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MCVIEW2: A RADIATION VIEW FACTOR COMPUTER PROGRAM FOR THREE DIMENSIONAL GEOMETRIES USING MONTE CARLO METHOD

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MCVIEW2 : A Radiation View Factor Computer Program for Three Dimensional Geometries using Monte Carlo Method

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The computer program MCVIEW2, which is a revised version of MCVIEW, has been developed for calculation of radiation view factors between surfaces for three dimensional geometries. The main revisions of the computer program are as follows:

(1) the alteration of algorithms of making the random numbers for the non-computer dependent,
(2) the alteration of input data format from the free format to the fixed format.

In the paper, brief illustration of calculation method using the Monte Carlo for view factors is presented in the second section. The third section presents comparisons between view factors of various methods such as the area integration method, the line integration method, the cross string method and the Monte Carlo method, concerning with the calculation errors and the computer execution time. The fourth section provides an user's guide for MCVIEW2.

Keywords: Computer Program, Radiation, Heat Transfer, View Factor, Shape Factor, Configuration Factor, Angle Factor, Monte Carlo Method, Radiation View Factor, Radiation Heat Transfer, Radiation Geometric View Factor

MCVIEW2：モンテカルロ法による3次元形態係数計算プログラム

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モンテカルロ法による3次元形態係数の計算プログラムMCVIEW2はMCVIEWの改良版として作成された。主要な改良は次の通りである。

(1) 計算プログラムを計算機の種類に関係なく容易に使用できるようにするために，乱数の計算ルーチンを，計算機によって異なるアセンブラーからフォートランに変更した。

(2) 入力データの形式をフリーフォマットから固定フォマットに変更した。

本文では，モンテカルロ法による形態係数の計算方法について記述した。次に，その他の形態係数の計算法である，面積積分法，線積分法，クロスストリング法などとモンテカルロ法によって計算した結果を計算精度と計算時間に関して比較した。最後に，MCVIEW2の使用のための，入力データ等のユーザーガイドについても記述した。

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Contents

目　　次

1. Introduction

It is necessary to obtain the radiation view factors for calculation of radiation heat transfer problems. There are many studies for the calculation methods of the view factors that are the area integration(1), the line integration(2), Mitalas and Stephenson(3), Hottel's cross string(4) and the Monte Carlo methods(5). The view factors can be calculated by the area integration and the Monte Carlo methods when the third surface shading exists.

There are many computer programs for the view factors calculations such as COVUFAC(6), VIEWPIN(7), FACET(8) and so on. COVUFAC was originally developed by General Dynamics and modified by R. W. Wong. VIEWPIN was developed by G. L. Singer to calculate the view factors for a fuel pin bundle in the two dimensional planar. FACET was developed by A. B. Shapiro to calculate view factors between surfaces for axi-symmetric, two dimensional planar and three dimensional geometries with or without the interposed third surface obstructions. The computer program MONTE(9), using a Monte Carlo method, can be used to calculate exchange factors for specular emitting and reflecting surfaces for two dimensional geometries.

It is considered that the Monte Carlo methods are computer time consuming. However, it is clarified from the results that a small amount of emission leads the reasonable view factors and resulting a small amount of computer time. Moreover, using the Monte Carlo methods, the view factors of the whole system could be obtained through only once computing execution.

The computer program MCVIEW(Monte Carlo method computer program for radiation VIEW factor calculation) was developed to calculate the view factors for input data of heat transfer computer programs such as TRUMP(10), HEATING-5(11), HEATING-6(12) and so on. MCVIEW2 calculates the radiation geometric view factors between surfaces for axi-symmetric, two dimensional planar and three dimensional geometries with or without interposed third surface obstructions.

MCVIEW2 is a revised version of MCVIEW(13) and the main revisions of MCVIEW2 are as follows:

(1) the alteration of algorithms of making the random numbers for the non−computer dependent,

(2) the alteration of input data format from the free format to the fixed format.

In the paper, the Chapter 2 presents a brief illustration of calculation method using the Monte Carlo for the view factors. The Chapter 3 presents comparisons between the view factors of various methods such as the line integration method, the area integration method, cross string method and the Monte Carlo method concerning error and computer execution time. The Chapter 4 provides an user's guide for MCVIEW2.

2. Illustration of view factor calculation

The view factor defines the fraction of the diffusely distribution radiant energy leaving one surface I that arrives at a second surface J. The basic assumptions used in deriving the equation of the view factor are as follows:

(1) the two surfaces are diffusely emitting and reflecting,

(2) the two surfaces are black,

(3) the two surface are isothermal.

A derivation of the equation of the view factor can be found from Sparrow and Cess(1) as following.

$$F_{ij} = \frac{1}{A_I} \int_{A_I} \int_{A_J} \frac{\cos\beta_i \cos\beta_j dA_i dA_j}{\pi r_{ij}^2} \quad . \tag{1}$$

The symbols used in Eq.(1) are defined in Fig. 2.1. As shown in Eq.(1) the view factor depends only on the geometry of the system.

Equation (1) is numerically integrated for three dimensional geometries. If the two surfaces Ai and Aj are divided into n finite subsurfaces ΔAi :i=1,2,......,n, and ΔAj :j=1,2,......,n, Eq.(1) may be approximated by

$$F_{ij} = \frac{1}{A_I} \sum_{i=1}^{n} \sum_{j=1}^{n} \frac{\cos\beta_i \cos\beta_j \Delta A_i \Delta A_j}{\pi r_{ij}^2} \quad . \tag{2}$$

The calculation scheme, Eq.(2) is referred to as double area summation.

In the complex geometries, the Monte Carlo method has been the advantage that simple relations will specify the path of a bundle, whereas most other methods require integrations over surface areas. Such integrations become difficult when a variety of curved or skewed surfaces are present.

The Monte Carlo method requires that case histries of the travel of indivisual particles through the geometries are constructed. One particle history includes the birth of a particle at its source surface, and its random walk through the transporting medium as it undergoes reflection and its absorption at other surface, which terminates the history. A dead can occur when the particle becomes absorption.

In the Monte Carlo method, the view factor Fij between surfaces I and J is derived from the following equation.

$$F_{ij} = \frac{n_J}{n_I} , \tag{3}$$

where n_I : number of emitted particles at the I-th surface,

n_J : number of absorbed particles at the J-th surface.

The formula for the variance of the mean is

$$\sigma^2 = \frac{1}{N-1} \left\{ \frac{1}{n} \sum_{i=1}^{N} n_i x_i^2 - \frac{1}{n^2} \left(\sum_{i=1}^{N} n_i x_i \right)^2 \right\} , \tag{4}$$

where N : number of batches,

n : total number of independent histories,

n_i : number of independent histories in the i-th batches,

x_i : accumulated estimate in the i-th batch.

$$n = \sum_{i=1}^{N} n_i , \tag{5}$$

$$x_i = \frac{1}{n_i} \sum_{i=1}^{n_i} x_{ij} , \tag{6}$$

where x_{ij} is the estimate from the j-th histories in the i-th batch.

$$\bar{x} = \frac{1}{n} \sum_{i=1}^{N} n_i x_i , \tag{7}$$

where $\bar{x}$ is the mean, averaged over histories.

The fractional standard deviation(f.s.d.) is as follow:

$$\text{f.s.d.} = \frac{\sqrt{\sigma^2}}{\bar{x}} . \tag{8}$$

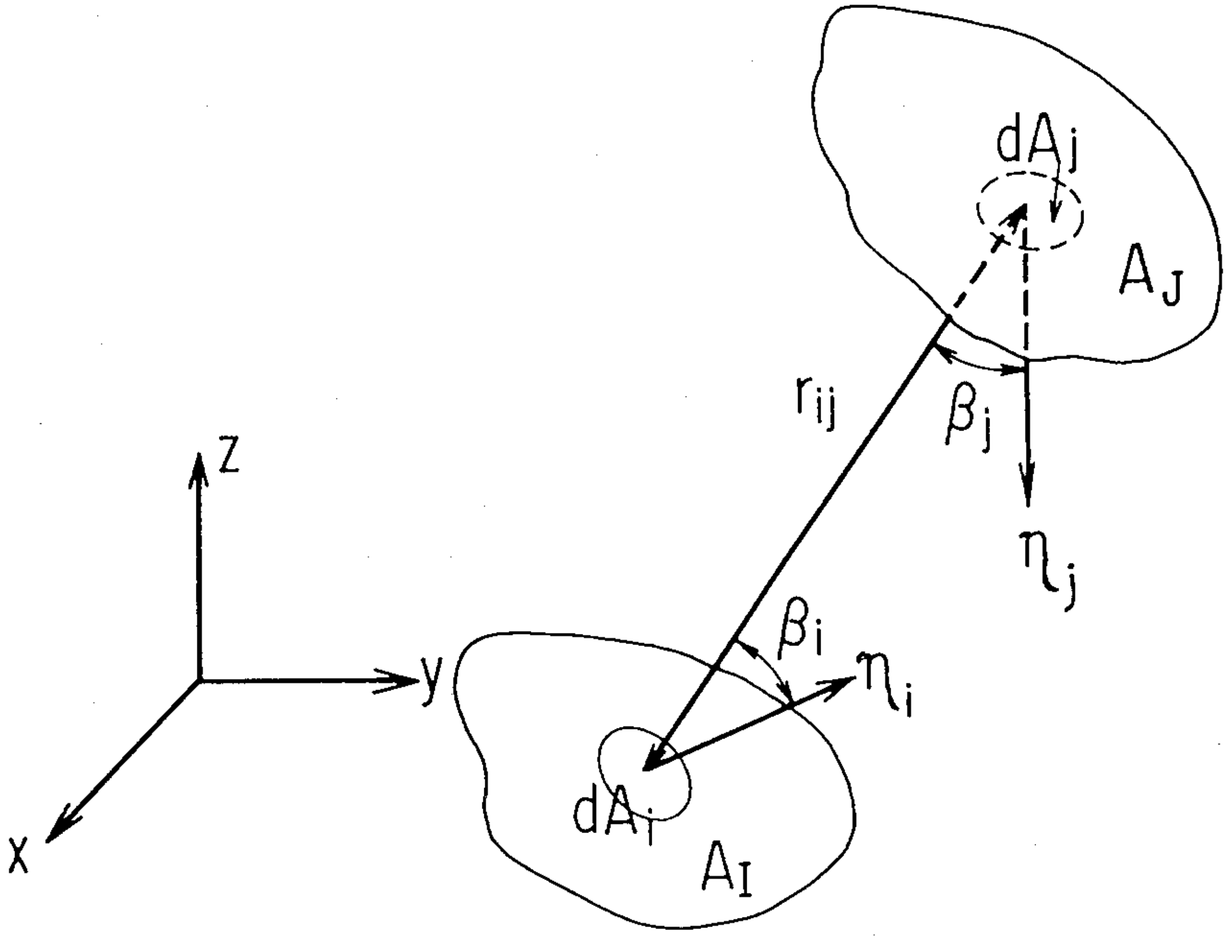


Fig. 2.1 Illustration of symbols used in Eqs. (1) through (3) to calculate view factor

3. Calculation results

(1) Two long parallel cylinders

Figure 3.1 shows the view factors of the two long parallel cylinders obtained by various methods that are the cross string, the area integration and the Monte Carlo methods. Those values are same as the exact value.

(2) Two plates inclined angle 60 degrees to each other

Figure 3.2 shows the view factors of the two long plates inclined 60 degrees to each other, obtained by the Monte Carlo method comparing with the exact value. The value of the Monte Carlo method is in good agreement with the exact value.

(3) Two parallel circular disks

Figure 3.3 shows the view factors of the two parallel circular disks, obtained by the Monte Carlo method comparing with the exact value. The value of Monte Carlo method is in good agreement with the exact value.

(4) Sphere to disk

Figure 3.4 shows the view factors of in the case of one sphere to one disk, obtained by the Monte Carlo method comparing with the exact value. The value of the Monte Carlo method is in good agreement with the exact value.

(5) Two long parallel plates

Figure 3.5 shows the view factors of the two long parallel plates, obtained by the Monte Carlo method comparing with the exact value. The value of the Monte Carlo method is in good agreement with the exact value.

(6) Two long perpendicular plates

Figure 3.6 shows the view factors of the two long perpendicular plates, obtained by the Monte Carlo method comparing with the exact value. The value of the Monte Carlo method is in good agreement with the exact value.

(7) Enclosure of cone cavity

Figure 3.7 shows the view factors of the enclosure of the frustum of a cone, obtained by the Monte Carlo method comparing with the line integration method. The values of the Monte Carlo method are in fairly good agreement with that of the line integration.

(8) Enclosure of rectangular cavity

Figure 3.8 shows the view factors of the enclosure of a rectangular cavity with two shields, obtained by the Monte Carlo method comparing with that of the cross string method. The values of the Monte Carlo method are in fairly good agreement with that of the cross string method.

(9) Cubic cavity with internal shield

Figure 3.9 shows the view factors of the enclosure of a cubic cavity with two shields, obtained by the Monte Carlo method comparing with that of the area integration method. The values of the Monte Carlo method are in fairly good agreement with that of the area integration method.

(10) Parallel plates with obstacle

The area integration method and the Monte Carlo method are compared in the view factor in the case where there exists third plate between the two parallel plates so that third plate shadows the view between the other two plates.

In Fig. 3.10, the view factor obtained by the area integration method is shown as a function of the number of divisions per edge on a plate for integration. In the figure, the computer execution time with a computer FACOM M−380 is also shown. As seen, with increasing the number of divisions per edge, the view factor approaches toward the analytical solution. On the other hand, the computer execution time increases rapidly with increasing the number of divisions per edge.

The view factor obtained by the Monte Carlo method for the same as above calculation model is shown in Fig. 3.11. In the figure, the view factor and the computer execution time are shown as a function of the number of emissions. The view factor is shown together with the standard deviation. With incresing number of emissions, the view factor approaches to the analytical solution and the standard deviation becomes small. Even when the number of emissions is small, the view factor is close to the analytical solution.

(11) Perpendicular plates with obstacle

The area integration method and the Monte Carlo method are compared in the view factor in the case where there exists third plate between the two perpendicular plates so that third plate shadows the view between the other two plates.

In Fig. 3.12, the view factor obtained by the area integration method is shown as a function of the number of divisions per edge on a plate for integration. In the figure, the computer execution time is also shown. As seen, with increasing the number of divisions per edge, the view factor approaches toward the analytical solution. On the other hand, the computer execution time increases rapidly with increasing the number of divisions per edge.

The view factor obtained by the Monte Carlo method for the same as above calculation model is shown in Fig. 3.13. In the figure, the view factor and the computer execution time are shown as a function of the number of emissions. The view factor is shown together with the standard deviation. With incresing number of emissions, the view factor approaches to the analytical solution and the standard deviation also becomes small. Even when the number of emissions is small, the view factor is close to the analytical solution.

(12) BWR fuel assembly

Other feature of the Monte Carlo method is that in a complex system containing multiple bodies, the method is able to calculate easily the view factor by a procedure similar to that for a two-body system. As an example of this calculation, a case of view factor between fuel pins in a BWR fuel assembly will be described.

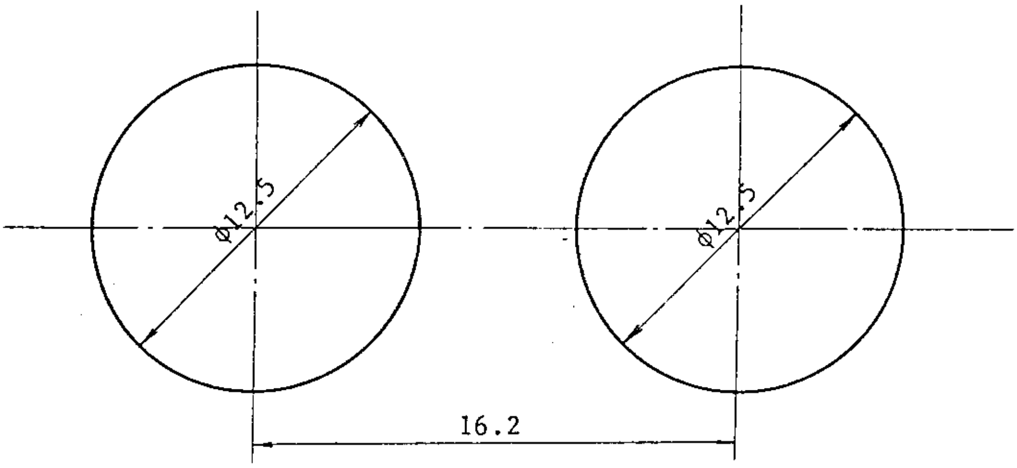
Figure 3.14 is the view factors between fuel pins in a fuel assembly, calculated by the Monte Carlo method. In the figure, the view factors between the fuel pin No.29 and other fuel pins and between the same pin and the channel box of the fuel assembly are shown. The figure in the parentheses is the value calculated, and the figure above it, is its rounded one up to the third decimal number. In the figure, the fuel pins without figures are shadowed entirely by other fuel pins so that the view factors are zero.

The view factors between the fuel pins Nos. 29 and 20, and between the fuel pins Nos. 29 and 21 are shown in Fig. 3.15 as a function of the number of emissions. In the figure, the view vactors obtained by analytical solution and the computer execution time are shown.

The difference between the view factor in the fuel pin No.21 and the value by analytical solution, as its error, is indicated in Fig. 3.16. In the figure, the relation between the error, the standard deviation and the number of emissions is shown. As seen in Figs. 3.15 and 3.16, at a small number of emissions , the view factors with little error are obtainable and the computer execution time is samller than the area integration method.

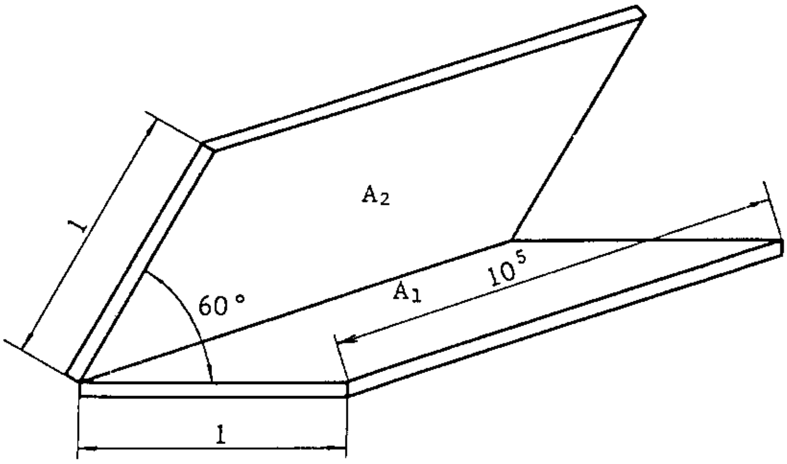
(13) PWR fuel assembly

Figure 3.17 is the view factors between fuel pins in a PWR fuel assembly, calculated by the Monte Carlo method. In the figure, the view factors between the fuel pin No.121 and other fuel pins and between the same pin and the channel box of the fuel assembly are shown. As seen in Fig. 3.17, the view factors of this complex model are easily obtained by one computer run.



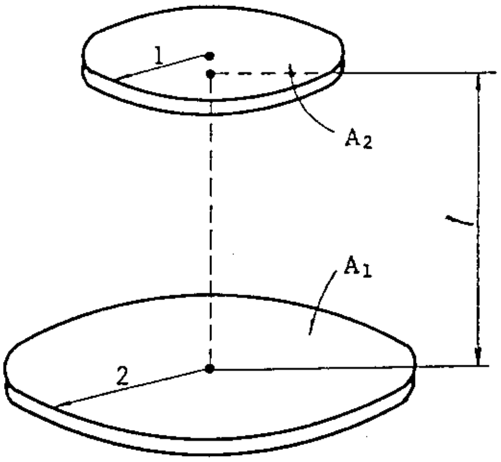
Calculation method	Exact	Cross string	Area integration	Monte Carlo
View factor	0.13043	0.13043	0.13043	0.12890(f.s.d.=0.936%)
Computer execution time (s)	0	0	0.025	1.0

Fig. 3.1 Comparison of calculation methods on view factor and computer execution time in the case of infinitely long parallel cylinders of the same diameter



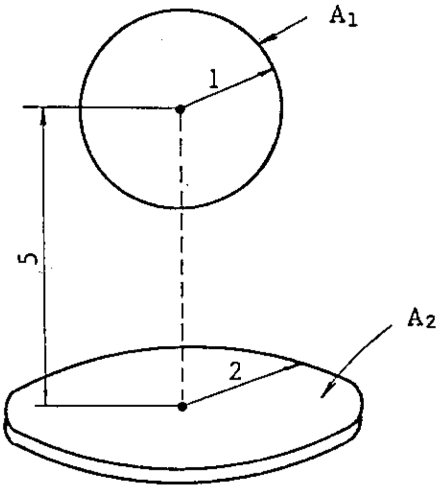
Surface	View factor	
	Monte Carlo	Exact value (2D)
$F_{12}=F_{21}$	0.49989 (f.s.d.=0.341%)	0.5

Fig. 3.2 View factor for two long plates of equal finite width, having one common edge and at an inclined angle 60° to each other



Surface	View factor	
	Monte Carlo	Exact value
F_{21}	0.76227 (f.s.d=0.173%)	0.76393

Fig. 3.3 View factor for parallel circular disks with center along the same normal



Surface	View factor	
	Monte Carlo	Exact value
F_{12}	0.05226 (f.s.d.=0.721%)	0.05279

Fig. 3.4 View factor for sphere to disk, normal to center of disk passes through center of sphere

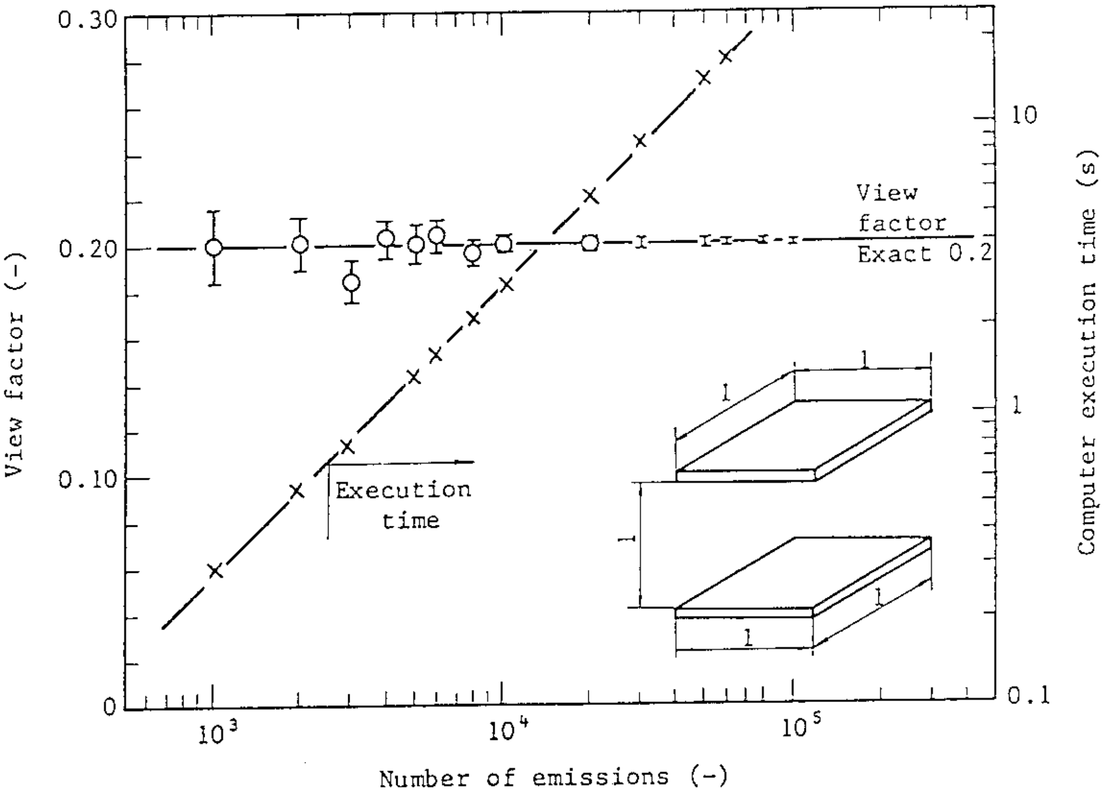


Fig. 3.5 Effect of number of emissions on view factor and computer execution time in the case of directly opposed square plates

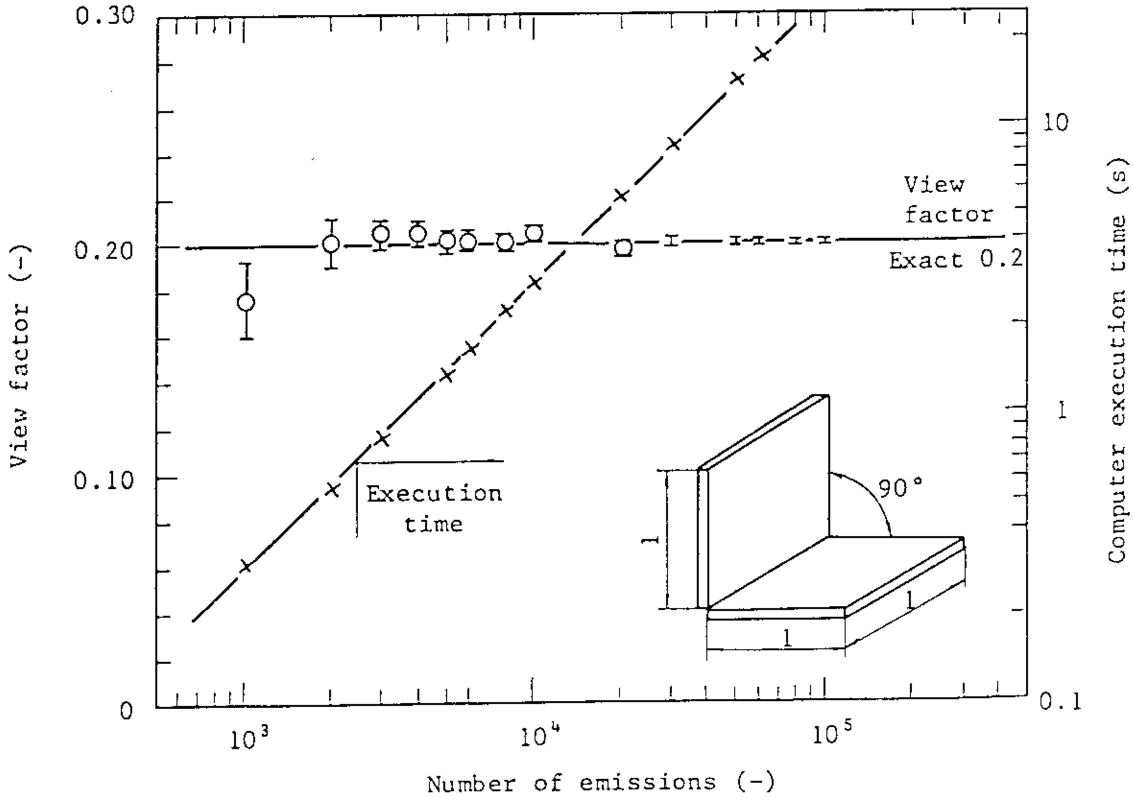
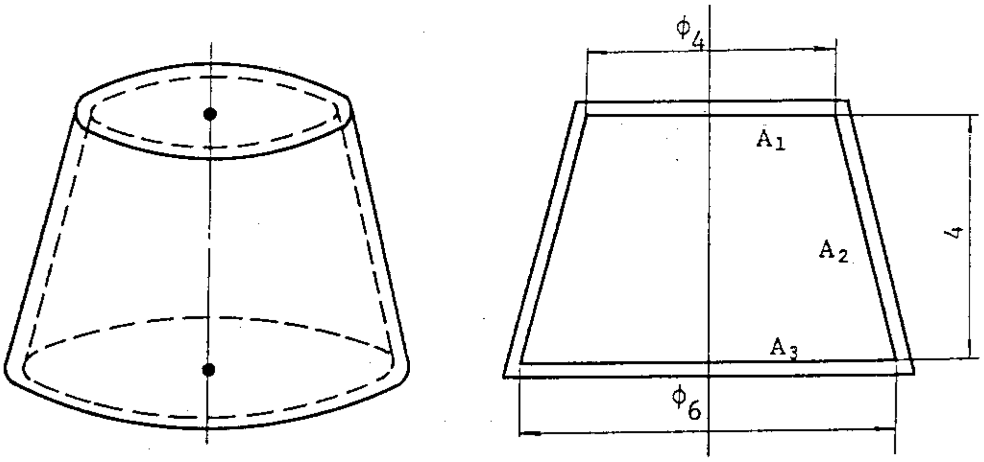
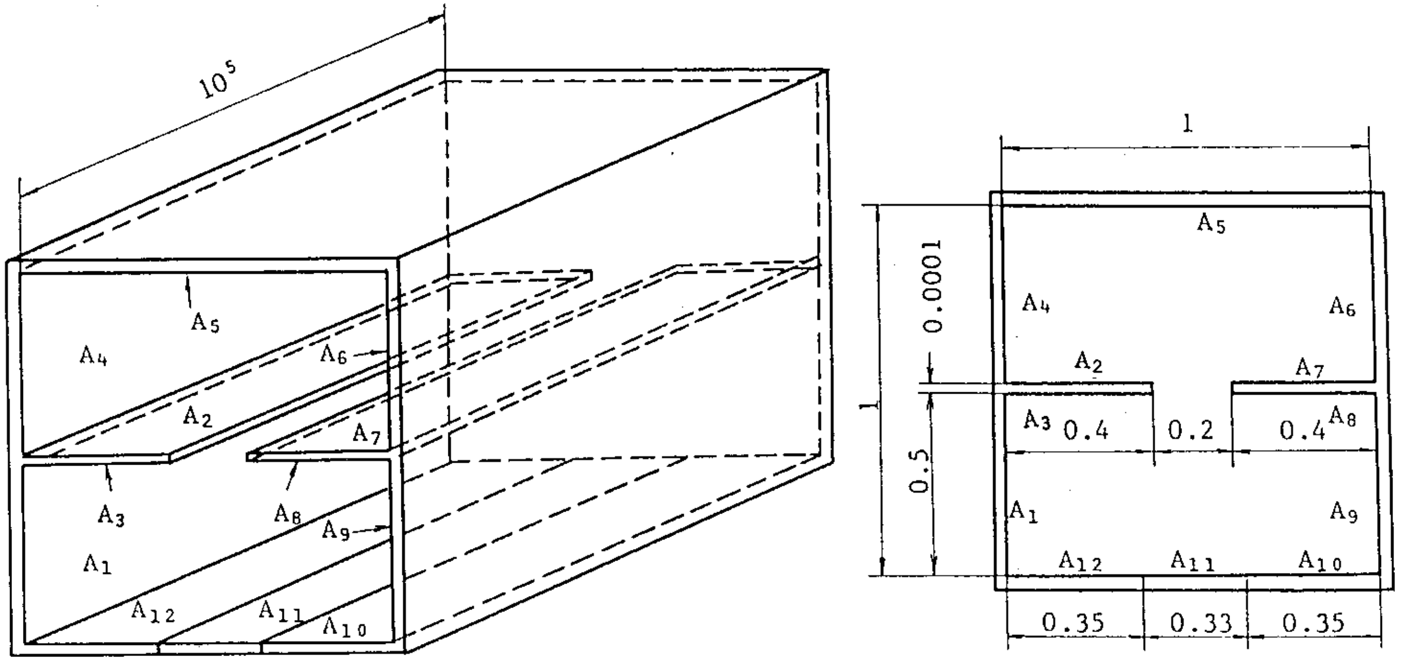


Fig. 3.6 Effect of number of emissions on view factor and computer execution time in the case of prependicular square plates



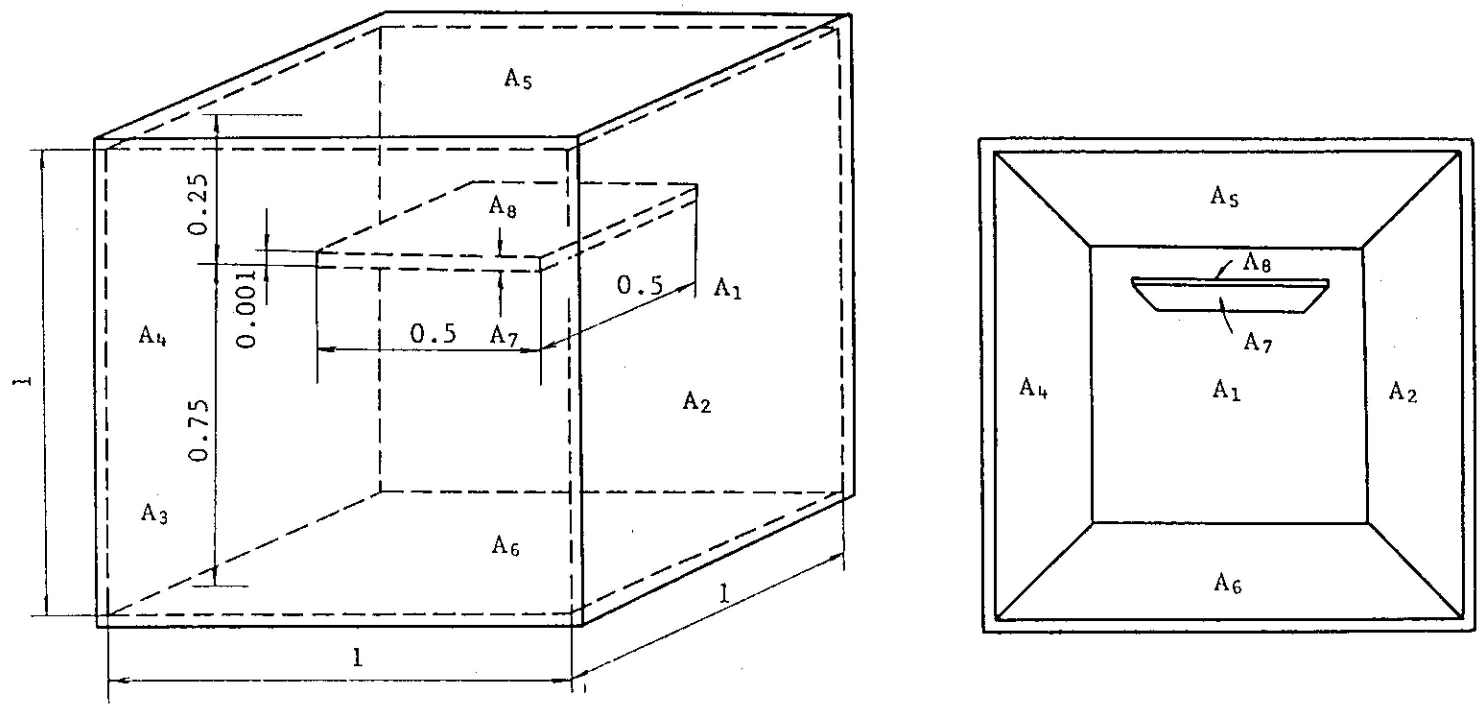
Surface	View factor	
	Monte Carlo	Line integration
F_{12}	0.67772 (f.s.d.=0.282%)	0.6751
F_{13}	0.32226 (f.s.d.=0.593%)	0.3249

Fig. 3.7 View factor for truncated angle cone



Sarface	View factor		Surface	View factor	
	Monte Carlo	Cross string (2D)		Monte Carlo	Cross string (2D)
F_{51}	0.0037	0.0035	F_{59}	0.0035	0.0035
F_{52}	0.2376	0.2387	$F_{5,10}$	0.0388	0.0385
F_{54}	0.1923	0.1910	$F_{5,11}$	0.0575	0.0565
F_{56}	0.1902	0.1910	$F_{5,12}$	0.0386	0.0385
F_{57}	0.2377	0.2387			

Fig. 3.8 View factor for rectangular enclosure cavity with two internal shields



Surface	View factor	
	Monte Carlo	Area integration
F_{51}	0.1716	0.1743
F_{52}	0.1707	0.1743
F_{53}	0.1707	0.1743
F_{54}	0.1702	0.1743
F_{56}	0.1165	0.1283
F_{58}	0.1984	0.1986

Fig. 3.9 View factor for cubic enclosure cavity with an internal shield

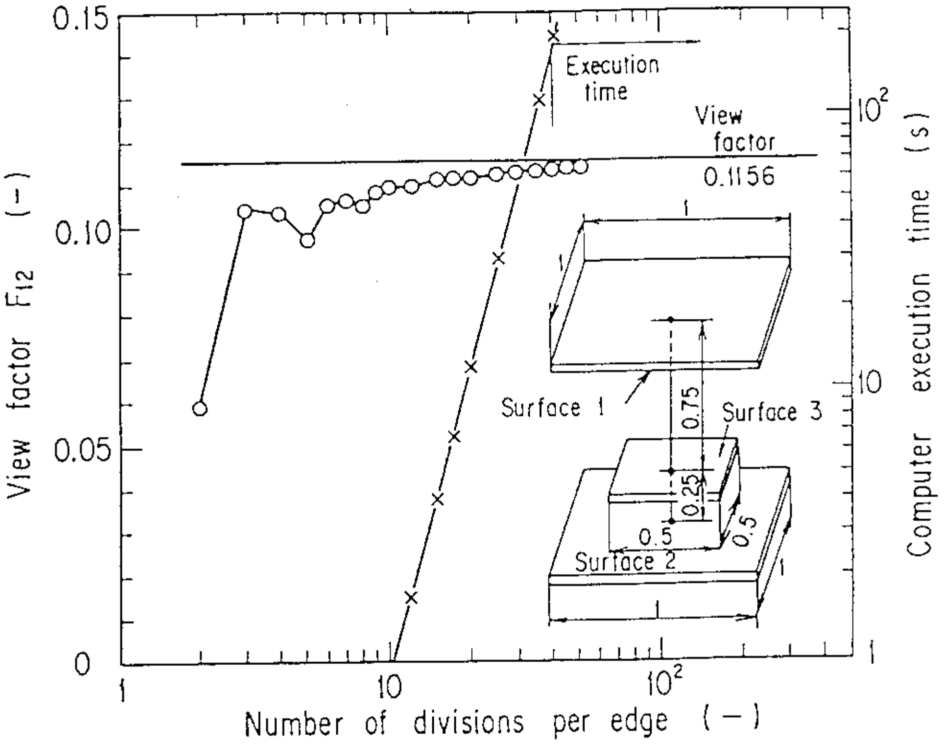


Fig. 3.10 Effect of number of divisions per edge on view factor and computer execution time in the case of surface 3 shadows the view between surfaces 1 and 2 (area integration method)

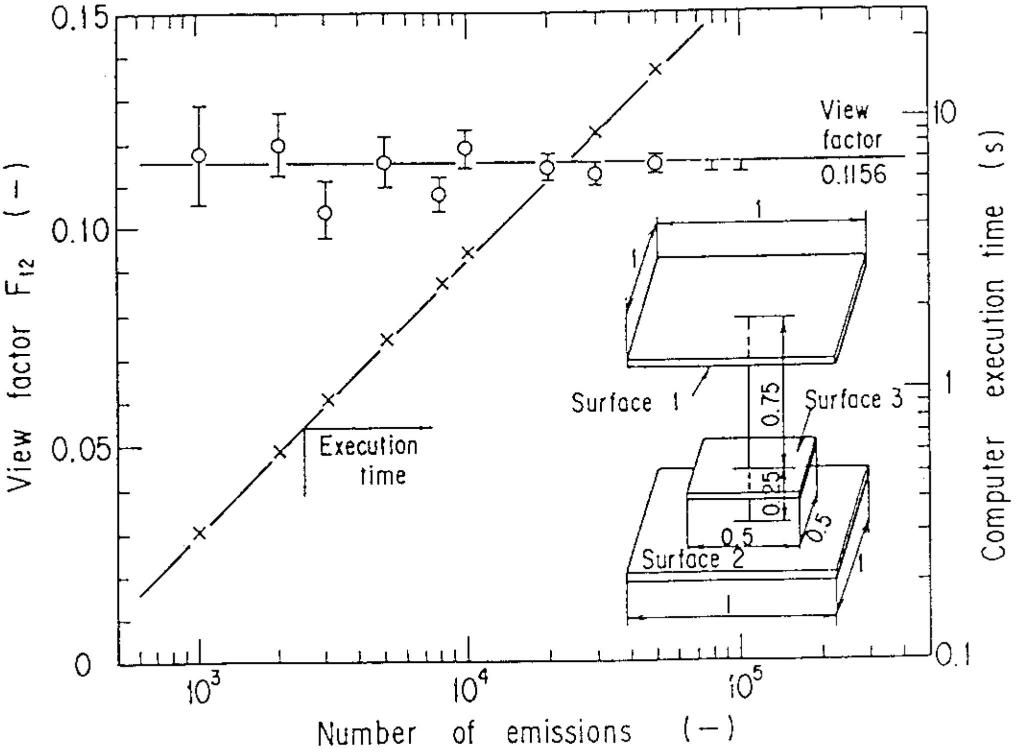


Fig. 3.11 Effect of number of emissions on view factor and computer execution time in the case of surface 3 shadows the view between surfaces 1 and 2 (Monte Carlo method)

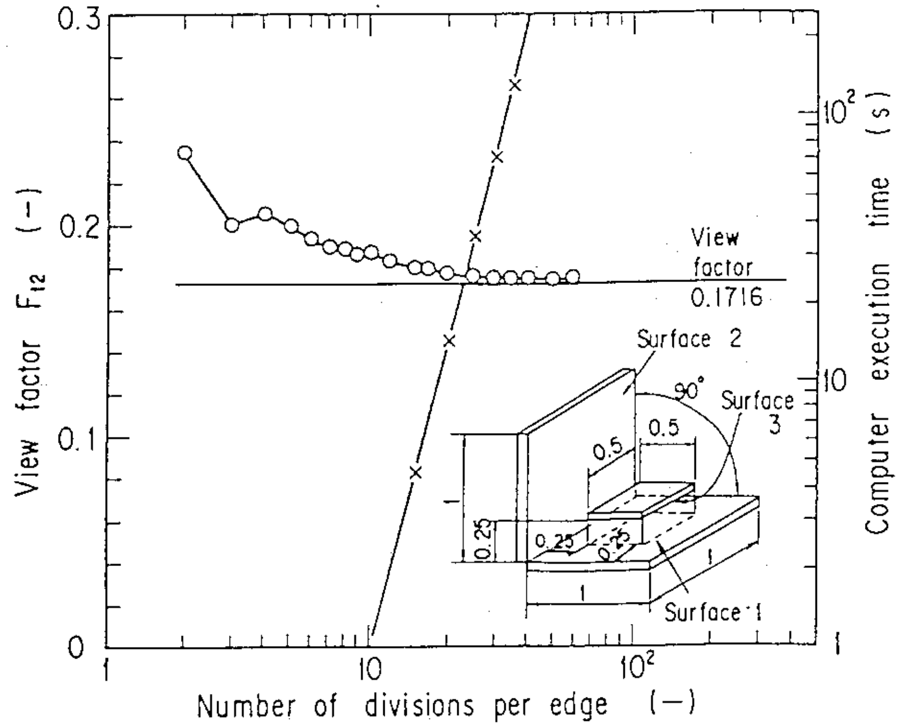


Fig. 3.12 Effect of number of divisions per edge on view factor and computer execution time in the case of surface 3 shadows the view between perpendicular plate surfaces 1 and 2 (area integration method)

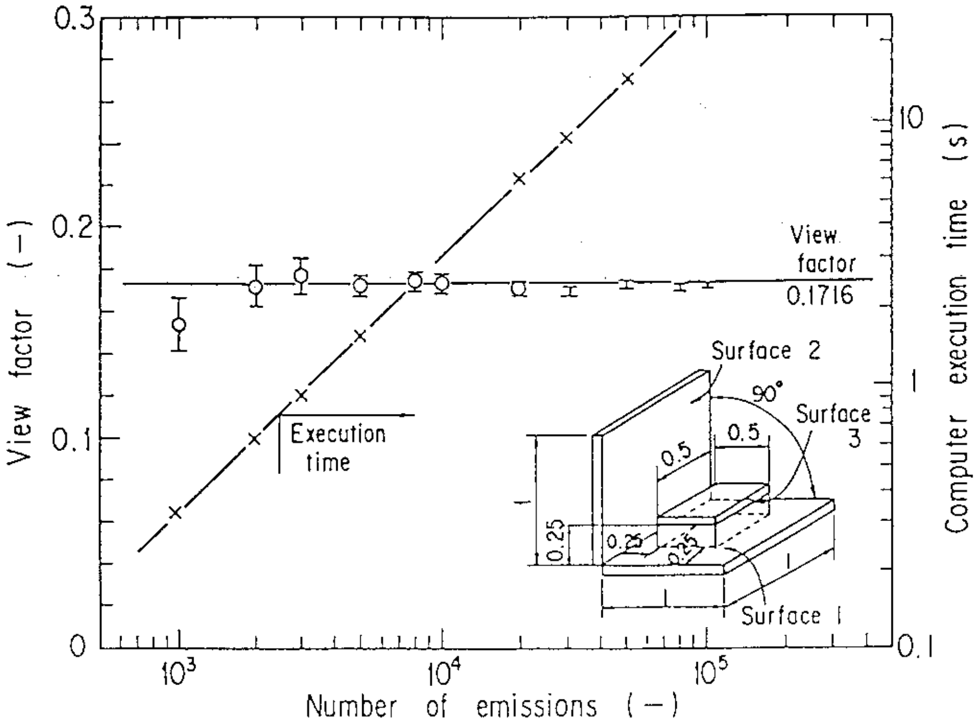


Fig. 3.13 Effect of number of emissions on view factor and computer time in the case of surface 3 shadows the view between perpendicular plate sarfaces 1 and 2 (Monte Carlo method)

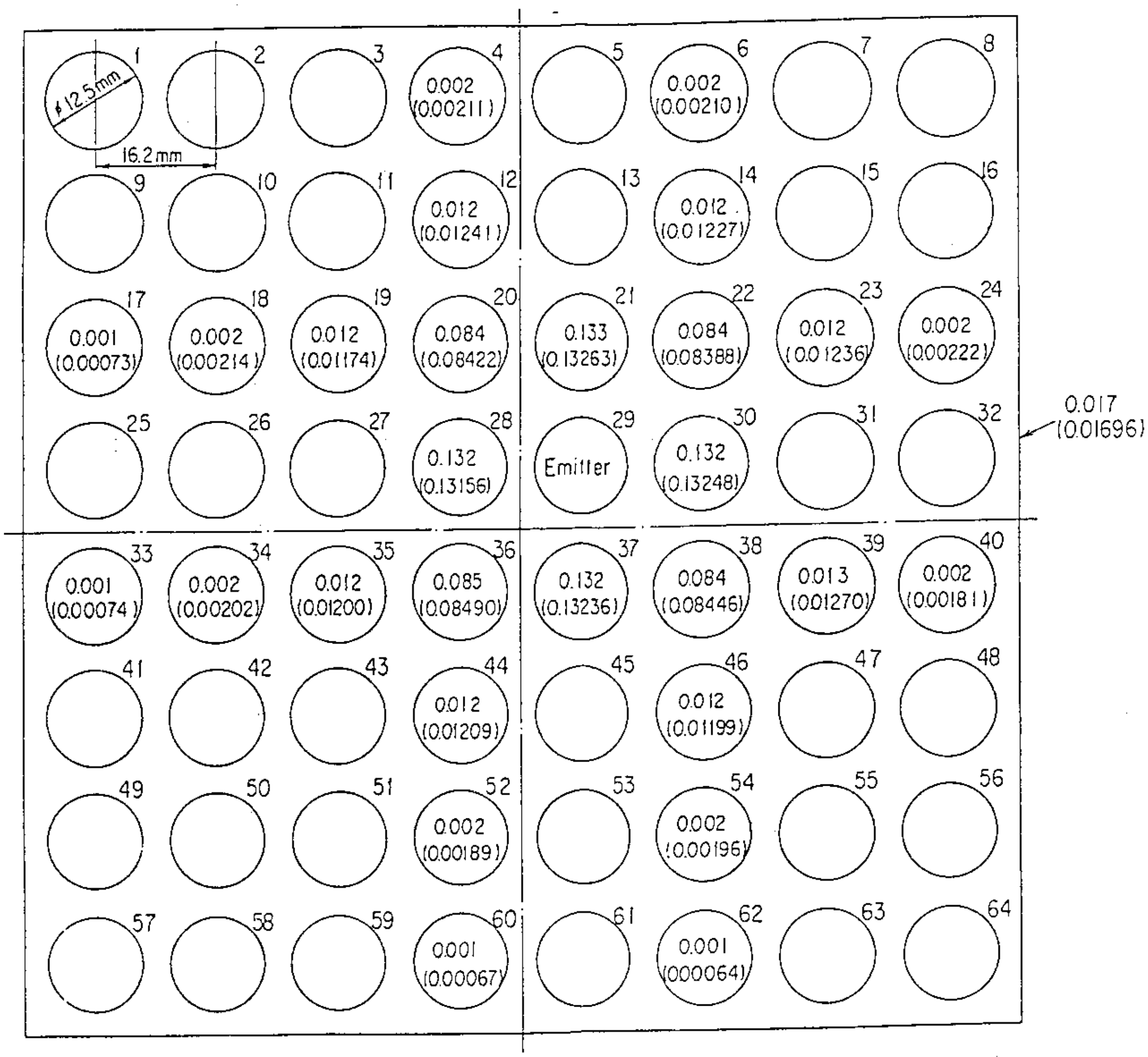


Fig. 3.14 View factor of BWR (8×8) fuel assembly

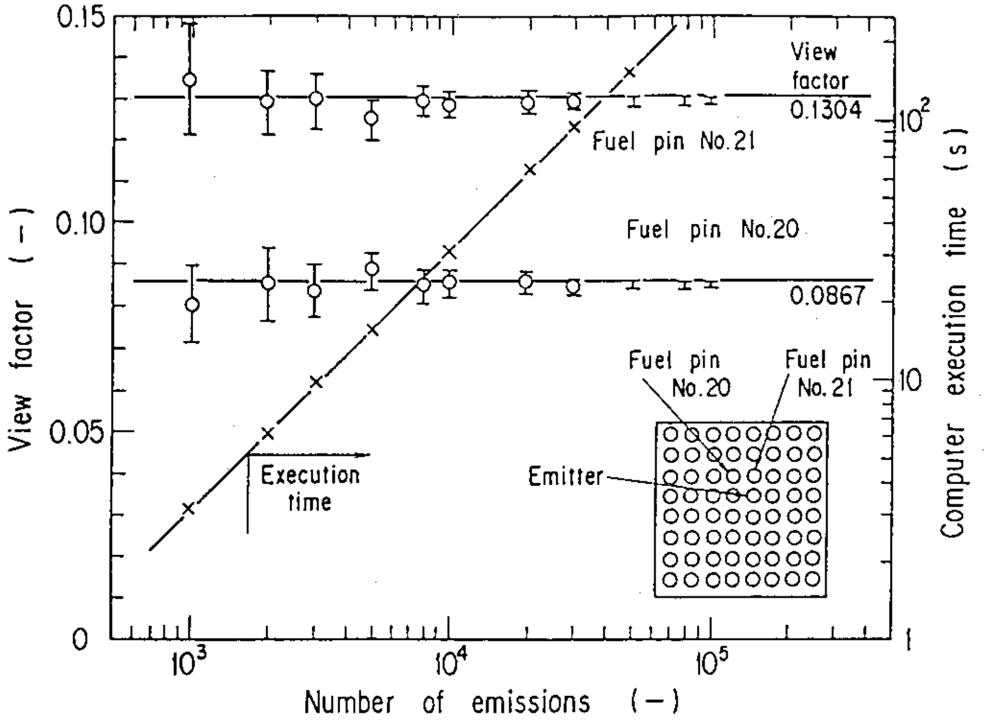


Fig. 3.15　Effect of number of emissions on view factor and computer execution time in the case of BWR (8×8) fuel assembly (Monte Carlo method)

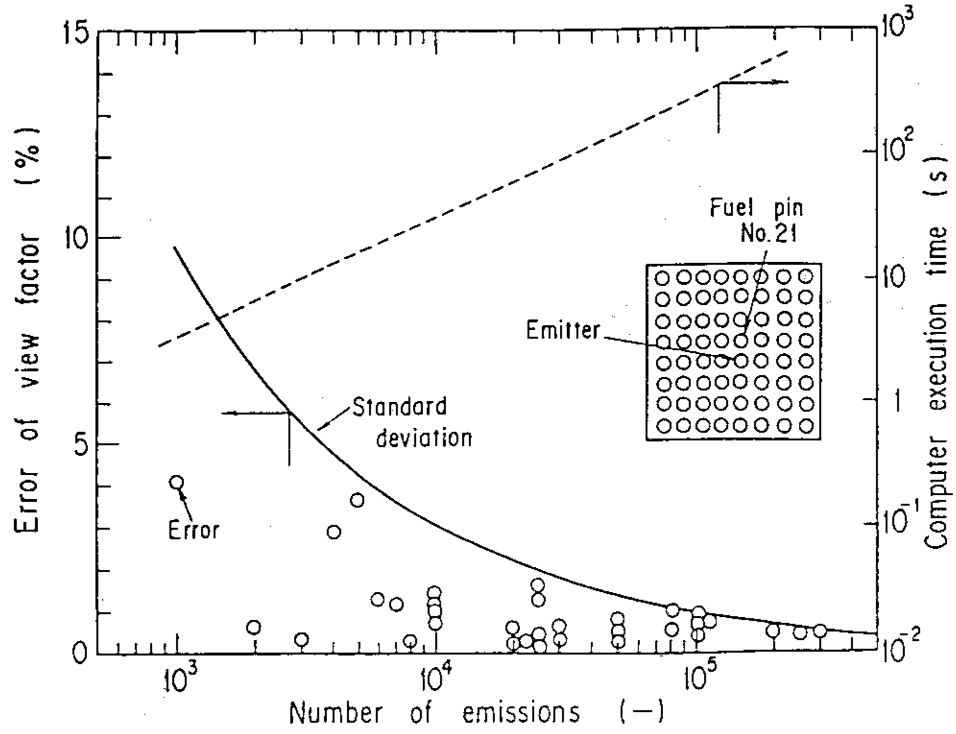


Fig. 3.16　Effect of number of emissions on error and computer execution time in the case of BWR (8×8) fuel assembly (Monte Carlo method)

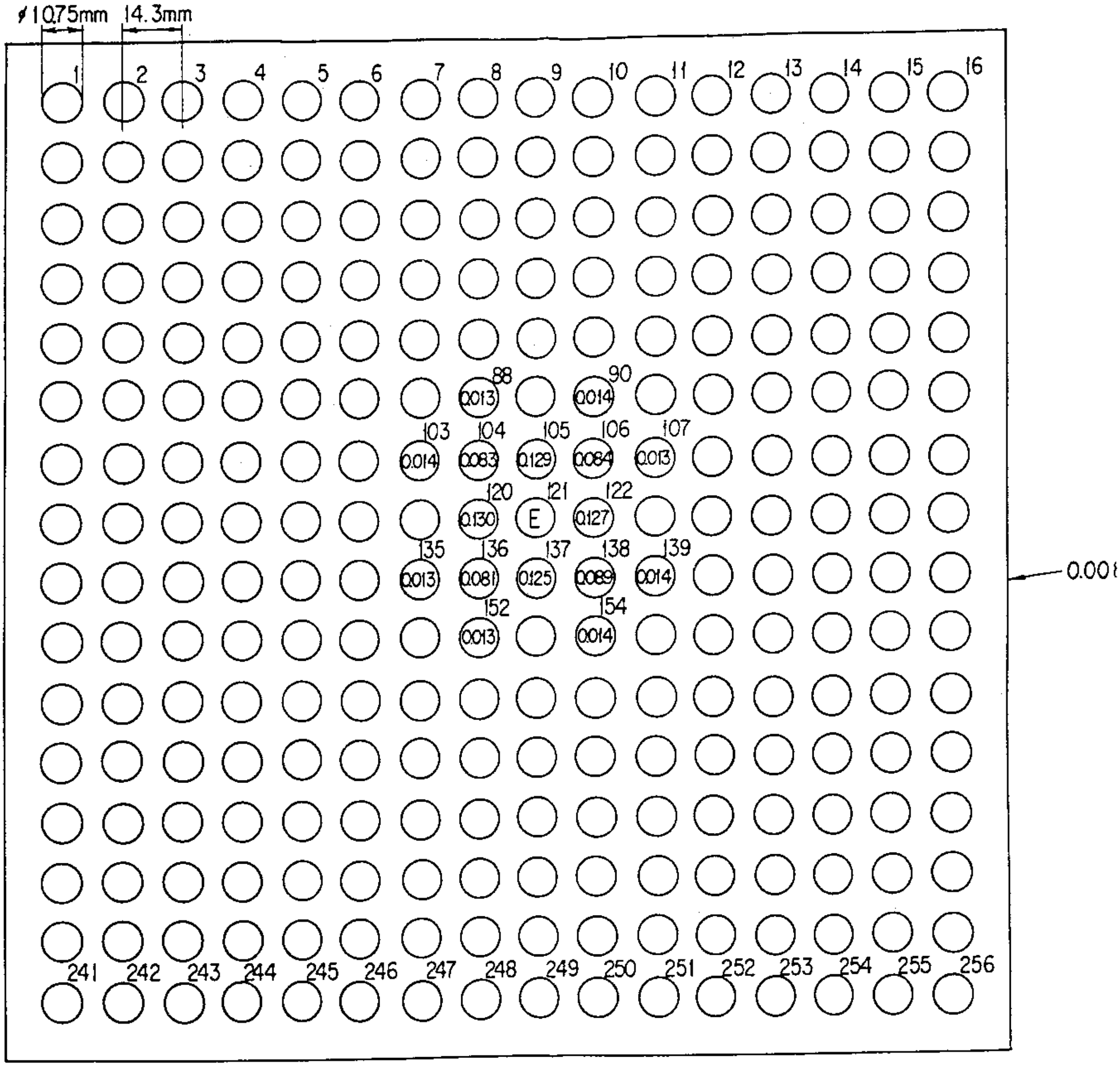


Fig. 3.17 View factor of PWR (16×16) fuel assembly

4. Computer program

The computer program MCVIEW2 performs view factor calculation for three dimensional geometries using the Monte Carlo method.

4.1 Program description

The computer program MCVIEW2, to some extent, has its origins with the work of M. B. Emmett and his computer program MORSE−CG(14) which is the radiation shielding transport program using the Monte Carlo method.

4.2 Description of input data

This section describes the input data required by MCVIEW2. The input data consist of the job description, control data, combinatorial geometry data, region specification data, number of bodies, reflecting ratio and definition of emission body data.

The input data for MCVIEW2 are similar to MORSE−CG. All input data are the fixed format type data. The input instructions are simple and easy to follow. The input data forms are presented in Table 4.1.

Data set No.1 : Job description.
Data set No.2 : Control data.
Data set No.3 : Combinatorial geometry data.
Data set No.4 : Region specification data.
Data set No.5 : Total number of bodies defined the reflecting ratio.
Data set No.6 : Reflecting ratio of bodies.
Data set No.7 : Definition of emission body.

4.3 Combinatorial geometry

4.3.1 Body type

Combinatorial geometry(CG) describes general three dimensional material configurations by considering unions, differences and intersections of simple bodies such as sphere, boxes, cylinders, etc. In effect, the geometric description subdivides the problem space into unique zones. Each zone is the results of combining one or more of following geometric bodies (see Table 4.2 and Fig. 4.1 through 4.10).

(1) BOX (BOX).
(2) Rectangular ParallelPiped (RPP).
(3) SPHere (SPH).
(4) Right Circular Cylinder (RCC).
(5) Right Elliptical Cylinder (REC).
(6) Truncated Right angle Cone (TRC).
(7) ELLipsoid (ELL).
(8) Right Angle Wedge (RAW).
(9) ARBitrary polyhedron of 4, 5 or 6 sides (ARB).
(10)Right Circular cylinder Grid generator (RCG).

Body types (2) through (9) may be arbitrary oriented with respect to the x, y and z coordinates axes used to determine the space. Body type (1), a special body type described below, must have sides which are parallel to the coordinate axes.

4.3.2 Description of body type

The information required to specify each type of body is as follows:

(1) Box (BOX)

Specify the vertex V at one of the corners by giving its x, y and z coordinates. Specify a set of three mutually perpendicular vectors ai representing the height, width and length of the box, respectively. That is, the x, y and z components of the height, width and length vectors are given. Definition of geometrical data is shown in Fig. 4.1.

(2) Rectangular parallelpiped (RPP)

Specify the minimum and maximum values of the x, y and z coordinates which bound the parallelpiped. Definition of geometrical data is shown in Fig. 4.2.

(3) Sphere (SPH)

Specify the vertex V at the center and a scalar R, denoting the radius. Definition of geometrical data is shown in Fig. 4.3.

(4) Right circular cylinder (RCC)

Specify the vertex V at the center of one base, a height vector H, expressed in terms of its x, y and z components and a scalar R, denoting the radius. Definition of geometrical data is shown in Fig. 4.4.

(5) Right elliptical cylinder (REC)

Specify coordinates of the center of the base, a height vector and two vectors in the plane of the base defining the major and minor axes. Definition of geometrical data is shown in Fig. 4.5.

(6) Truncated right angle cone (TRC)

Specify the vertex V at the center of lower base, a height vector H, expressed in terms of its x, y and z components and two scalars R1 and R2, denoting the radii of the lower and upper bases. Definition of geometrical data is shown in Fig. 4.6.

(7) Ellipsoid (ELL)

Specify two vertices V1 and V2, denoting the coordinates of foci and a scalar R denoting the length of the major axis. Definition of geometrical data is shown in Fig. 4.7.

(8) Right angle wedge (RAW)

Specify the vertex V at one of the corners by giving its x, y and z coordinates. Specify a set of three mutually perpendicular vectors ai with a1 and a2 describing the two legs of the right triangle of wedge. That is, the x, y and z components of the height, width and length vectors are given. Definition of geometrical data is shown in Fig. 4.8.

(9) Arbitrary polyhedron (ARB)

Assign an index (1 to 8) to each vertex. For each vertex, given the x, y and z coordinates. Each of the six faces are then described by a four-digit number giving the indices of the four vertex points in that surface. For each face , these indices must be entered in either clockwise or counterclockwise order. Definition of geometrical data is shown in Fig. 4.9.

(10)Right circular cylinder grid generator (RCG)

The grid generator for RCC data is provides in MCVIEW2. The grid genrator RCG data are shown in Fig. 4.10.

Table 4.1 Input data for MCVIEW2

Columns	Format	Variables	Descriptions
Data set No.1 : Job description.			
1 - 2	2X	—	Blank.
3 - 5	A3	—	'TIT'.
6 - 80	75A1	TITLE	Job description.
Data set No.2 : Control data(1).			
1 - 2	2X	—	Blank.
3 - 5	A3	—	'CTL'.
6 - 10	5X	—	Blank.
11 - 15	I5	MEDIA	Number of bodies.
16 - 20	I5	NSTRT	Maximum number of particles per batch.
21 - 25	I5	NTIS	Number of batches.
Data set No.3 : Combinatorial geometry data(1). One set of CG data is required for each body and for the END data(see Table 4.2). Leave column between '---' blank on all continuation data.			
1 - 2	2X	—	Blank.
3 - 5	A3	ITYPE	Geometry type. 'BOX' : Box . 'RPP' : Right parallelepiped. 'SPH' : Sphere. 'RCC' : Right circular cylinder. 'REC' : Right elliptical cylinder. 'TRC' : Truncated right cone. 'ELL' : Ellipsoid. 'WED' or 'RAW' : Right angle wedge. 'ARB' : Arbitrary polyhedron. 'RCG' : Grid generator. 'END' : Termination of body input data. ' ' : Continuation data.
6 - 10	I5	IALP	Body number assigned by user(all input body

Table 4.1 (Continued)

Columns	Format	Variables	Descriptions
			numbers must form a sequence set beginning at 1). If left blank none of the numbers. Leave blank for continuation data.
11 - 20	F10.0	FPD(1)	Real data requried for the given body as shown in Table 4.2 and Fig. 4.1 through 4.10.
21 - 30	F10.0	FPD(2)	. . . . .
31 - 40	F10.0	FPD(3)	. . . . .
41 - 50	F10.0	FPD(4)	. . . . .
51 - 60	F10.0	FPD(5)	. . . . .
61 - 70	F10.0	FPD(6)	same as above.
Data set No.3A : Combinatorial geometry data(2).			
1 - 10	10X	—	Blank.
11 - 20	F10.0	FPD(7)	same as above.
21 - 30	F10.0	FPD(8)	. . . . .
31 - 40	F10.0	FPD(9)	. . . . .
41 - 50	F10.0	FPD(10)	. . . . .
51 - 60	F10.0	FPD(11)	. . . . .
61 - 70	F10.0	FPD(12)	same as above. Repeat data set No.3A.
Data set No.4 : Region specification data. One set of data required for each region, with input region numbers being assigned sequentially.			
1 - 2	2X	—	Blank.
3 - 5	A3	IALP	'RG1' or '001' : Region 1. 'RG2' or '002' : Region 2. 'RG3' or '003' : Region 3. 'RG4' or '004' : Region 4. 'RG5' or '005' : Region 5.

Table 4.1 (Continued)

Columns	Format	Variables	Descriptions
			'RG6' or '006' : Region 6. . . . . . 'END' : Data terminate. ' ' : Continuation data. Specifies region data type or END to terminate reading of region data. IALP must be a non-blank for the first data of each set of data defining an input region. If IALP is blank,this data treated as a continuation of the previous region data. IALP=END denotes the end of region description.
6 - 10	I5	NNN	Number of data of JTY(I)(maximum data is less equal nine).
11 - 15	I5	JTY(1)	Body number with the (+) or (-) sign as required for the region description.
16 - 20	I5	JTY(2)	Same as above.
21 - 25	I5	JTY(3)	. . . . .
26 - 30	I5	JTY(4)	. . . . .
31 - 35	I5	JTY(5)	. . . . .
36 - 40	I5	JTY(6)	. . . . .
41 - 45	I5	JTY(7)	. . . . .
46 - 50	I5	JTY(8)	. . . . .
51 - 55	I5	JTY(9)	Same as above.
Data set No.5 ; Number of bodies defined the reflecting ratio(1).			
1 - 2	2X	—	Blank.
3 - 5	A3	—	'REF'.
6 - 10	5X	—	Blank.
Data set No.6 ; Number of bodies defined the reflecting ratio(1).			
1 - 10	10X	—	Blank.

Table 4.1 (Continued)

Columns	Format	Variables	Descriptions
11 - 15	I5	MGALB(1)	Number of body No.1.
16 - 20	F5.0	RALB(1)	Reflecting ratio of body No.1.
21 - 25	I5	MGALB(2)	Number of body No.2.
26 - 30	F5.0	RALB(2)	Reflecting ratio of body No.2.
31 - 35	I5	MGALB(3)	Number of body No.3.
36 - 40	F5.0	RALB(3)	Reflecting ratio of body No.3.
41 - 45	I5	MGALB(4)	Number of body No.4.
46 - 50	F5.0	RALB(4)	Reflecting ratio of body No.4.
51 - 55	I5	MGALB(5)	Number of body No.5.
56 - 60	F5.0	RALB(5)	Reflecting ratio of body No.5.
61 - 65	I5	MGALB(6)	Number of body No.6.
66 - 70	F5.0	RALB(6)	Reflecting ratio of body No.6.
			Repeat data set No.6.
Data set No.7 ; Definition of emission body(1).			
1 - 2	2X	—	Blank.
3 - 5	A3	ITYPE	Body type of emission. 'BOX' : Box . 'RPP' : Right parallelepiped. 'SPH' : Sphere. 'RCC' : Right circular cylinder. 'REC' : Right elliptical cylinder. 'TRC' : Truncated right cone. 'ELL' : Ellipsoid. 'RAW' : Right angle wedge. 'END' : Termination of body input data. ' ' : Continuation data.
6 - 10	I5	ISUF	Definition of emission surface(see Fig. 4.11 through 4.18).
11 - 15	I5	IOPT	Option for weight of emitted particles. IOPT=0 : cosine.

Table 4.1 (Continued)

Columns	Format	Variables	Descriptions
			IOPT=1 : 1.
15 - 20	F10.0	NV	Number of geometrical data.
21 - 30	F10.0	VECTOR(1)	Geometrical data for body(see Chapter 4.3.2 and Fig.4.11 through Fig.4.18).
31 - 40	F10.0	VECTOR(2)	Same as above.
41 - 50	F10.0	VECTOR(3)	. . . . .
51 - 60	F10.0	VECTOR(4)	. . . . .
61 - 70	F10.0	VECTOR(5)	Same as above.
Data set No.7A ; Definition of emission body(2).			
1 - 10	10X	—	Blank.
11 - 20	F10.0	VECTOR(6)	Same as above.
21 - 30	F10.0	VECTOR(7)	. . . . .
31 - 40	F10.0	VECTOR(8)	. . . . .
41 - 50	F10.0	VECTOR(9)	. . . . .
51 - 60	F10.0	VECTOR(10)	Same as above. Repeat data set No.7A.

Table 4.2 Input required for each body type

Body type	ITYPE	IALP	Real data defined paticular body					
Box	BOX	IALP is assigned by the user or by the program if left blank.	Vx	Vy	Vz	H1x	H1y	H1z
			H2x	H2y	H2z	H3x	H3y	H3z
Right parallelepiped	RPP		Xmin	Xmax	Ymin	Ymax	Zmin	Zmax
Sphere	SPH		Vx	Vy	Vz	R	--	--
Right circular cylinder	RCC		Vx	Vy	Vz	Hx	Hy	Hz
			R	--	--	--	--	--
Right elliptical cylinder	REC		Vx	Vy	Vz	Hx	Hy	Hz
			R1x	R1y	R1z	R2x	R2y	R2z
Truncated right cone	TRC		Vx	Vy	Vz	Hx	Hy	Hz
Ellipsoid	ELL		V1x	V1y	V1z	V2x	V2y	V2z
			R	--	--	--	--	--
Right angle wedge	RAW or WED		Vx	Vy	Vz	H1x	H1y	H1z
			H2x	H2y	H2z	H3x	H3y	H3z
Arbitrary polyhedron	ARB		V1x	V1y	V1z	V2x	V2y	V2z
			V3x	V3y	V3z	V4x	V4y	V4z
			V5x	V5y	V5z	V6x	V6y	V6z
			V7x	V7y	V7z	V8x	V8y	V8z
Grid generator	RCG		Vx	Vy	Vz	Hx	Hy	Hz
			R	DX	NX	DY	NY	--
Termination of body	END							

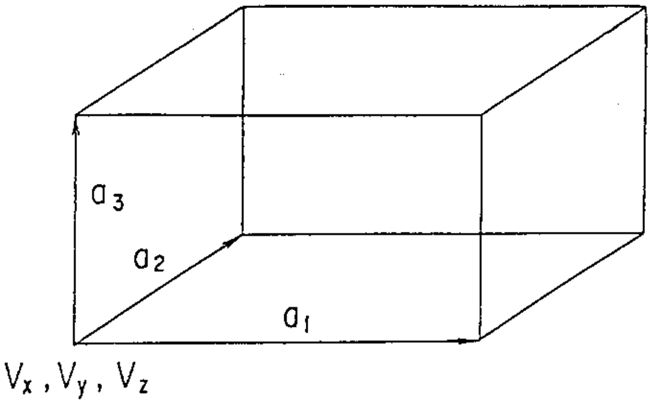


Fig. 4.1 Box (BOX)

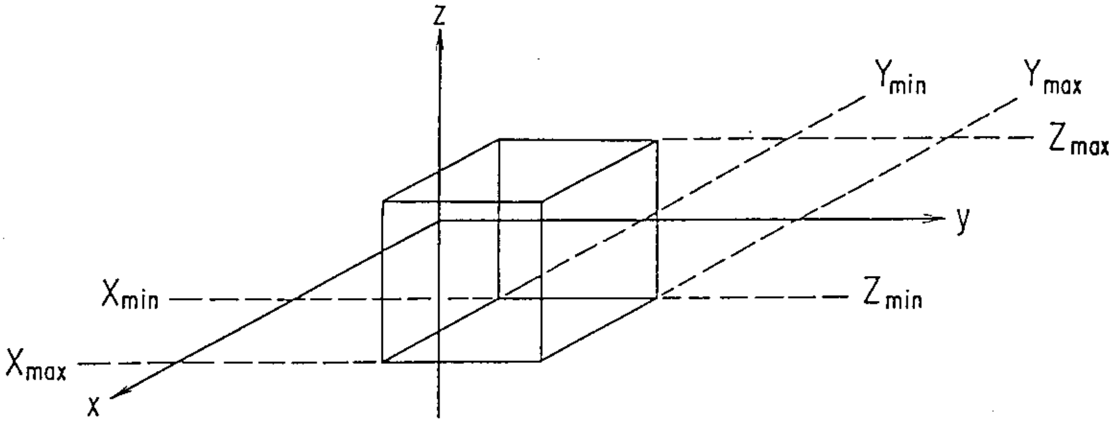


Fig. 4.2 Rectangular Parallelepiped (RPP)

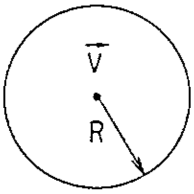


Fig. 4.3 Sphere (SPH) .

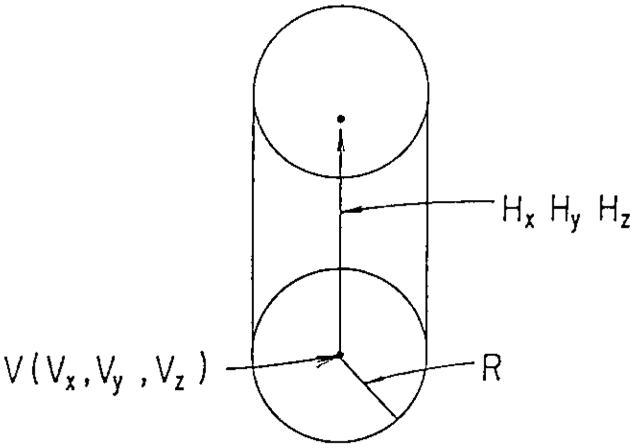


Fig. 4.4 Right Circular Cylinder (RCC) .

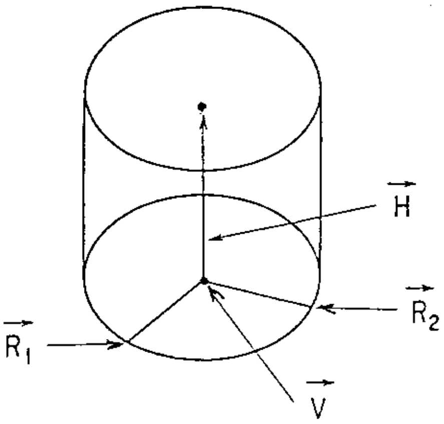


Fig. 4.5 Right Elliptical Cylinder (REC) .

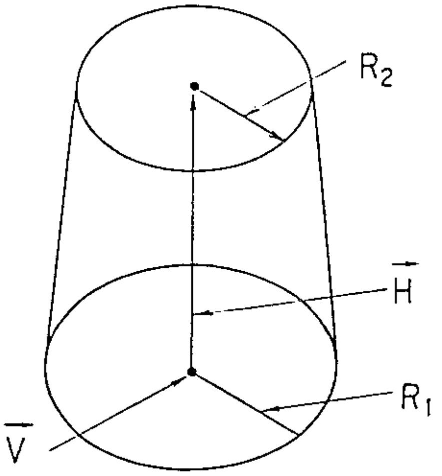


Fig. 4.6 Truncated Right Angle Cone (TRC) .

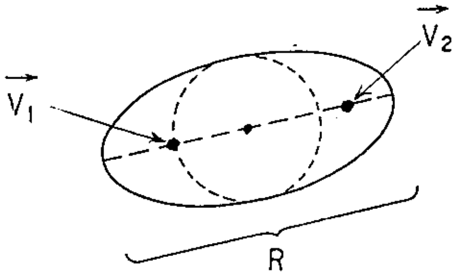


Fig. 4.7 Ellipsoid (ELL) .

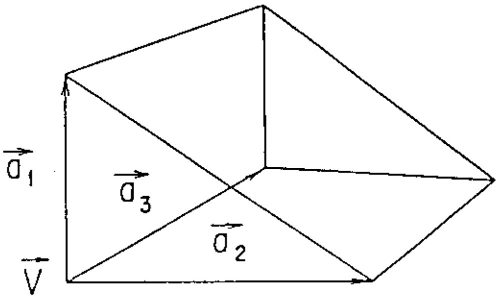


Fig. 4.8 Right Angle Wedge (RAW) .

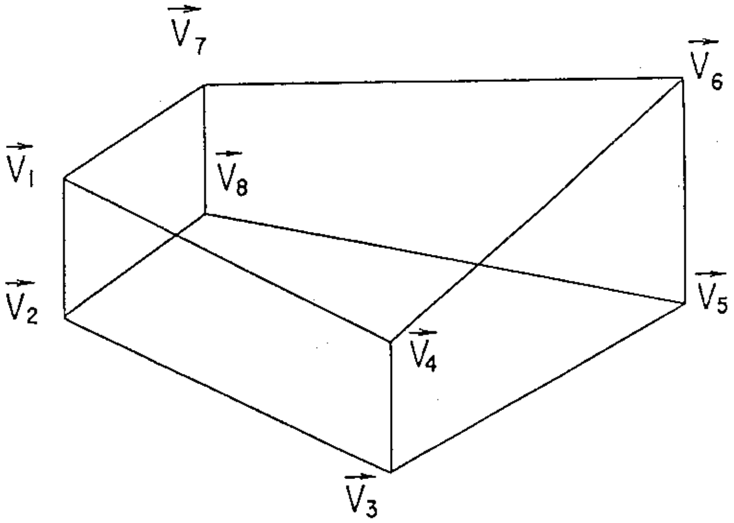


Fig. 4.9 Arbitrary Polyhedron (ARB) .

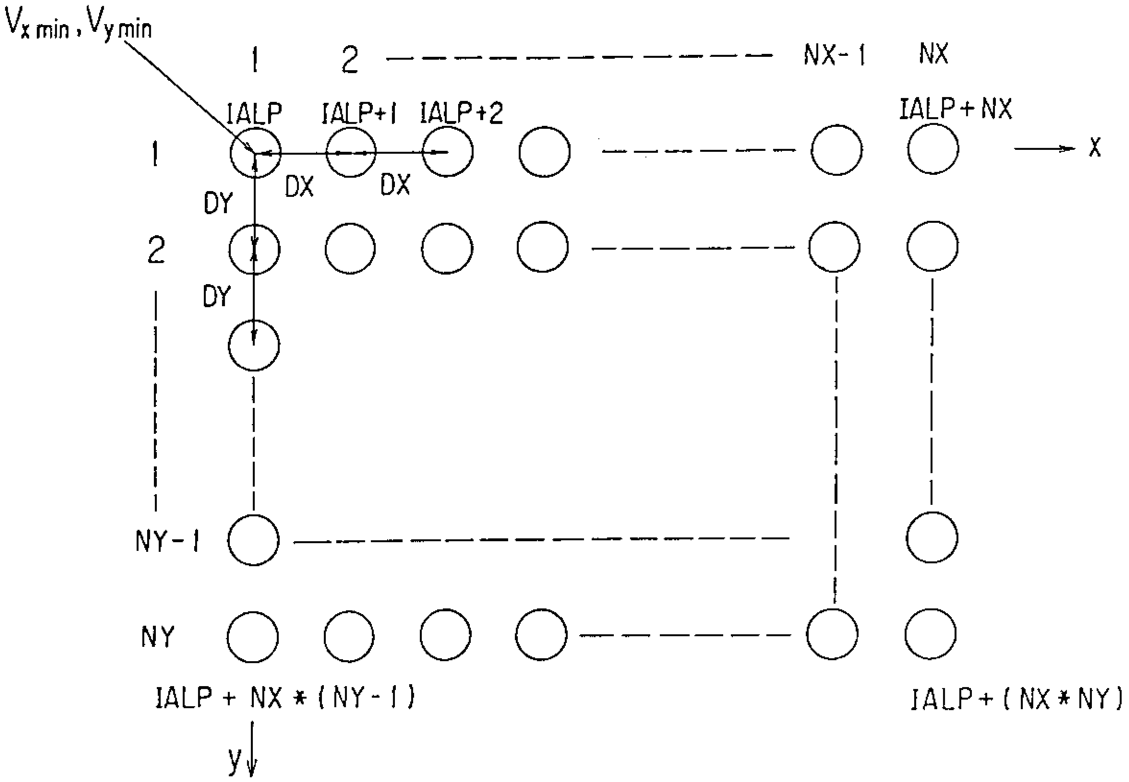


Fig. 4.10 Description of RCG grid notation

4.4 Emission body

4.4.1 Combinatorial geometry

Definition of emission bodies is same as MORSE-CG combinatorial geometries in addition to definition of emission surfaces. Definitions of emission bodies and surfaces are presented from Fig. 4.11 to 4.18. Eight emission bodies are provided as follows:

(1) BOX (BOX).
(2) Rectangular ParallelPiped (RPP).
(3) SPHere (SPH).
(4) Right Circular Cylinder (RCC).
(5) Right Elliptical Cylinder (REC).
(6) Truncated Right angle Cone (TRC).
(7) ELLipsoid (ELL).
(8) Right Angle Wedge (RAW).

4.4.2 Description of body type

The information required to specify each type of body is as follows:

(1) Box (BOX)

Specify the vertex V at one of the corners by giving its x, y and z coordinates. Specify a set of three mutually perpendicular vectors Hi representing the height, width and length of the box, respectively. That is, the x, y and z components of the height, width and length vectors are given. Definition of geometrical data and emission surface data are shown in Fig. 4.11.

(2) Rectangular parallelpiped (RPP)

Specify the minimum and maximum values of the x, y and z coordinates which bound the parallelpiped. Definition of geometrical data and emission surface data are shown in Fig. 4.12.

(3) Sphere (SPH)

Specify the vertex V at the center and a scalar R, denoting the radius. Definition of geometrical data and emission surface data are shown in Fig. 4.13.

(4) Right circular cylinder (RCC)

Specify the vertex V at the center of one base, a height vector H, expressed in terms of its x, y and z components and a scalar R, denoting the radius. Definition of geometrical data and emission surfaces data are shown in Fig. 4.14.

(5) Right elliptical cylinder (REC)

Specify coordinates of the center of the base, a height vector and two vectors in the plane of the base defining the major and minor axes. Definition of geometrical data and emission surface data are shown in Fig. 4.15.

(6) Truncated right angle cone (TRC)

Specify the vertex V at the center of lower base, a height vector H, expressed in terms of its x, y and z components and two scalars R1 and R2, denoting the radii of the lower and upper bases. Definition of geometrical data and emission surface data are shown in Fig. 4.16.

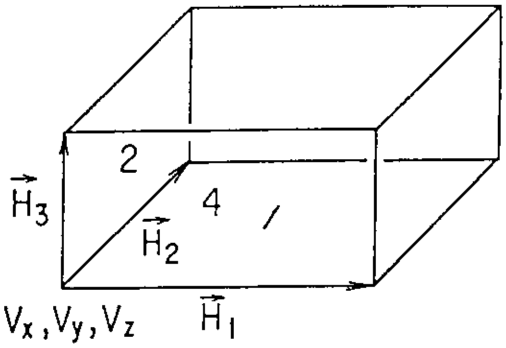
(7) Ellipsoid (ELL)

Specify two vertices V1 and V2, denoting the coordinates of foci and a scalar R denoting the length of the major axis. Definition of geometrical data and emission surface data shown in Fig. 4.17.

(8) Right angle wedge (RAW)

Specify the vertex V at one of the corners by giving its x, y and z coordinates. Specify a set of three mutually perpendicular vectors ai with a1 and a2 describing the two legs of the right triangle of wedge. That is, the x, y and z components of the height, width and length vectors are given. Definition of geometrical data and emission surface data are shown in Fig. 4.18.

BOX V_x , V_y , V_z , H_{1x} , H_{1y} , H_{1z} ,
H_{2x} , H_{2y} , H_{2z} , H_{3x} , H_{3y} , H_{3z}



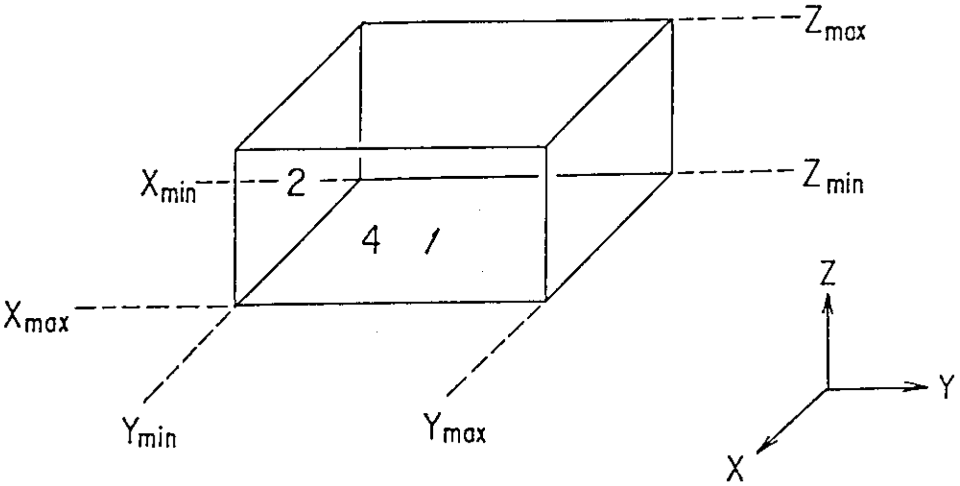
$\vec{H}_1 = (H_{1x} , H_{1y}, H_{1z})$
$\vec{H}_2 = (H_{2x} , H_{2y}, H_{2z})$
$\vec{H}_3 = (H_{3x} , H_{3y}, H_{3z})$

Definition of emitted surface

ISUF	Emitted surface
1	Surface of $\vec{H}_1 - \vec{H}_2$
2	Surface of $\vec{H}_2 - \vec{H}_3$
4	Surface of $\vec{H}_3 - \vec{H}_1$
8	Opposite side of 1
16	Opposite side of 2
32	Opposite side of 4
63	All surface

Fig. 4.11 Emitter body of box (BOX) type

RPP X_{min} , X_{max} , Y_{min} , Y_{max} , Z_{min} , Z_{max}

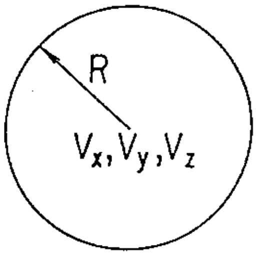


Definition of emitted surface

ISUF	Emitted surface
1	X - Y surface ($Z = Z_{min}$)
2	Z - X surface ($Y = Y_{min}$)
4	Y - Z surface ($X = X_{min}$)
8	Opposite side of 1
16	Opposite side of 2
32	Opposite side of 4
63	All surface

Fig. 4.12 Emitter body of right parallelpiped (RPP) type

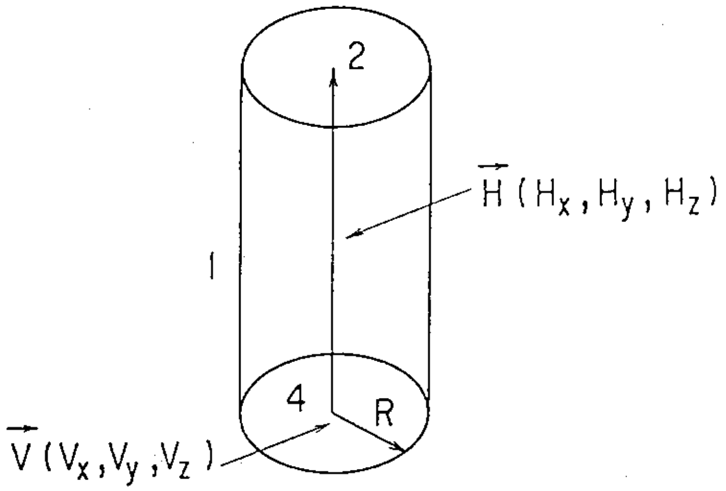
SPH V_x , V_y , V_z , R



Definition of emitted surface	
ISUF	Emitted surface
0	Dummy data is necessary

Fig. 4.13 Emitter body of sphere (SPH) type

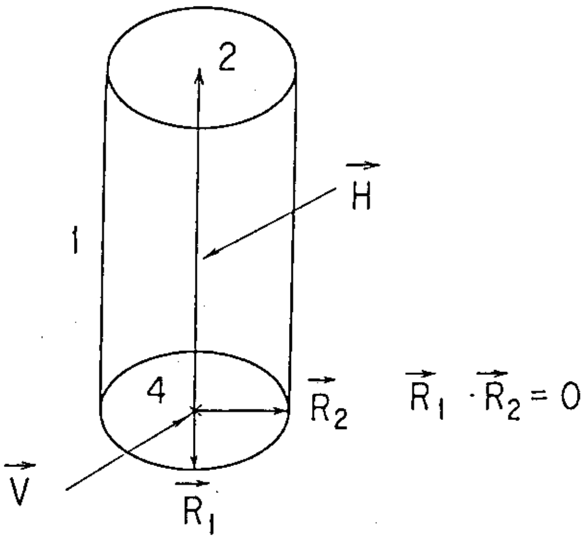
RCC V_x , V_y , V_z , H_x , H_y , H_z , R



Definition of emitted surface	
ISUF	Emitted surface
1	Side surface
2	Upper surface
4	Bottom surface
7	All surface

Fig. 4.14 Emitter body of right circular cylinder (RCC) type

REC V_x , V_y , V_z , H_x , H_y , H_z
R_{1x} , R_{1y} , R_{1z} , R_{2x} , R_{2y} , R_{2z}

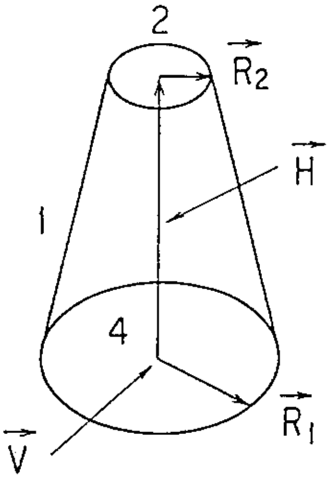


Definition of emitted surface

ISUF	Emitted surface
1	Side surface
2	Upper surface
4	Bottom surface
7	All surface

Fig. 4.15 Emitter body of right elliptic cylinder (REC) type

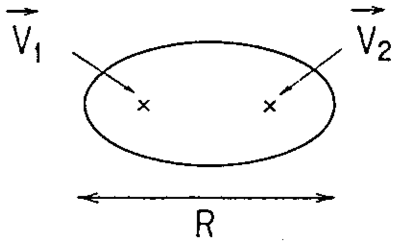
TRC V_x , V_y , V_z , H_x , H_y , H_z , R_1 , R_2



Definition of emitted surface	
ISUF	Emitted surface
1	Side surface
2	Upper surface
4	Bottom surface
7	All surface

Fig. 4.16 Emitter body of truncated right cone (TRC) type

ELL $V_{1x}, V_{1y}, V_{1z}, V_{2x}, V_{2y}, V_{2z}$, R



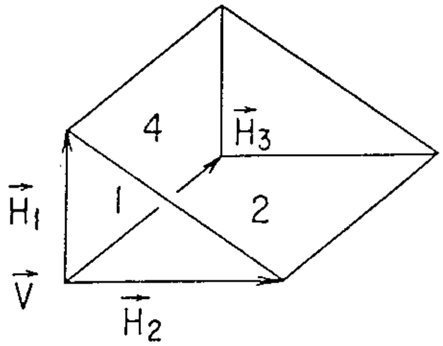
$\vec{V}_1, \vec{V}_2$: Focus

R : Width of the line of apsides

Definition of emitted surface	
ISUF	Emitted surface
0	Dummy data is necessary

Fig. 4.17 Emitter body of ellipsoid (ELL) type

RAW V_x , V_y , V_z , H_{1x} , H_{1y} , H_{1z} ,
H_{2x}, H_{2y}, H_{2z}, H_{3x}, H_{3y} , H_{3z}



Definition of emitted surface	
ISUF	Emitted surface
1	Surface of $\vec{H}_1 - \vec{H}_2$
2	Surface of $\vec{H}_2 - \vec{H}_3$
4	Surface of $\vec{H}_3 - \vec{H}_1$
8	Opposite side of 1
16	Surface of slope
32	All surface

Fig. 4.18 Emitter body of right angle wedge (RAW) type

4.5 Description of output data

This section describes the output data required MCVIEW2. In the computer program MCVIEW2 the output data are minimized.

(1) Input data

The input data are printed in two formats. The first printout format is exactly the same as they are read. Second, the program lists the data as interpreted by the program.

(2) Calculation data

The calculation values, the view factors together with the standard deviations are printed.

5. Conclusions

A computer program MCVIEW2, revised version of MCVIEW for the view factor calculation of three dimensional geometries using the Monte Carlo method, has been developed. The calculation equations have been presented and the numerical results were compared with that of the other methods, such as the area integration method, the cross string method and so on. The following conclusions have been drawn:

(1) the alteration of algorithms of making the random numbers for the non-computer dependent, is successfully perfomed,

(2) the central processing unit(CPU) time of MCVIEW2 increases only several percents comparing with MCVIEW, which uses the machine language for making random numbers,

(3) the Monte Carlo results agree well with other methods,

(4) the present method can be used for the view factor calculations.

Aknowledgements

The author is indebted to Mr. E. Tamura in IBM Japan Ltd., Co. for supplying the computer subprograms of random number calculation. The author would like to thank Dr. A. B. Shaphiro for supplying the computer program FACET(a computer program for view factor calculation using the area integration, the line integration and Mitalas and Stephenson methods).

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Appendix A Sample problems input data

Appendix A1 Two long parallel cylinders

```
                             INPUT DATA ECHO

         1         2         3         4         5         6         7         8
----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0

  TIT  MCVIEW2:RCRCRT: TWO LONG PARALLEL CYLINDERS
  CTL    4  200  200
  RCC    1       0.0       0.0       0.0       0.0       0.0     100.0
                6.25
  RCC    2      16.2       0.0       0.0       0.0       0.0     100.0
                6.25
  RPP    3-1.000E+03 1.000E+03-1.000E+03 1.000E+03-1.000E+03 1.000E+03
  RPP    4-2.000E+03 2.000E+03-2.000E+03 2.000E+03-2.000E+03 2.000E+03
  END
  RG1    1   +1
  RG2    1   +2
  RG3    3   +3   -1   -2
  RG4    2   +4   -3
  END
  REF    3
              1  1.0    2  0.0    4  0.0
  RCC    1    0    7       0.0       0.0       0.0       0.0       0.0
               100.0      6.25
END  ************** FINISH ********************

----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0
         1         2         3         4         5         6         7         8

      * * *  INPUT DATA END  * * *
```

Appendix A2 Two plates inclined angle 60 defrees to each other

```
                             INPUT DATA ECHO

         1         2         3         4         5         6         7         8
----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0

  TIT MCVIEW2:CXPL60:TWO PLATES INCLINED ANGLE 60 DEGREES TO EACH OTHER
  CTL    4  200  200
  RPP    1       0.0       1.0       0.0       1.0      -1.0       0.0
  BOX    2-1.000E+02       0.0       0.0 2.000E+02       0.0       0.0
                 0.0       0.5   0.86602       0.0  -0.86602       0.5
  RPP    3-1.000E+03 1.000E+03-1.000E+03 1.000E+03-1.000E+03 1.000E+03
  RPP    4-2.000E+03 2.000E+03-2.000E+03 2.000E+03-2.000E+03 2.000E+03
  END
  RG1    1   +1
  RG2    1   +2
  RG3    3   +3   -1   -2
  RG4    2   +4   -3
  END
  REF    3
              1  1.0    2  0.0    4  0.0
  RPP    8    0    6       0.0       1.0       0.0       1.0      -1.0
                 0.0
END  ************** FINISH ********************

----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0
         1         2         3         4         5         6         7         8

      * * *  INPUT DATA END  * * *
```

Appendix A3 Two parallel circular disks

INPUT DATA ECHO

```
         1         2         3         4         5         6         7         8
----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0

  TIT  MCVIEW2:RCCRCC2: TWO PARALLEL CIRCULAR DISKS
  CTL    4  200  200
  RCC    1       0.0       0.0      -1.0       0.0       0.0       1.0
                 2.0
  RCC    2       0.0       0.0       1.0       0.0       0.0       1.0
                 1.0
  RPP    3     -10.0      10.0     -10.0      10.0     -10.0      10.0
  RPP    4     -20.0      20.0     -20.0      20.0     -20.0      20.0
  END
  RG1    1   +1
  RG2    1   +2
  RG3    3   +3   -1   -2
  RG4    2   +4   -3
  END
  REF    3
              1  0.0    2  1.0    4  0.0
  RCC    4    0    7       0.0       0.0       1.0       0.0       0.0
                 1.0       1.0
END  ************** FINISH *******************

----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0
         1         2         3         4         5         6         7         8

      * * *  INPUT DATA END  * * *
```

Appendix A4 Sphere to disk

INPUT DATA ECHO

```
         1         2         3         4         5         6         7         8
----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0

  TIT  MCVIEW2:SPHRCC: SPHERE TO DISK
  CTL    4  200  200
  SPH    1       0.0       0.0       5.0       1.0       0.0       0.0
  RCC    2       0.0       0.0      -1.0       0.0       0.0       1.0
                 2.0
  RPP    3-1.000E+03 1.000E+03-1.000E+03 1.000E+03-1.000E+03 1.000E+03
  RPP    4-2.000E+03 2.000E+03-2.000E+03 2.000E+03-2.000E+03 2.000E+03
  END
  RG1    1   +1
  RG2    1   +2
  RG3    3   +3   -1   -2
  RG4    2   +4   -3
  END
  REF    3
              1  1.0    2  0.0    4  0.0
  SPH    0    0    4       0.0       0.0       5.0       1.0
END  ************** FINISH *******************

----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0
         1         2         3         4         5         6         7         8

      * * *  INPUT DATA END  * * *
```

Appendix A5 Two parallel plates

```
                                INPUT DATA ECHO

         1         2         3         4         5         6         7         8
----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0

  TIT   MCVIEW2:RPPRPP: TWO PARALLEL PLATES
  CTL    4  200  200
  RPP    1      -0.5       0.5      -0.5       0.5      -1.0       0.0
  RPP    2      -0.5       0.5      -0.5       0.5       1.0       2.0
  RPP    3-1.000E+03 1.000E+03-1.000E+03 1.000E+03-1.000E+03 1.000E+03
  RPP    4-2.000E+03 2.000E+03-2.000E+03 2.000E+03-2.000E+03 2.000E+03
  END
  RG1    1   +1
  RG2    1   +2
  RG3    3   +3   -1   -2
  RG4    2   +4   -3
  END
  REF    3
              1  1.0    2  0.0    4  0.0
  RPP    8    0    6      -0.5       0.5      -0.5       0.5      -1.0
                 0.0
END  ************** FINISH ********************

----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0
         1         2         3         4         5         6         7         8

      * * *  INPUT DATA END  * * *
```

Appendix A6 Two perpendicular plates

```
                                INPUT DATA ECHO

         1         2         3         4         5         6         7         8
----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0

  TIT   MCVIEW2:CXPL90: TWO PERPENDICULAR PLATES
  CTL    4  200  200
  RPP    1       0.0       1.0       0.0       1.0      -1.0       0.0
  RPP    2      -1.0       0.0       0.0       1.0       0.0       1.0
  RPP    3-1.000E+03 1.000E+03-1.000E+03 1.000E+03-1.000E+03 1.000E+03
  RPP    4-2.000E+03 2.000E+04-2.000E+03 2.000E+03-2.000E+03 2.000E+03
  END
  RG1    1   +1
  RG2    1   +2
  RG3    3   +3   -1   -2
  RG4    2   +4   -3
  END
  REF    3
              1  1.0    2  0.0    4  0.0
  RPP    8    0    6       0.0       1.0       0.0       1.0      -1.0
                 0.0
END  ************** FINISH ********************

----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0
         1         2         3         4         5         6         7         8

      * * *  INPUT DATA END  * * *
```

Appendix A7 Enclosure of cone cavity

```
                             INPUT DATA ECHO

         1         2         3         4         5         6         7         8
----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0

  TIT  MCVIEW2:INNTRC: ENCLOSURE OF CONE CAVITY
  CTL    4  200  200
  RCC    1       0.0       0.0       4.0       0.0       0.0       1.0
                 2.0
  RCC    2       0.0       0.0       0.0       0.0       0.0      -1.0
                 3.0
  TRC    3       0.0       0.0       0.0       0.0       0.0       4.0
                 3.0       2.0
  RPP    4-1.000E+03 1.000E+03-1.000E+03 1.000E+03-1.000E+03 1.000E+03
  END
  RG1    1   +1
  RG2    1   +2
  RG3    1   +3
  RG4    4   +4   -1   -2   -3
  END
  REF    3
              1  1.0    2  0.0    4  0.0
  RCC    4    0    7       0.0       0.0       4.0       0.0       0.0
                 1.0       2.0
END  ************** FINISH ********************

----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0
         1         2         3         4         5         6         7         8

      * * *  INPUT DATA END  * * *
```

Appendix A8 Enclosure of rectangular cavity

```
                                     INPUT DATA ECHO

         1         2         3         4         5         6         7         8
----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0

  TIT   MCVIEW2:TWRPBX: RECTANGULAR CAVITY WITH INTERNAL SHIELDS
  CTL   14  200  200
  RPP    1       0.0 1.000E+02      -1.0       0.0       0.0       0.5
  RPP    2       0.0 1.000E+02       0.0       0.4       0.5   0.50005
  RPP    3       0.0 1.000E+02       0.0       0.4   0.50005    0.5001
  RPP    4       0.0 1.000E+02      -1.0       0.0       0.5       1.0
  RPP    5       0.0 1.000E+02       0.0       1.0       1.0       2.0
  RPP    6       0.0 1.000E+02       1.0       2.0       0.5       1.0
  RPP    7       0.0 1.000E+02       0.6       1.0   0.50005    0.5001
  RPP    8       0.0 1.000E+02       0.6       1.0       0.5   0.50005
  RPP    9       0.0 1.000E+02       1.0       2.0       0.0       0.5
  RPP   10       0.0 1.000E+02      0.65       1.0      -1.0       0.0
  RPP   11       0.0 1.000E+02      0.35      0.65      -1.0       0.0
  RPP   12       0.0 1.000E+02       0.0      0.35      -1.0       0.0
  RPP   13-1.000E+03 1.000E+03-1.000E+03 1.000E+03-1.000E+03 1.000E+03
  RPP   14-2.000E+03 2.000E+03-2.000E+03 2.000E+03-2.000E+03 2.000E+03
  END
  RG1    1    +1
  RG2    1    +2
  RG3    1    +3
  RG4    1    +4
  RG5    1    +5
  RG6    1    +6
  RG7    1    +7
  RG8    1    +8
  RG9    1    +9
  RGA    1   +10
  RGB    1   +11
  RGC    1   +12
  RGD    9   +13    -1    -2    -3    -4    -5    -6    -7    -8
         4    -9   -10   -11   -12
  RGE    2   +14   -13
  END
  REF   13
              1  0.0    2  0.0    3  0.0    4  0.0    5  1.0    6  0.0
              7  0.0    8  0.0    9  0.0   10  0.0   11  0.0   12  0.0
             14  0.0
  RPP    1    0    6       0.0 1.000E+02       0.0       1.0       1.0
                 2.0
END  ************** FINISH ********************
----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0
         1         2         3         4         5         6         7         8

      * * *  INPUT DATA END  * * *
```

Appendix A9 Cubic cavity with internal shield

```
                                INPUT DATA ECHO

         1         2         3         4         5         6         7         8
----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0

  TIT   MCVIEW2:ONPLBX: CUBIC CAVITY WITH INTERNAL SHIELD
  CTL   10  200  200
  RPP    1       0.0       1.0       0.0       1.0      -1.0       0.0
  RPP    2       1.0       2.0       0.0       1.0       0.0       1.0
  RPP    3       0.0       1.0       0.0       1.0       1.0       2.0
  RPP    4      -1.0       0.0       0.0       1.0       0.0       1.0
  RPP    5       0.0       1.0       1.0       2.0       0.0       1.0
  RPP    6       0.0       1.0      -1.0       0.0       0.0       1.0
  RPP    7      0.25      0.75      0.75    0.7505      0.25      0.75
  RPP    8      0.25      0.75    0.7505    0.7510      0.25      0.75
  RPP    9-1.000E+03 1.000E+03-1.000E+03 1.000E+03-1.000E+03 1.000E+03
  RPP   10-2.000E+03 2.000E+03-2.000E+03 2.000E+03-2.000E+03 2.000E+03
  END
  RG1    1   +1
  RG2    1   +2
  RG3    1   +3
  RG4    1   +4
  RG5    1   +5
  RG6    1   +6
  RG7    1   +7
  RG8    1   +8
  RG9    9   +9   -1   -2   -3   -4   -5   -6   -7   -8
  RGA    2  +10   -9
  END
  REF    9
              1  0.0    2  0.0    3  0.0    4  0.0    5  1.0    6  0.0
              7  0.0    8  0.0   10  0.0
  RPP    2    0    6       0.0       1.0       1.0       2.0       0.0
                 1.0
END  ************** FINISH ********************

----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0
         1         2         3         4         5         6         7         8

      * * *  INPUT DATA END  * * *
```

Appendix A10 Parallell plates with obstacle

```
                               INPUT DATA ECHO

         1         2         3         4         5         6         7         8
----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0

  TIT   MCVIEW2:TWPLOB: TWO PRALLEL PLATES WITH OBSTACLE
  CTL    5  200  200
  RPP    1      -0.5       0.5      -0.5       0.5      -1.0       0.0
  RPP    2      -0.5       0.5      -0.5       0.5       1.0       2.0
  RPP    3     -0.25      0.25     -0.25      0.25      0.75    0.7501
  RPP    4-1.000E+03 1.000E+03-1.000E+03 1.000E+03-1.000E+03 1.000E+03
  RPP    5-2.000E+03 2.000E+03-2.000E+03 2.000E+03-2.000E+03 2.000E+03
  END
  RG1    1   +1
  RG2    1   +2
  RG3    1   +3
  RG4    4   +4   -1   -2   -3
  RG5    2   +5   -4
  END
  REF    4
              1  1.0    2  0.0    3  0.0    5  0.0
  RPP    8    0    6      -0.5       0.5      -0.5       0.5      -1.0
                 0.0
END  ************** FINISH ********************

----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0
         1         2         3         4         5         6         7         8

      * * *  INPUT DATA END  * * *
```

Appendix A11 Perpendicular plates with obstacle

```
                               INPUT DATA ECHO

         1         2         3         4         5         6         7         8
----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0

  TIT   MCVIEW2:RCPLOB: RECTANGLE PLATE WITH OBSTACLE
  CTL    5  200  200
  RPP    1       0.0       1.0       0.0       1.0       0.0       1.0
  RPP    2      -1.0       0.0       0.0       1.0       1.0       2.0
  RPP    3      0.25      0.75      0.25      0.75      1.25    1.2501
  RPP    4-1.000E+03 1.000E+03-1.000E+03 1.000E+03-1.000E+03 1.000E+03
  RPP    5-2.000E+03 2.000E+03-2.000E+03 2.000E+03-2.000E+03 2.000E+03
  END
  RG1    1   +1
  RG2    1   +2
  RG3    1   +3
  RG4    4   +4   -1   -2   -3
  RG5    2   +5   -4
  END
  REF    4
              1  1.0    2  0.0    3  0.0    5  0.0
  RFP    8    0    6       0.0       1.0       0.0       1.0       0.0
                 1.0
END  ************** FINISH ********************

----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0
         1         2         3         4         5         6         7         8

      * * *  INPUT DATA END  * * *
```

Appendix A12 BWR fuel assembly(8x8) pins

```
                                    INPUT DATA ECHO

         1         2         3         4         5         6         7         8
----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0

  TIT  MCVIEW2:BWR8X8G: BWR FUEL ASSEMBLY(8X8) PINS
  CTL    66  200  200
  RCG     1     -5.67     -5.67    -140.0       0.0       0.0     280.0
                0.625      1.62       8.0      1.62       8.0
  RPP    65      -6.6       6.6      -6.6       6.6    -150.0     150.0
  RPP    66     -20.0      20.0     -20.0      20.0    -200.0     200.0
  END
  001     1   +1
  002     1   +2
  003     1   +3
  004     1   +4
  005     1   +5
  006     1   +6
  007     1   +7
  008     1   +8
  009     1   +9
  010     1  +10



  055     1  +55
  056     1  +56
  057     1  +57
  058     1  +58
  059     1  +59
  060     1  +60
  061     1  +61
  062     1  +62
  063     1  +63
  064     1  +64
  065     9  +65   -1   -2   -3   -4   -5   -6   -7   -8
          9   -9  -10  -11  -12  -13  -14  -15  -16  -17
          9  -18  -19  -20  -21  -22  -23  -24  -25  -26
          9  -27  -28  -29  -30  -31  -32  -33  -34  -35
          9  -36  -37  -38  -39  -40  -41  -42  -43  -44
          9  -45  -46  -47  -48  -49  -50  -51  -52  -53
          9  -54  -55  -56  -57  -58  -59  -60  -61  -62
          2  -63  -64
  066     2  +66  -65
  END
  REF    65
              1  0.0    2  0.0    3  0.0    4  0.0    5  0.0    6  0.0
              7  0.0    8  0.0    9  0.0   10  0.0   11  0.0   12  0.0
             13  0.0   14  0.0   15  0.0   16  0.0   17  0.0   18  0.0
             19  0.0   20  0.0   21  0.0   22  0.0   23  0.0   24  0.0
             25  0.0   26  0.0   27  0.0   28  0.0   29  1.0   30  0.0
             31  0.0   32  0.0   33  0.0   34  0.0   35  0.0   36  0.0
             37  0.0   38  0.0   39  0.0   40  0.0   41  0.0   42  0.0
             43  0.0   44  0.0   45  0.0   46  0.0   47  0.0   48  0.0
             49  0.0   50  0.0   51  0.0   52  0.0   53  0.0   54  0.0
             55  0.0   56  0.0   57  0.0   58  0.0   59  0.0   60  0.0
             61  0.0   62  0.0   63  0.0   64  0.0   66  0.0
  RCC     7    0    7     0.810    -0.810    -140.0       0.0       0.0
               280.0    0.6250
END  ************** FINISH ********************

----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0
         1         2         3         4         5         6         7         8

      * * *  INPUT DATA END  * * *
```

Appendix A13 PWR feul assembly(16x16) pins

```
                             INPUT DATA ECHO
         1         2         3         4         5         6         7         8
----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0

  TIT   MCVIEW2:PWR16XG: PWR FUEL ASSEMBLY(16X16) PINS
  CTL  258  200  200  300
  RCG    1   -10.725   -10.725    -140.0       0.0       0.0     280.0
            0.5375      1.43      16.0      1.43      16.0
  RPP  257   -12.135    12.135   -12.135    12.135    -150.0     150.0
  RPP  258     -20.0      20.0     -20.0      20.0    -200.0     200.0
  END
  001    1   +1
  002    1   +2
  003    1   +3
  004    1   +4
  005    1   +5
  006    1   +6
  007    1   +7
  008    1   +8
  009    1   +9
  010    1  +10



  240    1 +240
  241    1 +241
  242    1 +242
  243    1 +243
  244    1 +244
  245    1 +245
  246    1 +246
  247    1 +247
  248    1 +248
  249    1 +249
  250    1 +250
  251    1 +251
  252    1 +252
  253    1 +253
  254    1 +254
  255    1 +255
  256    1 +256
  257    9 +257   -1   -2   -3   -4   -5   -6   -7   -8
         9   -9  -10  -11  -12  -13  -14  -15  -16  -17
         9  -18  -19  -20  -21  -22  -23  -24  -25  -26
         9  -27  -28  -29  -30  -31  -32  -33  -34  -35
         9  -36  -37  -38  -39  -40  -41  -42  -43  -44
         9  -45  -46  -47  -48  -49  -50  -51  -52  -53
         9  -54  -55  -56  -57  -58  -59  -60  -61  -62
         9  -63  -64  -65  -66  -67  -68  -69  -70  -71
         9  -72  -73  -74  -75  -76  -77  -78  -79  -80
         9  -81  -82  -83  -84  -85  -86  -87  -88  -89
         9  -90  -91  -92  -93  -94  -95  -96  -97  -98
         9  -99 -100 -101 -102 -103 -104 -105 -106 -107
         9 -108 -109 -110 -111 -112 -113 -114 -115 -116
         9 -117 -118 -119 -120 -121 -122 -123 -124 -125
         9 -126 -127 -128 -129 -130 -131 -132 -133 -134
         9 -135 -136 -137 -138 -139 -140 -141 -142 -143
----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0
         1         2         3         4         5         6         7         8

      * * *  CONTINUE  * * *
```

Appendix A13 (Continued)

INPUT DATA ECHO

```
         1         2         3         4         5         6         7         8
----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0
         9 -144 -145 -146 -147 -148 -149 -150 -151 -152
         9 -153 -154 -155 -156 -157 -158 -159 -160 -161
         9 -162 -163 -164 -165 -166 -167 -168 -169 -170
         9 -171 -172 -173 -174 -175 -176 -177 -178 -179
         9 -180 -181 -182 -183 -184 -185 -186 -187 -188
         9 -189 -190 -191 -192 -193 -194 -195 -196 -197
         9 -198 -199 -200 -201 -202 -203 -204 -205 -206
         9 -207 -208 -209 -210 -211 -212 -213 -214 -215
         9 -216 -217 -218 -219 -220 -221 -222 -223 -224
         9 -225 -226 -227 -228 -229 -230 -231 -232 -233
         9 -234 -235 -236 -237 -238 -239 -240 -241 -242
         9 -243 -234 -245 -246 -247 -248 -249 -250 -251
         5 -252 -253 -254 -255 -256
 258     2 +258 -257
 END
 REF  257
              1  0.0    2  0.0    3  0.0    4  0.0    5  0.0    6  0.0
              7  0.0    8  0.0    9  0.0   10  0.0   11  0.0   12  0.0
             13  0.0   14  0.0   15  0.0   16  0.0   17  0.0   18  0.0
             19  0.0   20  0.0   21  0.0   22  0.0   23  0.0   24  0.0
             25  0.0   26  0.0   27  0.0   28  0.0   29  0.0   30  0.0
             31  0.0   32  0.0   33  0.0   34  0.0   35  0.0   36  0.0
             37  0.0   38  0.0   39  0.0   40  0.0   41  0.0   42  0.0
             43  0.0   44  0.0   45  0.0   46  0.0   47  0.0   48  0.0
             49  0.0   50  0.0   51  0.0   52  0.0   53  0.0   54  0.0
             55  0.0   56  0.0   57  0.0   58  0.0   59  0.0   60  0.0
             61  0.0   62  0.0   63  0.0   64  0.0   65  0.0   66  0.0
             67  0.0   68  0.0   69  0.0   70  0.0   71  0.0   72  0.0
             73  0.0   74  0.0   75  0.0   76  0.0   77  0.0   78  0.0
             79  0.0   80  0.0   81  0.0   82  0.0   83  0.0   84  0.0
             85  0.0   86  0.0   87  0.0   88  0.0   89  0.0   90  0.0
             91  0.0   92  0.0   93  0.0   93  0.0   95  0.0   96  0.0
             97  0.0   98  0.0   99  0.0  100  0.0  101  0.0  102  0.0
            103  0.0  104  0.0  105  0.0  106  0.0  107  0.0  108  0.0
            109  0.0  110  0.0  111  0.0  112  0.0  113  0.0  114  0.0
            115  0.0  116  0.0  117  0.0  118  0.0  119  0.0  120  0.0
            121  1.0  122  0.0  123  0.0  124  0.0  125  0.0  126  0.0
            127  0.0  128  0.0  129  0.0  130  0.0  131  0.0  132  0.0
            133  0.0  134  0.0  135  0.0  136  0.0  137  0.0  138  0.0
            139  0.0  140  0.0  141  0.0  142  0.0  143  0.0  144  0.0
            145  0.0  146  0.0  147  0.0  148  0.0  149  0.0  150  0.0
            151  0.0  152  0.0  153  0.0  154  0.0  155  0.0  156  0.0
            157  0.0  158  0.0  159  0.0  160  0.0  161  0.0  162  0.0
            163  0.0  164  0.0  165  0.0  166  0.0  167  0.0  168  0.0
            169  0.0  170  0.0  171  0.0  172  0.0  173  0.0  174  0.0
            175  0.0  176  0.0  177  0.0  178  0.0  189  0.0  180  0.0
            181  0.0  182  0.0  183  0.0  184  0.0  185  0.0  186  0.0
            187  0.0  188  0.0  189  0.0  190  0.0  191  0.0  192  0.0
            193  0.0  194  0.0  195  0.0  196  0.0  197  0.0  198  0.0
            199  0.0  200  0.0  201  0.0  202  0.0  203  0.0  204  0.0
            205  0.0  206  0.0  207  0.0  208  0.0  209  0.0  210  0.0
            211  0.0  212  0.0  213  0.0  214  0.0  215  0.0  216  0.0
            217  0.0  218  0.0  219  0.0  220  0.0  221  0.0  222  0.0
            223  0.0  224  0.0  225  0.0  226  0.0  227  0.0  228  0.0
            229  0.0  230  0.0  231  0.0  232  0.0  233  0.0  234  0.0
            235  0.0  236  0.0  237  0.0  238  0.0  239  0.0  240  0.0
            241  0.0  242  0.0  243  0.0  244  0.0  245  0.0  246  0.0
            247  0.0  248  0.0  249  0.0  250  0.0  251  0.0  252  0.0
            253  0.0  254  0.0  255  0.0  256  0.0  258  0.0
 RCC     7    0    7     0.715    -0.715    -140.0       0.0       0.0
               280.0    0.5375
END  ************* FINISH ********************

----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0
         1         2         3         4         5         6         7         8

      * * *  INPUT DATA END  * * *
```

Appendix B Sample problem output

```
                             INPUT DATA ECHO

         1         2         3         4         5         6         7         8 DATA
----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0 SEQ.

  TIT  MCVIEW2:RCRCRT: TWO LONG PARALLEL CYLINDERS                                   1
  CTL    4  200  200                                                                 2
  RCC    1       0.0       0.0       0.0       0.0       0.0     100.0               3
                6.25                                                                 4
  RCC    2      16.2       0.0       0.0       0.0       0.0     100.0               5
                6.25                                                                 6
  RPP    3-1.000E+03 1.000E+03-1.000E+03 1.000E+03-1.000E+03 1.000E+03               7
  RPP    4-2.000E+03 2.000E+03-2.000E+03 2.000E+03-2.000E+03 2.000E+03               8
  END                                                                                9
  RG1    1   +1                                                                     10
  RG2    1   +2                                                                     11
  RG3    3   +3   -1   -2                                                           12
  RG4    2   +4   -3                                                                13
  END                                                                               14
  REF    3                                                                          15
              1  1.0    2  0.0    4  0.0                                            16
  RCC    1    0    7       0.0       0.0       0.0       0.0       0.0              17
               100.0      6.25                                                      18
END  ************** FINISH *********************                                    19

----5----0----5----0----5----0----5----0----5----0----5----0----5----0----5----0
         1         2         3         4         5         6         7         8

        * * *  INPUT DATA END  * * *

        * * *  INPUT DATA FROM FILE NO. = 5  * * *
```

Appendix B (Continued)

```
 1.JOB DESCRIPTION
    TIT  MCVIEW2:RCRCRT: TWO LONG PARALLEL CYLINDERS


 2.CONTROL DATA
    NUMBER OF BODIES               =      4
    NUMBER OF EMISSION PARTICLES =    200
    NUMBER OF BATCHES              =    200


 3.COMBINATORIAL GEOMETRY DATA
                                          BODY DATA
    RCC     1  0.000E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00  1.000E+02
               6.250E+00
    RCC     2  1.620E+01  0.000E+00  0.000E+00  0.000E+00  0.000E+00  1.000E+02
               6.250E+00
    RPP     3 -1.000E+03  1.000E+03 -1.000E+03  1.000E+03 -1.000E+03  1.000E+03
    RPP     4 -2.000E+03  2.000E+03 -2.000E+03  2.000E+03 -2.000E+03  2.000E+03
    END     5  0.000E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00
    NUMBER OF BODIES =     4

 4.REGION SPECIFICATION DATA
                                         REGION DATA
    RG1        1       0       0       0       0       0       0       0       0
    RG2        2       0       0       0       0       0       0       0       0
    RG3        3      -1      -2       0       0       0       0       0       0
    RG4        4      -3       0       0       0       0       0       0       0
    END        0       0       0       0       0       0       0       0       0
    NUMBER OF REGIONS =     4

    REGION NO.     BODY NO.    NO. OF BODIES INCLUDING REGION
             1            1                1
             2            2                1
             3            3                3
             4            4                2

 5.TOTAL NUMBER OF BODIES DEFINED REFLECTING RATIO
    NUMBER OF REFLECTING BODIES =     3

 6.REFLECTING RATIO OF BODIES
      NO.  BODY NO.     RATIO      NO.  BODY NO.     RATIO      NO.  BODY NO.     RATIO
       1          1    1.0000       2          2    0.0000       3          4    0.0000

 7.EMISSION BODY DATA
    GEOMETRY TYPE                =          RCC
    EMISSION SURFACE TYPE(ISUF) =            0
    OPTION FOR WEIGHT(IOPT)      =            1
    REAL DATA OF PATICULAR BODY
                              VX =  0.000E+00
                              VY =  0.000E+00
                              VZ =  0.000E+00
                              HX =  0.000E+00
                              HY =  0.000E+00
                              HZ =  1.000E+02
                              RL =  6.250E+00


 8.CALCULATION RESULTS(VIEW FACTORS)
    NO. BODY NO. REFLECTION FACTOR  VIEW FACTOR  STANDARD DEVIATION   F.S.D.(%)
     1        1          1.000000      0.000000          0.000000        0.0000
     2        2          0.000000      0.130253          0.001984        1.5230
     3        4          0.000000      0.869737          0.001990        0.2288
```

Appendix C Job control data

The job control data for MCVIEW2 execution on the computer FACOM M780 in JAERI is as follows:

```
//JCLG  JOB
// EXEC JCLG
//SYSIN DD DATA,DLM='++'
// JUSER XXXXXXXX.XX,XXXXXXXX,XXXX.XX,MCVIEW2
   T.03 C.02 W.01 I.02 CLS
   OPTP MSGCLASS=A,MSGLEVEL=(1,1,2),CLASS=2,NOTIFY=JXXXX
   OPTP PASSWORD=XXXXXXXX
//RUN EXEC LMGOEX,LM=J2322.LMMCVIEW,PNM=MCVIEW2
//FT05F001 DD DSN=JXXXX.DTMCVIEW.DATA,DISP=SHR
//FT01F001 DD SPACE=(TRK,(1,1)),UNIT=TSSWK
//FT02F001 DD SPACE=(TRK,(1,1)),UNIT=TSSWK
++
//
```

Appendix D Program abstract in NEA DATA BANK Format

1. Name :

   MCVIEW2

2. Computer for which the program is designed and others upon which it is possible:

   FACOM M-780(IBM compatible computer)

3. Nature of physical problem solved:

   Radiation view factor calculation for three dimensional geometries with or without obstacles.

4. Method of solutions:

   Monte Carlo method.

5. Restrictions on the complexity of the problem:

   None.

6. Typical running time:

   FACOM M-780 : 10 seconds.

7. Unusual features of the program:

   None.

8. Related and auxiliary program:

   None.

9. Status

   –

10. References:

    "MCVIEW : A Radiation View Factor Computer Program for Three dimensional Geometries Using Monte Carlo Method", JAERI-M 86-177(1986).

11. Machine requirement:

    FACOM M-780 : 1000 k bytes of core memory.

12. Program language used:

    FORTRAN-77

13. Operating system or monitor under the program is executed:

    FACOM M-780 : MSP

14. Any other program or operating information or restrictions:

    The program is approximately 5600 source steps.

15. Name and establishment of author:

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Tokai Research Establishment.
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Tokai-mura, Naka-gun, Ibaraki-ken,319-11
Japan

16. Material available:

Source.