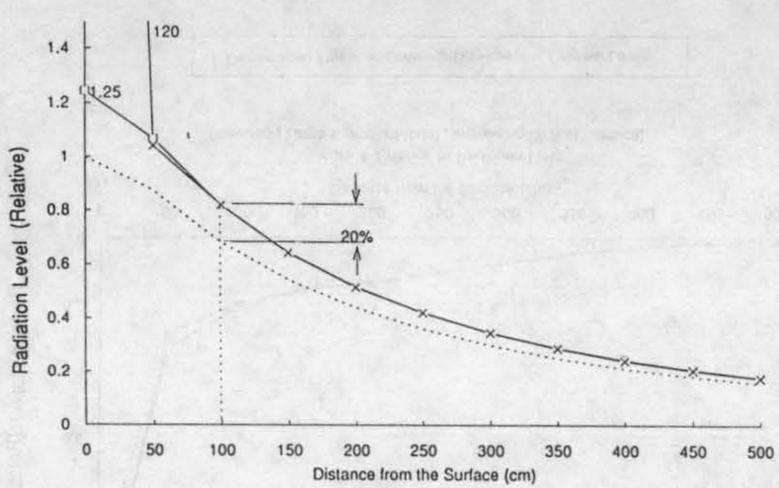


Figure 6 Change of Radiation Field
(Gamma Ray ; Large Cylinder Model ; Increasing 20% at 1m from Surface)

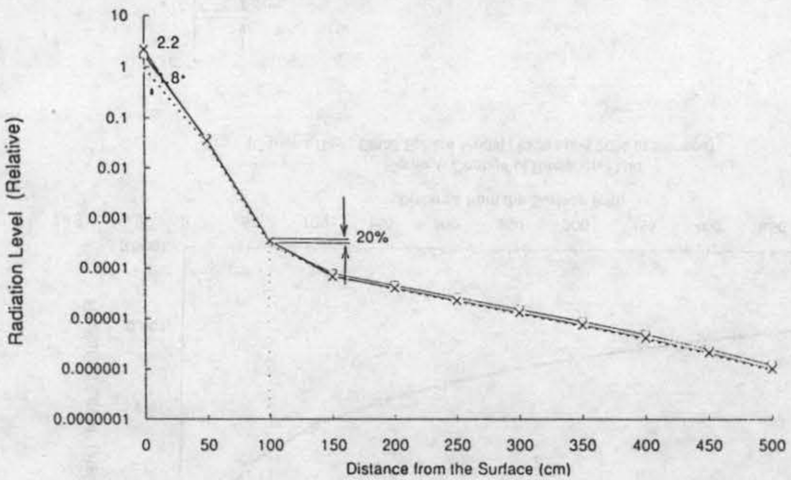


Figure 7 Change of Radiation Field
(Neutron ; Small Sphere Model ; Increasing 20% at 1m from Surface)

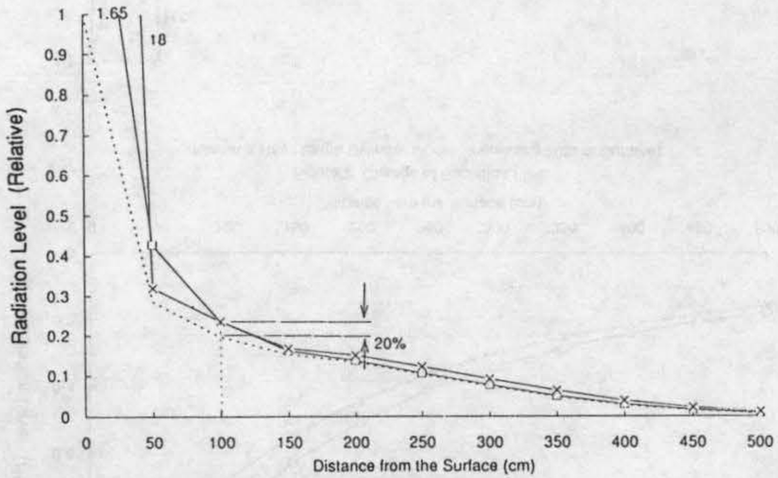


Figure 8 Change of Radiation Field
(Neutron ; Large Cylinder Model ; Increasing 20% at 1m from Surface)

○ Deformation;Flat × Deformation;Hole ·· Original Level

○ Deformation;Flat × Deformation;Hole ·· Original Level

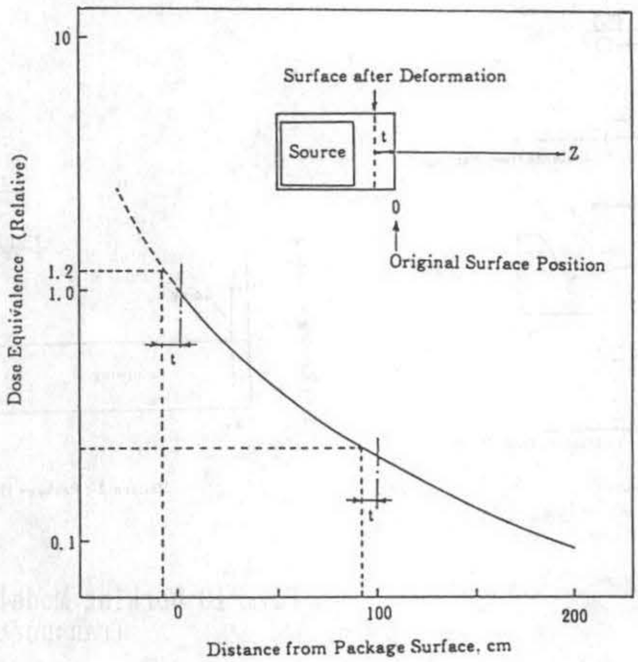


Fig. 9 Effect of Deforming the Package Void Requion

EVALUATION OF MEAN EXPOSURE DISTANCE

The effect of the radiation level increase due to package 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.

Pattarn 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. 10. The rest time of the driver is ignored in this pattern. The movement of the driver is divided into both going and returning.

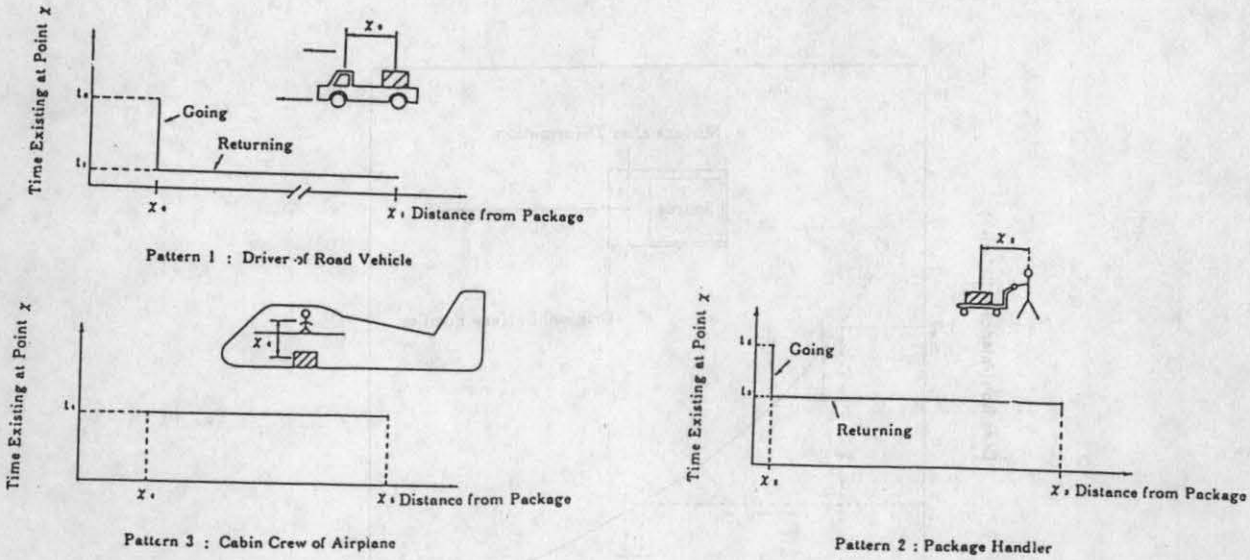


Fig. 10 Working Model of Transport Workers

Pattarn 2 : Package handlers
The movement of 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.

Pattarn 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.10.

· Evaluation of Effective Mean Exposure Distance

The effective mean exposure distance of patterns 1,2 and 3 are estimated in a former report. (Akamatsu et al. 1989) The results are summarized in the following.

Pattern 1 : Driver of a road vehicle
Assuming the data as follows.

x_0: 2m: Distance between driver's seat and center of the package
x_1: 500m: Transport distance of package
V : 36km/h: Speed of vehicle (constant speed)
TI: 10 : Transport index

Then, 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 calcuation. The effective exposure distance is evaluated by the following equation:

$$\bar{X} = 2.04\text{m}$$

Pattern 2 : Package handlers

x_2: 0.5m: Distance between worker and the package

x_3: 50m: Carrying distance of package

V : 6km/h: Speed of worker

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

$\overline{X} = 1.00m$

and at a rate of one to ten

$\overline{X} = 0.78m$

Pattern 3 : Cabin crew of airplane

x_4: 4m: Minimum distance between the crew and the package

x_5: 30m: Maximum distance between the crew and the package

V : 6km/h: Speed of crew

Then,

$\overline{X} = 9.70m$

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 change of the radiation level a few meters from the surface because 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 effect 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 the IAEA Transport Regulations, the requirements for shielding integrity of packaging after testing at normal conditions of transport should be considered in relation with 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 1 meter from the package rather than at any external surface.
The value of 1 meter complies with the definition of transport index.

ACKNOWLEDMENTS

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REFERENCES

Akamatsu, H. et al., "A Radiological Approach to Increasing the Radiation Level Standard of a Package," proc. of PATRAM '89, IAEA 1989.