STUDY OF MODEL OF A CASK AS A SOURCE TERM FOR SKYSHINE CALCULATION

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ABSTRACT

For the skyshine calculation of transport and storage casks, it is not reasonable to use the detailed cask geometry as a source because of the difficulty in modeling of the cask and too long calculation time. The proper source term may be different between radial and axial direction of a cask. A comparison is made for finding the model and normalizing method to be used for actual skyshine calculation. As a result, there is not so much difference between these source terms for the radial direction, but the point source for the axial direction shows a large conservative result compared with the disk source when the source intensity is normalized at 1m from the cask surface. To make a reasonable source term for axial direction, the normalization must be performed at far enough from the cask, such as 100m from the cask.

INTRODUCTION

Transport casks are temporarily stored at reactor site before shipping and storage casks are stored in a storage building for an interim period in Japan. For the temporarily or interim storage of these casks, the calculation of skyshine dose rate from the casks is very important to evaluate the public exposure at the boundary of the reactor site or the interim storage site. For the skyshine calculation, it is not reasonable to use the detailed cask geometry as a radiation source because of the difficulty in modeling of the cask geometry and too long calculation time. Simplified source term, usually a point source, is introduced for the conventional skyshine calculation. This paper discusses the method of making a simplified source term for it.

ASSUMPTION OF SOURCE GEOMETRY

Conventional skyshine calculation is performed by SN codes, such as DOT[1)] and DORT[2)]. For this calculation, only a point source is used because no other source geometry is applicable for the first collision source option that can only be applied to the skyshine calculation to get reasonable result by these codes. Recently, Monte Carlo codes become

applicable to the skyshine calculation, and this limitation becomes having no meaning, but still there is a necessity of having some simplified source geometries instead of using actual cask geometry for the limitation of core memory and calculation time. Figure 1 shows the several simplified source geometry against a cask geometry.

For the radial direction, following simplified source geometry is considered as shown in Fig.1(a).

1) Point source: Position in the center of the cask
2) Cylindrical source: Surface source is only on the cylindrical surface of the cask
3) Line source: Position on the z-axis, and axial length of line is the same with the cask hight
4) Spherical source: Position in the center of the cask, and the surface is tangent to the radius of the cask

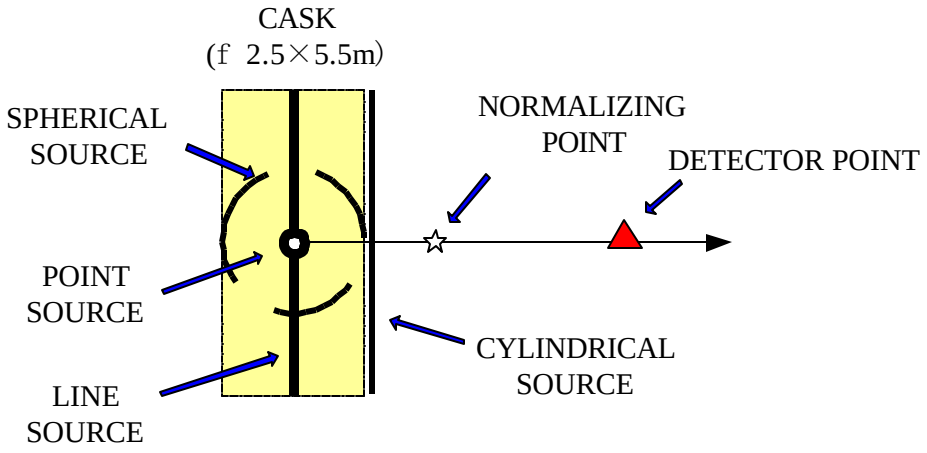


Fig.1 (a) Assumption of simplified source geomery of a cask (Radial direction)

For the axial direction, following is considered as shown in Fig.1(b).

1) Point source: Position in the center of the cask
2) Disk source: Surface source is only on the upper end disk surface of the cask
3) Spherical source: Position in the center of the cask, and the surface is tangent to the upper end disk surface of the cask

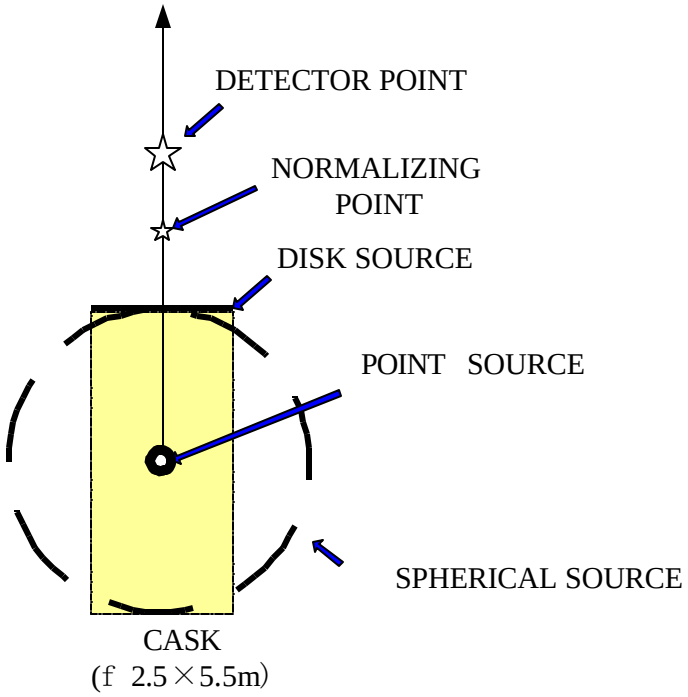


Fig.1 (b) Assumption of simplified source geomery of a cask
(Axial direction)

EFFECT OF NORMALIZATION OF SOURCE INTENSITY

For these simplified source geometry, comparison of dose rate attenuation against the distance form the sources are performed. The dose rate calculations of a cask using DOT+SPACETRAN[3] and DORT + FALSTF[4] are referred to make clear the difference between the actual cask geometry and the simplified one. In all these calculation, outside of the cask is assumed as void.

1) NORMALIZED AT 1M FROM A CASK

Usually, the source intensity of simplified source is normalized to 100μ Sv/h at 1m from the cask surface in Japan because the Japanese regulation specifies that the dose rate at 1m from the cask must be less than 100μ Sv/h. For this reason, the first comparison of the dose rate with these simplified source geometries is performed by normalizing at 1m form the cask. Table 1 and 2 show the results of radial and axial direction of a cask, respectively. From Table 1, all the results of the simplified source geometry are less than that of the actual cask geometry, but the different is not so large, up to 30% at 100 and 500m from the cask. On the other hand, there is large difference for the axial direction as shown in Table 2. A difference in factor of six is observed for the point geometry against the actual ones, but a better result,

around 30% less, is obtained by the disk source. The difference between the point and disk sources is almost a factor of ten for the axial direction.

Table-1 Comparison of the dose rate at typical point for several source geometry
(Radius direction, normalized at 1m from the surface of a cask)

(unit: μ Sv/h)

	Distance from a cask		
	1m from the surface of a cask	100m from the center of a cask	500m from the center of a cask
Point	100	5.063E-02	2.025E-03
Cylinder		5.037E-02	2.000E-03
Sphere		4.490E-02	1.796E-03
Line		6.048E-02	2.420E-03
Cask (DOT)		6.409E-02	2.533E-03
Cask (DORT)		6.048E-02	2.402E-03

Table-2 Comparison of the dose rate at typical point for several source geometry
(Axial direction, normalized at 1m from the surface of a cask)

(unit: μ Sv/h)

	Distance from a cask		
	1m from the surface of a cask	100m from the center of a cask	500m from the center of a cask
Point	100	1.406E-01	5.625E-03
Sphere		1.102E-01	4.408E-03
Disk		1.525E-02	5.835E-04
Cask (DOT)		2.531E-02	1.084E-03
Cask (DORT)		2.559E-02	8.771E-04

2) NORMALIZED AT 100M FROM A CASK

The evaluated point is usually far from the cask, such as 100m or 500m, and even in the nearest cases, the distance is more than several decade meters in the skyshine calculation. The dose rates from each source become very closer at some distance from a cask, because these sources can be treated as point source when the detector locates far from the source. In this meaning, normalization point may be better for far from the source. For having enough distance, every data is normalized for the dose rate at 100m of the cylindrical source on radius

direction and normalized for that of the disk source on axial direction as shown in Table 3 and Table 4, respectively. In these figures, the dose rates at the distance of 500m agree very well for the radius direction, and within 20 % for the axial direction. Of course, the dose rate at 1m from the surface of a cask has much difference, but this is not a problem, because the dose rate inside of the building is not interest for the skyshine calculation.

Table-3 Comparison of the dose rate at typical point for several source geometry
(Radius direction, normalized at 100m from the surface of a cask)

(unit: μ Sv/h)

	Distance from a cask		
	1m from the surface of a cask	100m from the center of a cask	500m from the center of a cask
Point	99.50	5.037E-02	2.015E-03
Cylinder	100.00		2.000E-03
Sphere	112.17		2.015E-03
Line	83.28		2.015E-03
Cask (DOT)	78.59		1.991E-03
Cask (DORT)	83.28		2.000E-03

Table-4 Comparison of the dose rate at typical point for several source geometry
(Axial direction, normalized at 100m from the surface of a cask)

(unit: μ Sv/h)

	Distance from a cask		
	1m from the surface of a cask	100m from the center of a cask	500m from the center of a cask
Point	10.85	1.525E-02	6.101E-04
Sphere	13.84		6.100E-04
Disk	100.00		5.835E-04
Cask (DOT)	60.28		6.535E-04
Cask (DORT)	59.60		5.228E-04

In this discussion, only the point and surface sources are considered, but there is a possibility to use of a volume source for considering both of radial and axial sources simultaneously. For evaluating the applicability of volume source, Table 5 shows the comparison with cylindrical

and line sources. The result shows that the volume source shows very similar behavior with line source, and this means that the volume source can only be applicable when the contribution of the axial radiation source is negligible small compared to the radius source.

Table-5 Comparison of the dose rate for line and volume sources

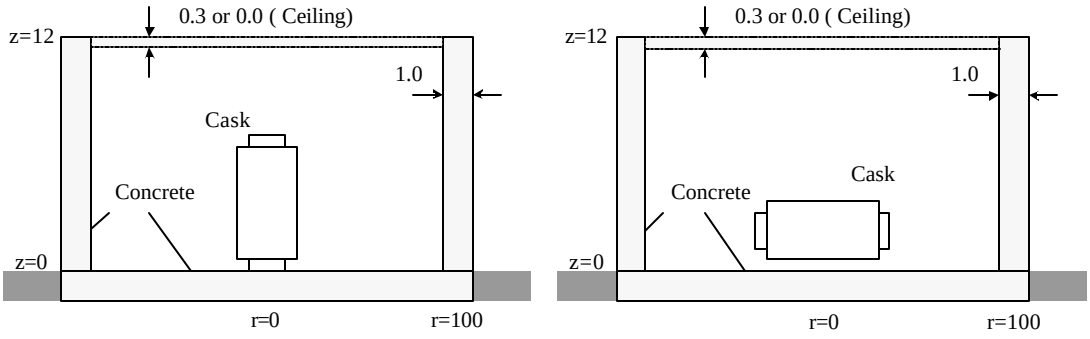
(Radius direction, normalized at 100m from the surface of a cask)

(unit: μ Sv/h)

	Distance from a cask		
	1m from the surface of a cask	100m from the center of a cask	500m from the center of a cask
Cylinder	100	5.037E-02	2.000E-03
Line	83.28		2.015E-03
Volume	83.69		2.014E-03

APPLICATION TO SKYSHINE GEOMETRY

The applicability of the simplified sources to the skyshine calculation is checked by the calculation using typical skyshine calculation model with ceiling and without ceiling. Figure 2 shows the skyshine calculation model used for the comparison. The cask is located at vertical position as storage cask or horizontal as transport cask condition.



(a) cask in vertical position (b) cask in horizontal position

Fig. 2 Skyshine calculation model for transport and storage casks

Table 6 and 7 show the dose rates at 100m and 500m from the cask for several source geometries in the case having no ceiling with vertical and horizontal position, respectively. The

normalized point of these cases is 100m from the center of the cask. Both of vertical and horizontal position, the contribution from the radial source shares major part, more than 2/3 of total dose rate. For the horizontal position, the contribution of the radial source is much larger. Table 8 shows the dose rate with ceiling on the building, and the contribution of the radial source becomes much larger when compared with Table 6. This means that the effect of radial source to the skyshine dose rate is most important and the importance is much larger when the cask is in horizontal position and/or the thickness of ceiling of the building becomes thicker.

Table-6 Calculated dose rate for the skyshine calculation model by assuming several simplified source geometry. Casks are positioned as vertical
(No ceiling, normalized at 100m from the surface of a cask)

(unit: μ Sv/h)

		Distance from a cask		
		1m from the surface of a cask	100m from the center of a cask	500m from the center of a cask
Axial (Top)	Point	1.66E+01	3.68E-03	1.48E-04
	Disk	1.01E+02	2.27E-03	9.19E-05
Radial	Point	1.10E+02	1.02E-02	4.57E-04
	Cylinder	1.09E+02	9.75E-03	4.63E-04
	Line	8.45E+01	1.01E-02	4.73E-04

Table-7 Calculated dose rate for the skyshine calculation model by assuming several simplified source geometry. Casks are positioned as horizontal.
(No ceiling, normalized at 100m from the surface of a cask)

(unit: μ Sv/h)

		Distance from a cask		
		1m from the surface of a cask	100m from the center of a cask	500m from the center of a cask
Axial (Top)	Point	1.98E+01	3.60E-03	1.31E-04
	Disk	1.08E+02	1.54E-03	6.05E-05
Radial	Point	1.13E+02	9.84E-03	4.92E-04
	Cylinder	1.04E+02	9.39E-03	4.53E-04
	Line	8.53E+01	9.92E-03	4.72E-04

Table-8 Calculated dose rate for the skyshine calculation model by assuming several simplified source geometry. Casks are positioned as vertical
(Ceiling with 30cm thick concrete, normalized at 100m from the surface of a cask)

(unit: μ Sv/h)

		Distance from a cask		
		1m from the surface of a cask	100m from the center of a cask	500m from the center of a cask
Axial (Top)	Point	1.80E+01	1.07E-04	4.67E-06
	Disk	1.02E+02	7.10E-05	3.25E-06
Radial	Point	-	-	-
	Cylinder	1.11E+02	3.76E-04	1.94E-05
	Line	-	-	-

CONCLUSION

There is not so much difference between these source terms for the radial direction, but the point source for the axial direction shows a large conservative result, around the factor of 10, compared with the disk source. To make a reasonable source term for axial direction, the normalization must be performed at far enough from the cask, such as 100m from the cask for getting the reasonable result. The contribution of radial source is quite high for the actual skyshine calculation.

REFERENCES

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