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86-177

MCVIEW

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

December 1986

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Japan Atomic Energy Research Institute

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編集兼発行　日本原子力研究所
印　　　刷　いばらき印刷㈱

MCVIEW
A Radiation View Factor Computer Program for Three Dimensional Geometries Using Monte Carlo Method

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(Received November 22, 1986)

A Computer program MCVIEW calculates the radiation view factor between surfaces for three dimensional geometries. MCVIEW was developed to calculate view factors for input data to heat transfer analysis programs TRUMP, HEATING-5, HEATING-6 and so on.

In the paper, brief illustration of calculation method using Monte Carlo for view factor is presented. The second section presents comparisons between view factors of other methods such as area integration, line integration and cross string and Monte Carlo methods, concerning with calculation error and computer execution time. The third section provides a user's input guide for MCVIEW.

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

MCVIEW
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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幾島　毅

（1986年11月22日受理）

計算プログラムMCVIEWは，3次元体系の表面間の形態係数を計算するものである。MCVIEWは熱計算プログラムTRUMP，HEATING－5，－6などの入力データとして必要な形態係数を計算する。

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，次に，他の計算法，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の比較について記述している。さらに，MCVIEWの入力データについて記述している。

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1. Introduction

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

There are many computer programs for view factor 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 view factors for fuel pin bundle in 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 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 Monte Carlo methods are computer time consuming. However, it is clarifed from the results that small amount of emissions leads resonable view factors and small amount of computer time. Moreover, using Monte Carlo method, view factors of 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 view factors for input data to heat transfer analysis programs such as TRUMP(10), HEATING-5(11), HEATING-6(12) and so on. MCVIEW calculates the radiation geometric view factor between surfaces for three dimensional geometries with and without interposed third surface obstructions.

In the paper, the Capter 2 presents a brief illustration of calculation method using Monte Carlo for view factors. The Chapter 3 presents comparisons between view factors of area integration and Monte Carlo methods concerning calculation error and computer execution time. The Capter 4 provides a user's input guide for MCVIEW.

2. Illustration of View Factor Calculation

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

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

(2) the two surfaces are black,

(3) the two surfaces are isothermal.

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

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

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

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

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

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

In complex geometries, Monte Carlo method has the advantage that simple relations will specify the path of a boundle, 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 we construct case histories of the travel of individual particles through the geometries. One particle history includes the birth of a particle at its source surface, its random walk through the transporting medium as it undergoes reflection and its absoption at other surfaces, which terminates the history. A dead can occur when the particle becomes absorbed.

In the Monte Carlo method, view factor F_{IJ} 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 batch,

x_i : accumulated estimate in the i-th batch.

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

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

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:

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

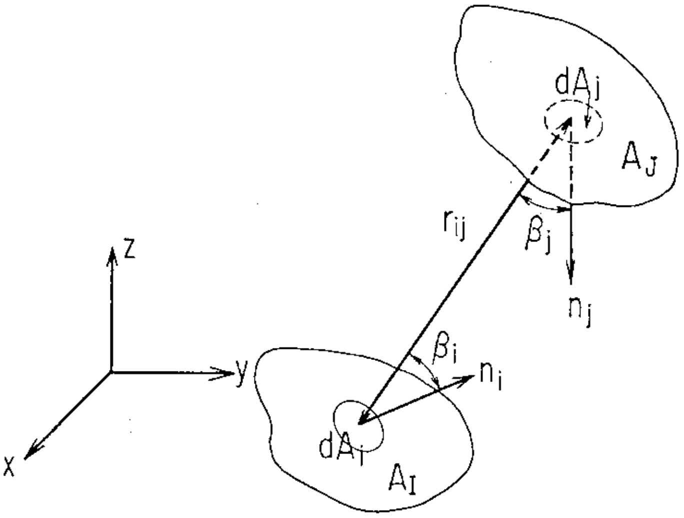


Fig.2.1 Illustration of view factor

3. Calculation Results

(1) Two long parallel cylinders

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

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

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

(3) Two parallell circular disks

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

(4) Sphere to disk

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

(5) Two parallell long plates

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

(6) Two long perpendicular plates

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

(7) Cone

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

(8) Enclosure of rectangular cavity

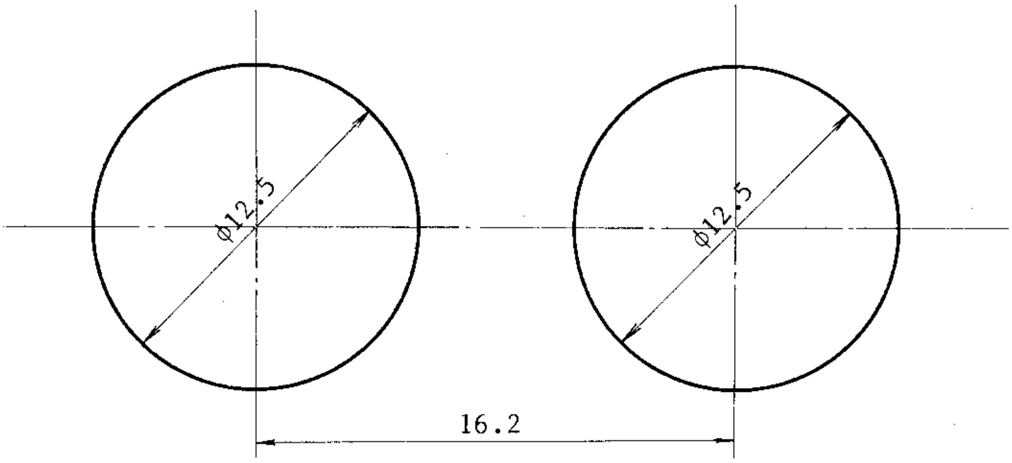
Figure 3.8 shows view factors of the enclosure of a rectanglar cavity with two shields, obtained by Monte Carlo method comparing with the values obtained by cross string method. Those values are fairly in good agreement each other.

(9) Cubic cavity with internal shield

Figure 3.9 shows view factors of the enclosure of the cubic cavity with an internal shield, obtained by Monte Carlo method comparing with the values obtained by area integration method. Those values are fairly in good agreement each other.

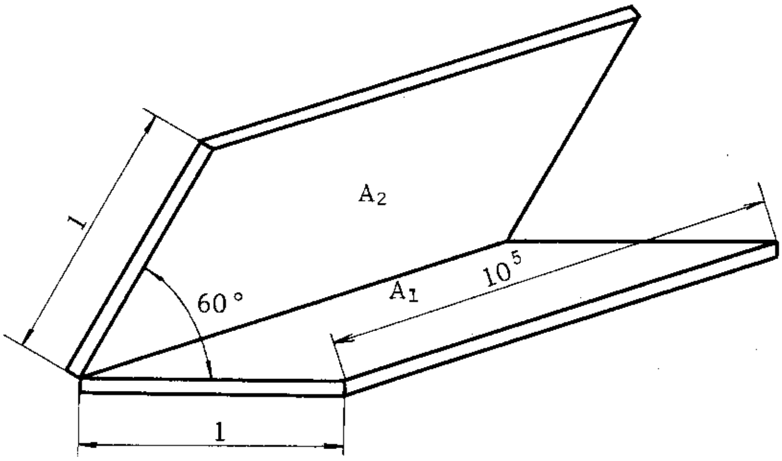
(10) BWR fuel assembly

Figure 3.10 and 3.11 show view factors of BWR(8x8) fuel assembly, obtained by Monte Carlo method comparing with exact values. Those values are fairly in good agreement with exact ones.



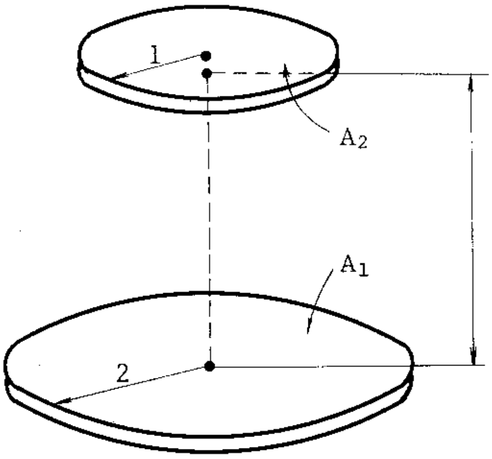
Calculation method	Exact	Cross string	Area integration	Monte Carlo
View factor	0.13043	0.13043	0.13043	0.12890(f.s.d.=0.936%)
Computer execution time (s)	0	0	0.025	1.0

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



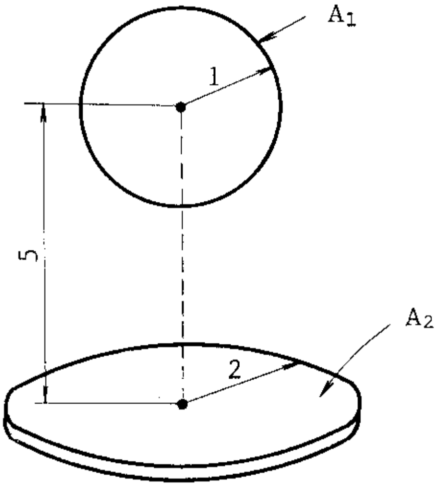
Surface	View factor	
	Monte Carlo	Exact value (2D)
$F_{12}=F_{21}$	0.49989 (f.s.d.=0.341%)	0.5

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



Surface	View factor	
	Monte Carlo	Exact value
F_{12}	0.76227 (f.s.d=0.173%)	0.7639

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

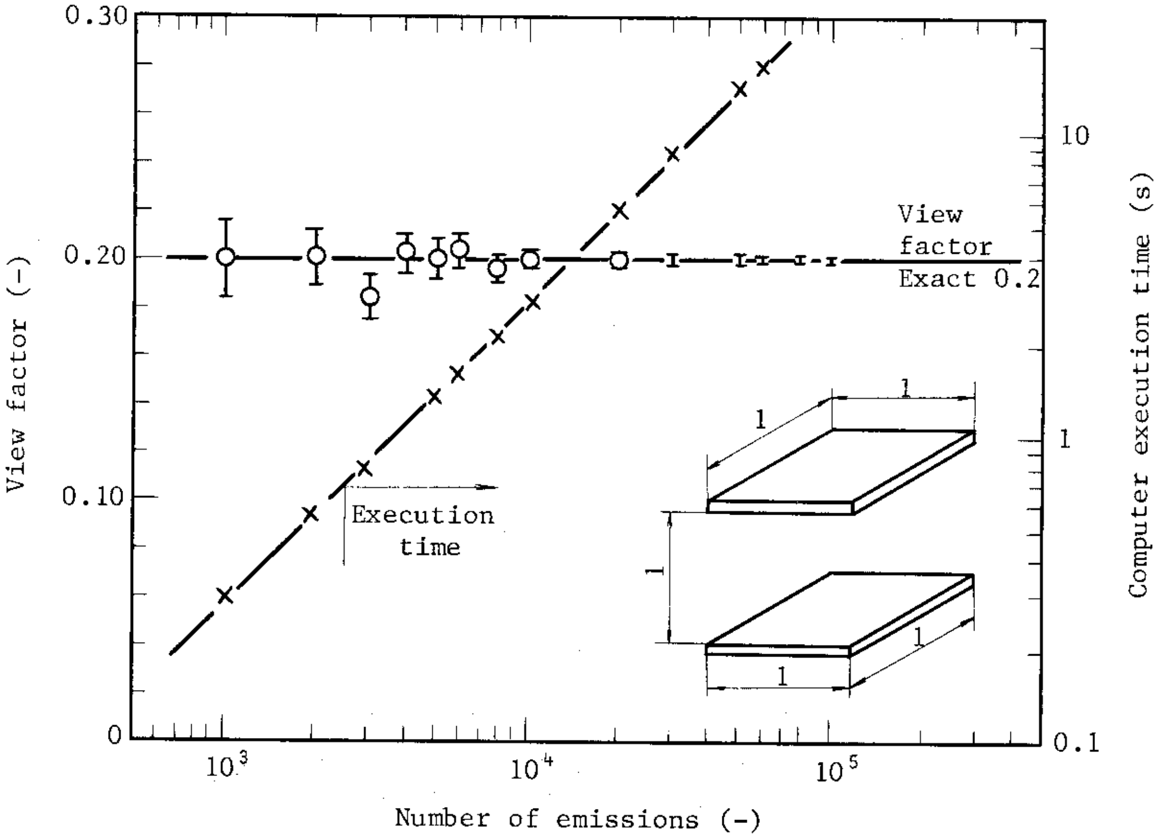


Fig. 3.5 Effect of number of emissions on view factor and computer execution time in the case of directly opposed square plates

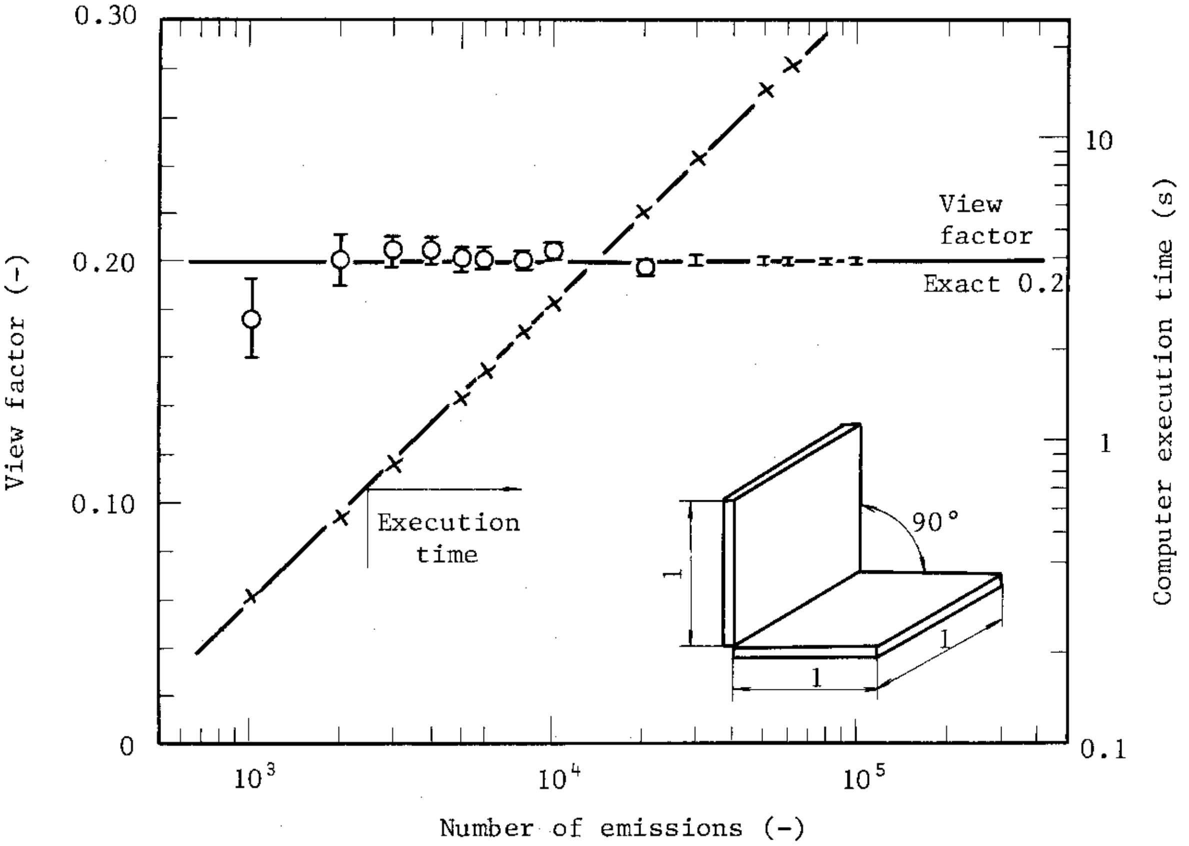
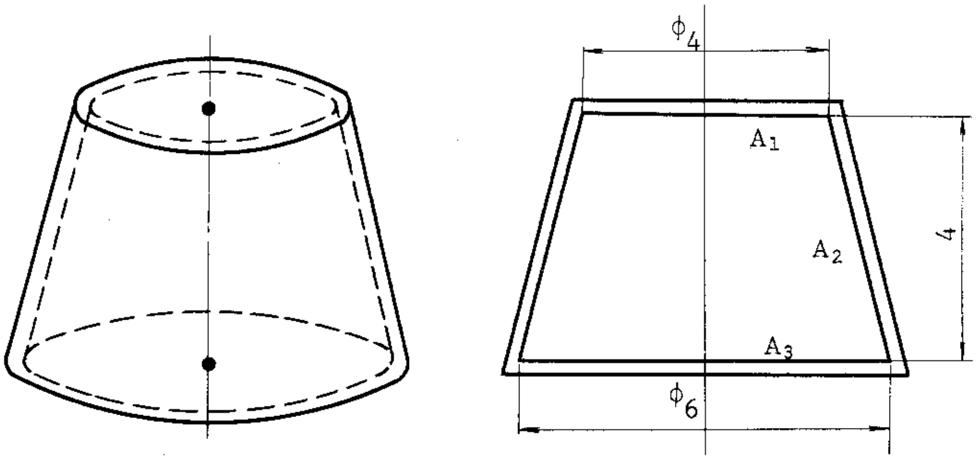
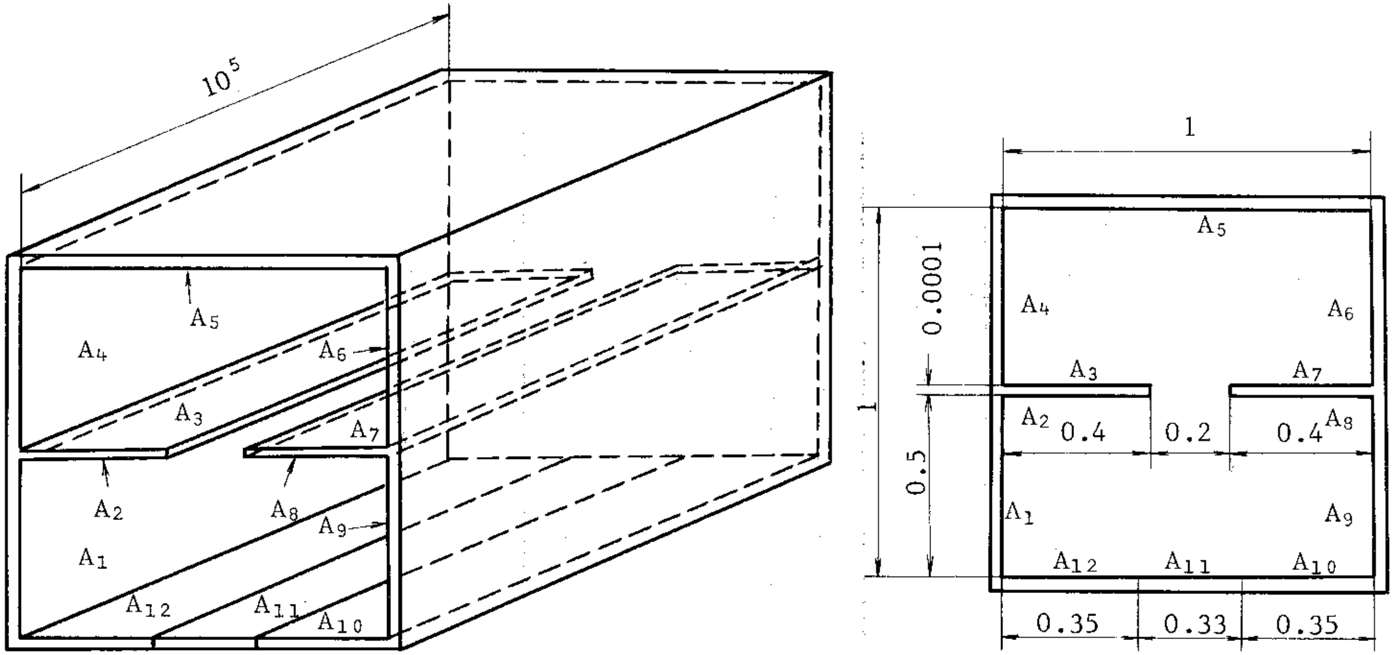


Fig. 3.6 Effect of number of emissions on view factor and computer execution time in the case of perpendicular square plates



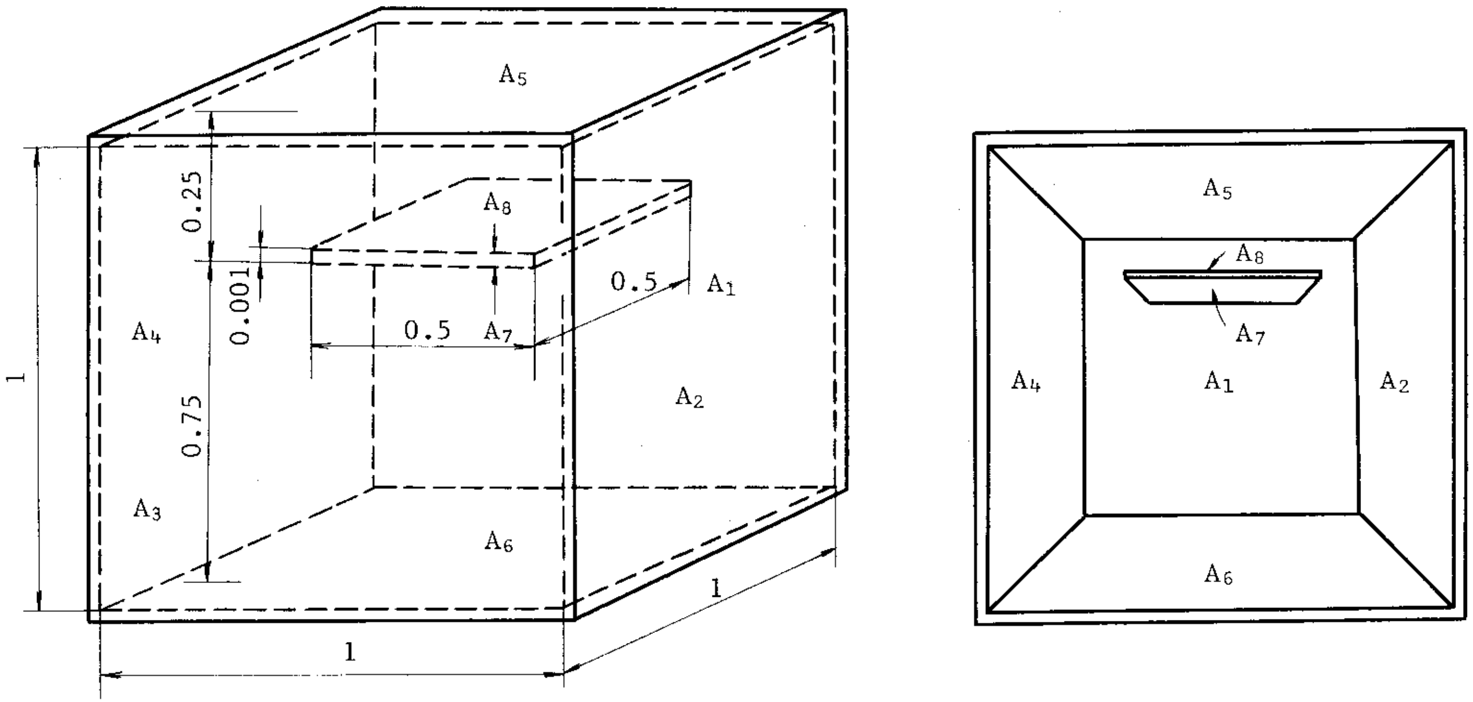
Surface	View factor	
	Monte Carlo	Line integration
F_{12}	0.67772 (f.s.d.=0.282%)	0.6751
F_{13}	0.32226 (f.s.d.=0.593%)	0.3249

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_{53}	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 shield



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

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

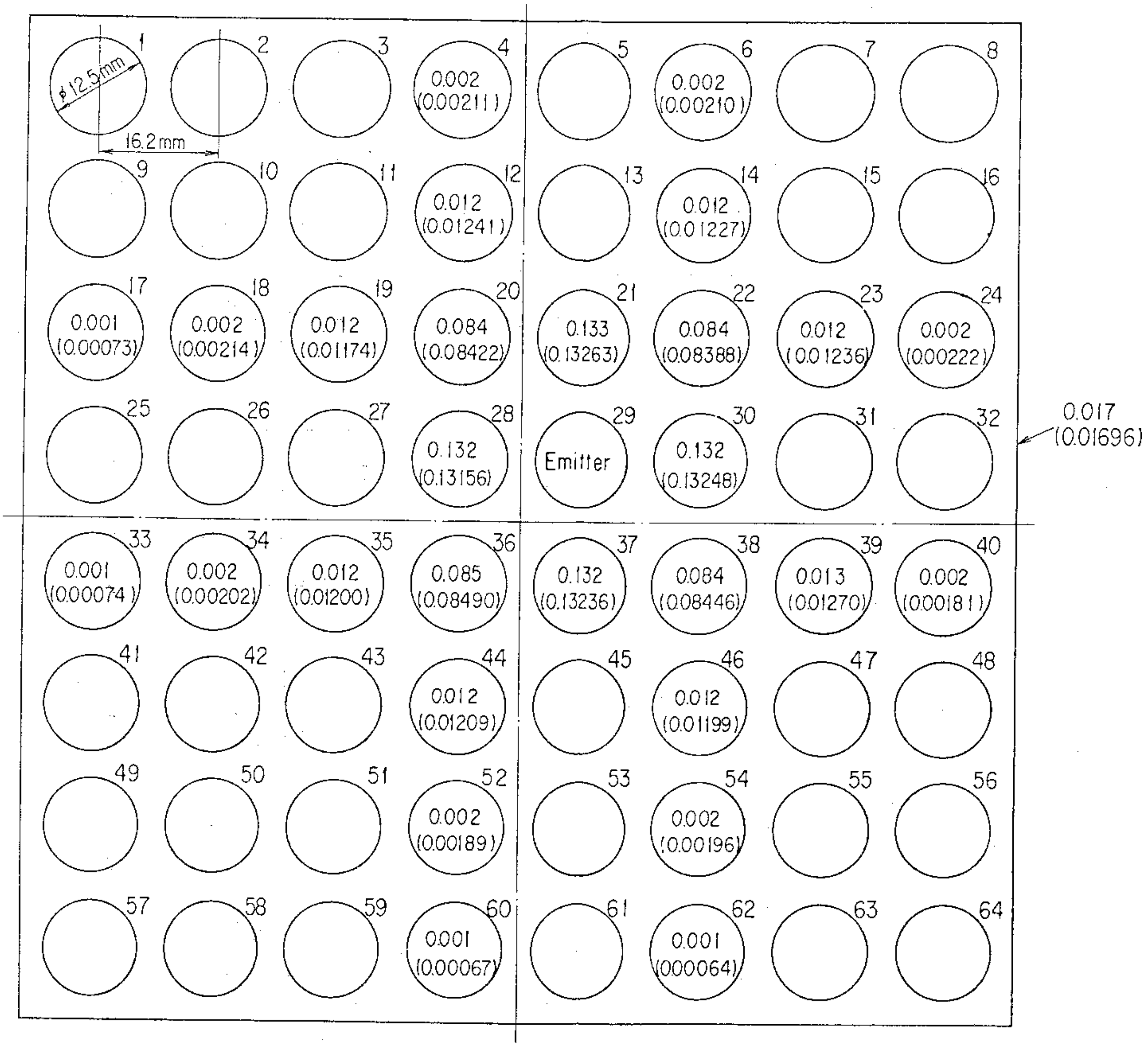


Fig.3.10 View factor of BWR(8x8) fuel assembly

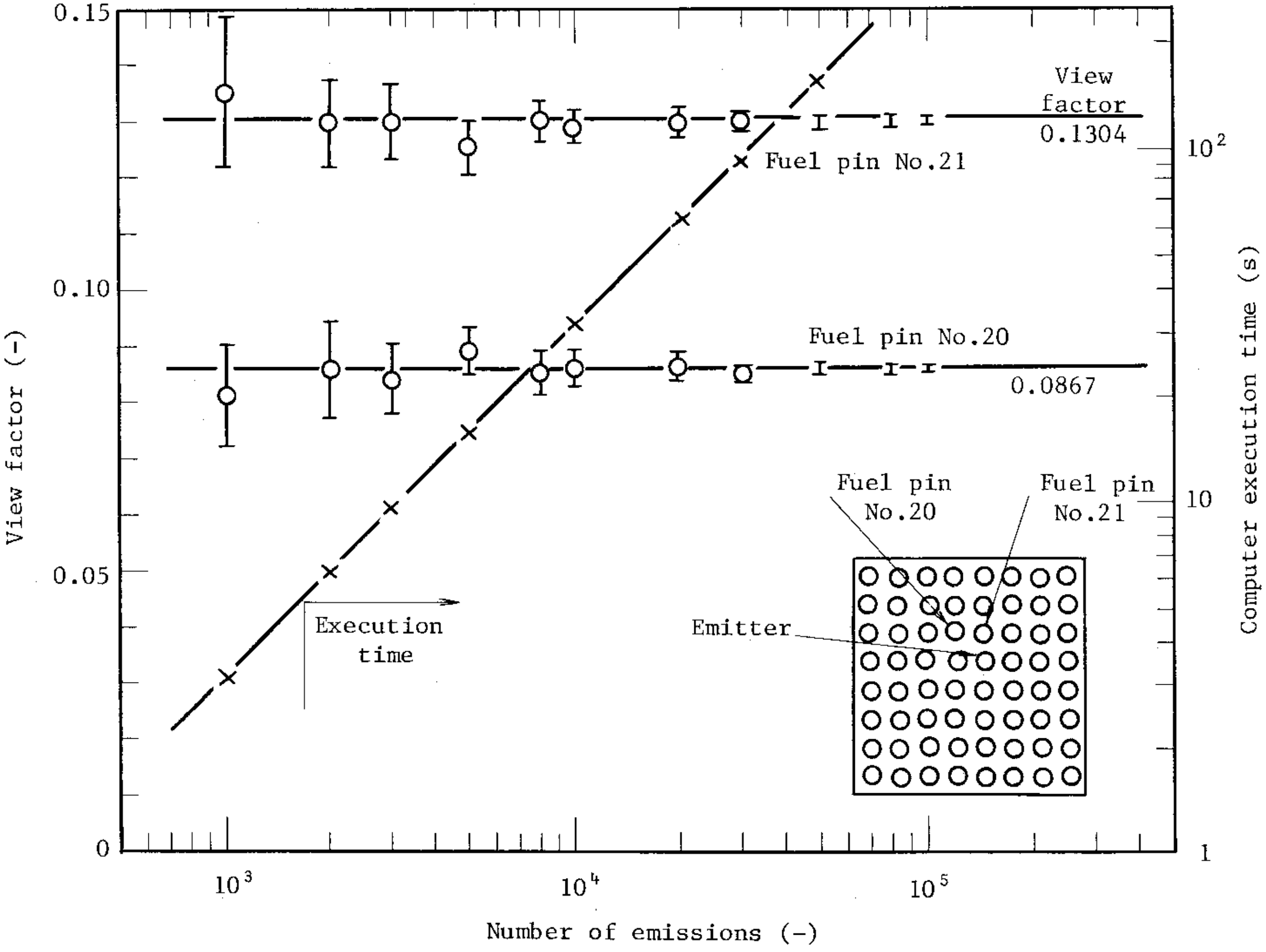


Fig. 3.11 Effect of number of emissions on view factor and computer execution time in the case of BWR (8×8) fuel assembly (Monte Carlo method)

4. Computer Program

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

4.1 Program Description

The computer program MCVIEW, to some extent, has its origins with the work of M. B. Emmett and his computer program MORSE-CG(13) which is Monte Carlo radiation transport code system.

4.2 Description of Input Data

This section describes the input data required by MCVIEW. The input data consist of the job description, control data, combinatrial geometry data, zone specification data, number of media, reflecting ratio and definition of emission body data.

The input data for MCVIEW are similar to MORSE-CG. All input data are free 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 (1).
Data set No.3 : Control data (2).
Data set No.4 : Combinatorial geometry data.
Data set No.5 : Zone specification data.
Data set No.6 ; Total number of media defined the reflecting ratio.
Data set No.7 : Reflecting ratio of media.
Data set No.8 : Definition of emission body.

Table 4.1 Input data for MCVIEW

Number	Variable	Description
Data set No. 1; Job description.		
First data	TITLE	JOb description.
Data set No. 2; Control data(1).		
First data	NSTRT	Number of particles per batch.
Second data	NMOST	Maximum number of particles allowed for in the bank(s); may equal NSTRT if no splitting and secondary generation.
Third data	NITS	Number of batches.
Fourth data	AXTIM	Maximum clock time in minutes allowed the problem to be on the computer(CPU time).
Fifth data	MEDIA	Number of media.
Data set No. 3; Control data(2).		
First data	WTHIH1	Weight above which splitting will occur.
Second data	WTLOW1	Weight below which Russian roulette is played.
Third data	WTAVE1	Weight given those particles surviving Russian roulette.
Data set No. 4; Combinatorial geometry data.		
		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.
First data	ITYPE	Specifies body type or END to terminate reading of body data(for example BOX, RPP, ARB, etc.). Leave

Number	Variable	Description
		blank for continuation data.
Second data	IALP	Body number assigned by user (all input body numbers must form a sequence set beginning at 1). If left blank, none of the numbers. Leave blank for continuation data.
Thirs data	FPD(I)	Real data required for the given body as shown in Table 4.2 and Fig.4.1 through 4.9. This data must be in cm.
Data set No. 5; Zone specification data.		
		Input zone specification data. One set of data required for each zone, with input zone numbers being assigned-sequentially.
First data	IALP	Specifies zone type or END to terminate reading of zone data. IALP must be a nonblank for the first data of each set of data defining an input zone. If IALP is blank, this data treated as a continuation of the previous zone data. IALP = END denotes the end of zone description.
Second data	NNN	Number of data of JTY(I) (mamimum data is less equal nine).
Third data	JTY(I)	Body number with the (+) or (−) sign as required for the zone description.
Data set No. 6; Number of media defined the reflecting ratio.		
First data	NMGALB	Number of media defined the reflecting ratio.

Number	Variable	Description
Data set No. 7; Reflecting ratio of media.		
First data	MGALB(1)	Number of medium No.1.
Second data	RALB(1)	Reflecting ratio of medium No.1.
Third data	MGALB(2)	Number of medium No.2.
Fourth data	RALB(2)	Reflecting ratio of medium No.2.
....	....	....
....	....	Repeates data same as above data.
....	....	....
2(N-1)th data	MGALB(N)	Number of medium No.N.
2N-th data	RALB(N) (N=NMGALB)	Reflecting ratio of medium No.N.
Data set No. 8; Definition of emission body.		
First data	TYPE	Body type of emission.
Second data	ISUF	Definition of emission surface.
Third data	IOPT	Option for weight of emitted particles. IOPT=0: cosine. IOPT=1: 1.
Fourth data	NV	Number of geometrical data.
Fifth data	VECTOR(I) (I=1,NV)	Geometrical data for body(see Chapter 4.3.2).

Notes for grid generator(RCCG).

The grid generator for RCC data is provides in MCVIEW. The grid data RCCG is as follows in the case of Fig. 4.10.

'RCCG', IALP, V_{xmin}, V_{ymin}, V_z, H_x, H_y, H_z, R, DX, NX, DY, NY

Number	Variable	Description
where	IALP	Body number.
	DX	Distance between RCC bodies for X-direction.
	DY	Distance between RCC bodies for Y-direction.
	NX	Number of grids for X-direction.
	NY	Number of grids for Y-direction.

4.3 Combinatorial Geometry

4.3.1 Body Type

Combinatrial geometry (CG) describes general three dimensional material configurations by considering unions, differences and intersections of simple bodies such as shperes, boxes, cylinders, etc. In effect, the geometric description subdivides the problem space into unique zones. Each zone is the result of combining one or more of the following geometric bodies (see Table 3.2 and Fig. 4.1 through 4.10).

(1) Rectangular ParallelePiped (RPP)
(2) BOX (An RPP randomly oriented in space) (BOX).
(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).

Body types (2)-(9) may be arbitrary oriented with respect to the x, y, z coordinate axes used to determine the space. Body (1) a special body 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) Rectangular parallelpiped (RPP)

Specifiy the minimum and maximum values of the x, y, z coordinates which bound the parallelepiped. Definition of geometrical data is shown in Fig. 4.1.

(2) Box (BOX)

Specify the vertex V at one of the corners by giving its (x,y,z) coordinates. Specify a set of three mutually perpendicular vectors a_i 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. 4.2.

(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 ellipse, 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 a vertex V at the center of the lower base, the height vector H, expressed in terms of its x, y, and z components and two scalara R_1 and R_2 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 V_1 and V_2 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) Wedge (WED) or Right angle wedge (RAW)

Specify the vertex V at the one of the corners by giving its (x,y,z) coodinates. Specify a set of three mutually perpendicular vectors a_i with a_1 and a_2 describing the two legs of the right triangle of the wedge. That is, the x, y and z componets of the height, width and length vectors are given. Definition of geometrical data is shown in Fig. 4.8.

(9) Arbitrary polyhedrin (ARB)

Assign an index (1 to 8) to each vertex. For each vertex, given the (x,y,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 face. 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) Grid generator (RCCG)

The grid generator for RCC data is provides in MCVIEW. The grid generator RCCG data format is shown in Fig. 4.10.

Table 4.2 Input Required for Each Body Type

Body Type	ITYPE	IALP	Real Data Defining Particular Body					
Box	BOX	IALP is assigned	Vx	Vy	Vz	H1x	H1y	H1z
		by the user or	H2x	H2y	H2z	H3x	H3y	H3z
Right Parallelepiped	RPP	by the code if	Xmin	Xmax	Ymin	Ymax	Zmin	Zmax
		left blank.						
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
Ellipsoid	ELL		V1x	V1y	V1z	V2x	V2y	V2z
Truncated Right Cone	TRC		Vx	Vy	Vz	Hx	Hy	Hz
Right Angle Wedge	WED or RAW		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
			Face Descriptions (see note below)					
Termination of Body Input Data	END							

NOTE: The arbitrary polyhedron input contains a four-digit number for each of the six faces of an ARB body.

4.4 Emission Body

4.4.1 Combinatorial geometry

Definition of emission bodies is the same as MORSE-CG combinatorial geometries in addition to definition of emission surfaces. Definition of emission bodies and surfaces are presented from Fig. 4.10 to 4.18. Eight emission bodies are provided as follows:

(1) Rectangular ParallelePiped (RPP)
(2) BOX (An RPP randomly oriented in space) (BOX).
(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) Rectangular parallelpiped (RPP)

Specifiy the minimum and maximum values of the x, y, z coordinates which bound the parallelepiped. Definitions of geometrical data and emission surfaces are shown in Fig. 4.11.

(2) Box (BOX)

Specify the vertex V at one of the corners by giving its (x,y,z) coordinates. Specify a set of three mutually perpendicular vectors H_i 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. Definitions of geometrical data and emission surfaces are shown in Fig. 4.12.

(3) Sphere (SPH)

Specify the vertex V at the center and a scalar R, denoting the radius. Definitions of geometrical data and emission surfaces 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. Definitions of geometrical data and emission surfaces are shown in Fig. 4.14.

(5) Right elliptical cylinder (REC)

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

(6) Truncated right angle cone (TRC)

Specify a vertex V at the center of the lower base, the height vector H, expressed in terms of its x, y, and z components and two scalara R_1 and R_2 denoting the radii of the lower and upper bases. Definitions of geometrical data and emission surfaces are shown in Fig. 4.16.

(7) Ellipsoid (ELL)

Specify two vertices V_1 and V_2 denoting the coordinates of foci and a scalar R denoting the length of the major axis. Definitions of geometrical data and emission surfaces are shown in Fig. 4.17.

(8) Wedge (WED) or Right angle wedge (RAW)

Specify the vertex V at the one of the corners by giving its (x,y,z) coodinates. Specify a set of three mutually perpendicular vectors H_i with H_1 and H^2 describing the two legs of the right triangle of the wedge. That is, the x, y and z componets of the height, width and length vectors are given. Definitions of geometrical data and emission surfaces are shown in Fig. 4.18.

4.5 Description of Output Data

In the computer program MCVIEW, output data are minimized. Input data is printed exactly the same as they are read. Definitions of variables of calculation results are as follows:

NMGALB : Total number of media.
MGALB : Number of media.
RALB : Reflecting ration of media.
CALB : View factors.
FALB : Fractional standard deviation.
CPU : Computer execution time(minutes, seconds and mili-seconds).

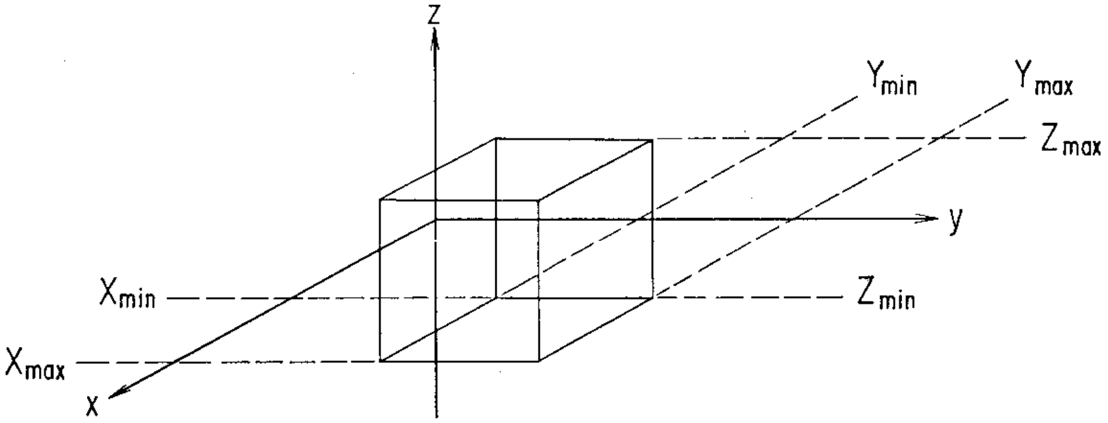


Fig.4.1 Rectangular Parallelepiped (RPP).

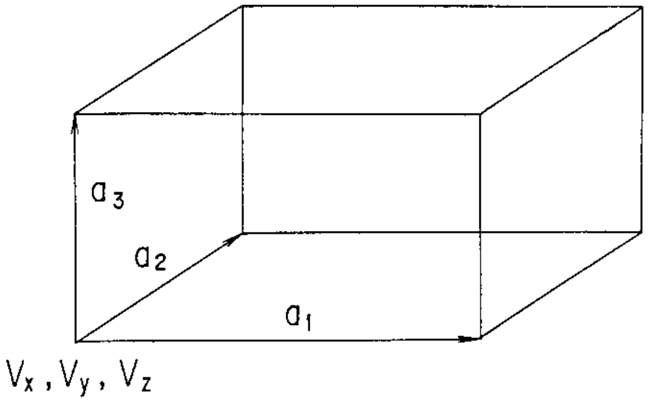


Fig.4.2 Box (BOX)

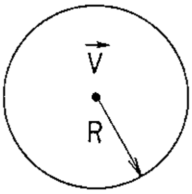


Fig.4.3 Sphere (SPH).

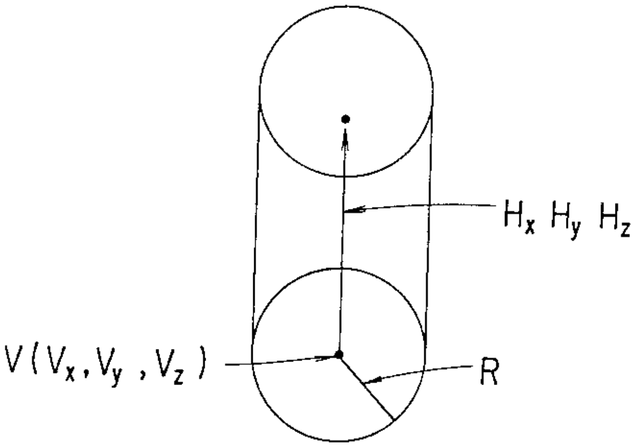


Fig.4.4 Right Circular Cylinder (RCC).

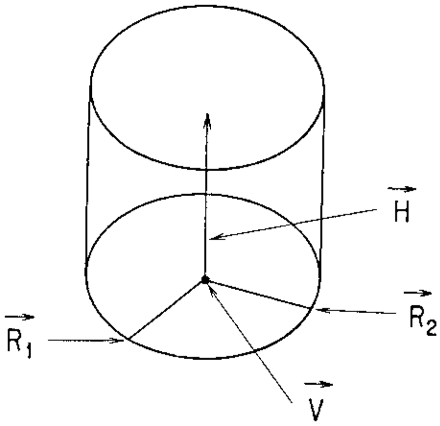


Fig.4.5 Right Elliptical Cylinder (REC).

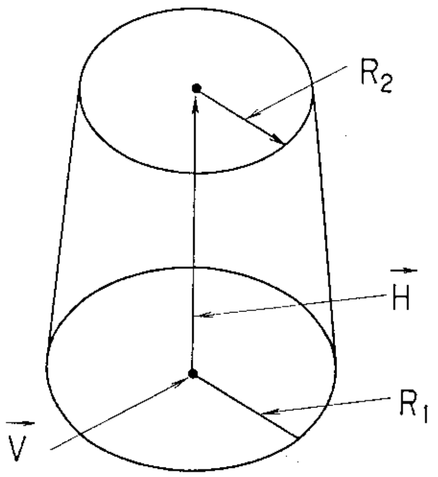


Fig.4.6 Truncated Right Angle Cone (TRC).

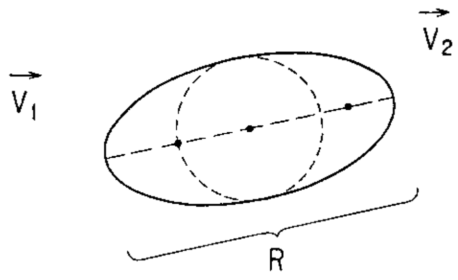


Fig.4.7 Ellipsoid (ELL).

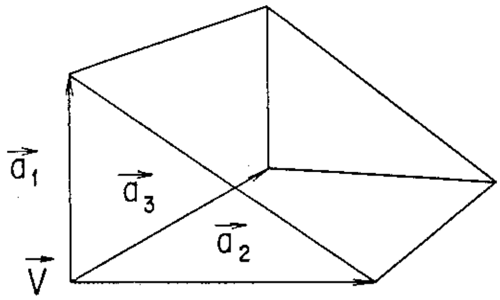


Fig.4.8 Right Angle Wedge (RAW).

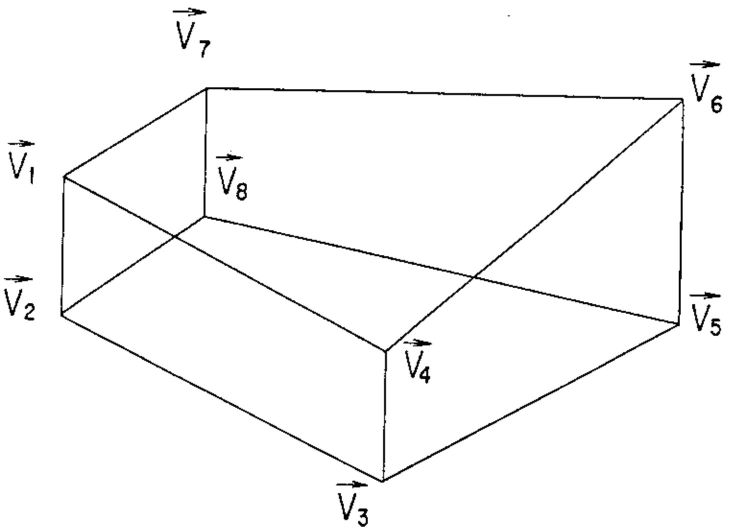


Fig.4.9 Arbitrary Polyhedron (ARB).

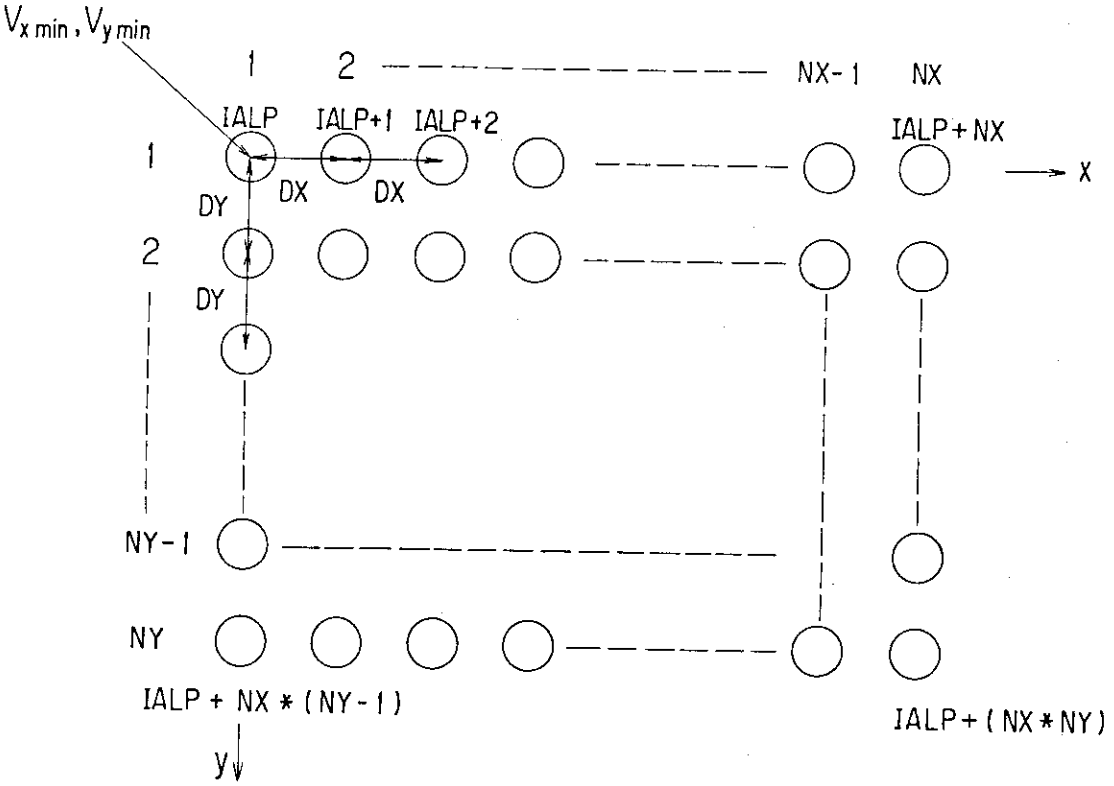
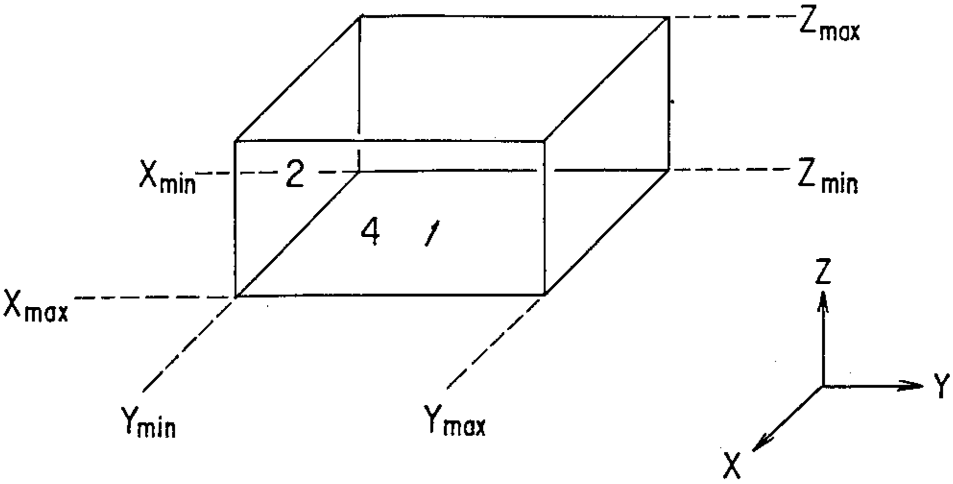


Fig.4.10 Description of RCC grid notation

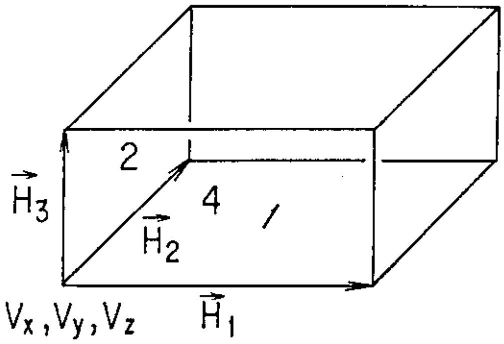
RPP X_{min} , X_{max} , Y_{min} , Y_{max} , Z_{min} , Z_{max}
(KBDY = 1)



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.4.11 Emitter body of right parallelpiped (RPP) type

BOX V_x , V_y , V_z , H_{1x} , H_{1y} , H_{1z} ,
(KBDT=2) H_{2x} , H_{2y}, H_{2z}, H_{3x} , H_{3y} , H_{3z}



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

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

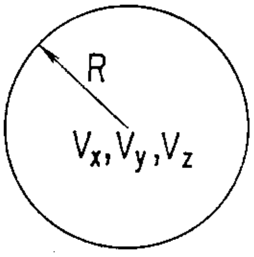
$\vec{H}_3 = (H_{3x}, H_{3y}, H_{3z})$

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.4.12 Emitter body of box (BOX) type

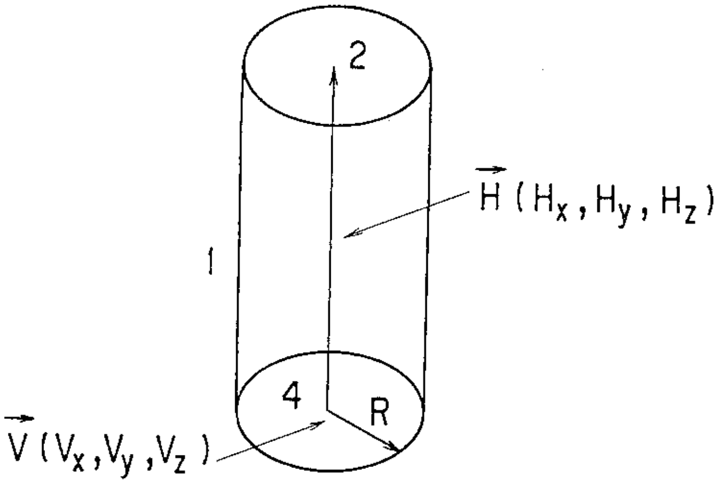
SPH. V_x , V_y , V_z , R
(KBDY = 3)



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

Fig.4.13 Emitter body of sphere (SPH) type

RCC (KBDY=4) V_x , V_y , V_z , H_x , H_y , H_z , R

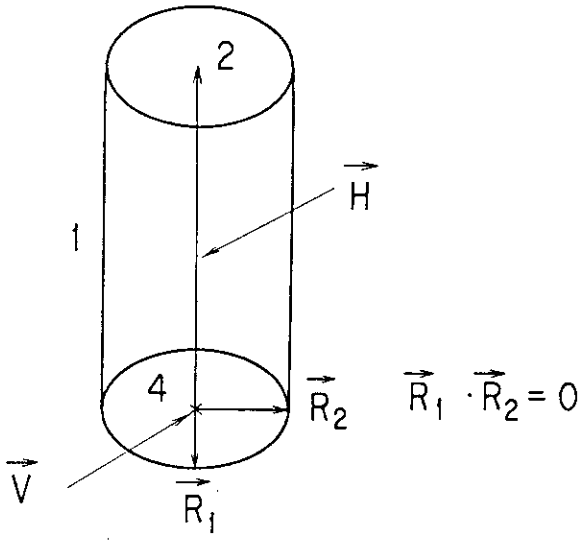


Definition of emitted surface

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
(KBDY=5) R_{1x} , R_{1y} , R_{1z} , R_{2x} , R_{2y} , R_{2z}

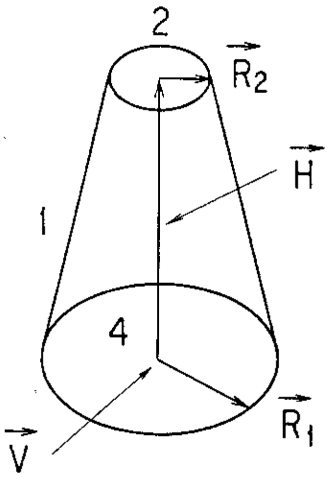


Definition of emitted surface

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

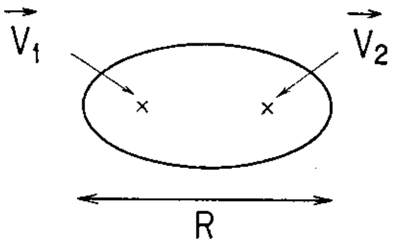
TRC V_x , V_y , V_z , H_x , H_y , H_z , R_1 , R_2
(KBDY=6)



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 $V_{1x}, V_{1y}, V_{1z}, V_{2x}, V_{2y}, V_{2z}, R$
(KBDY=7)

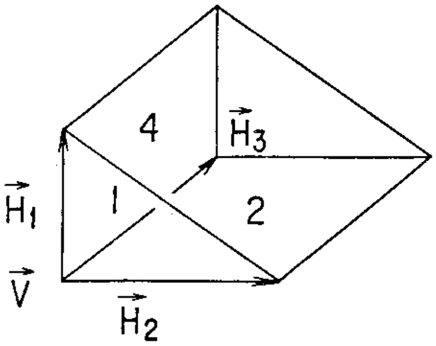


$\vec{V}_1, \vec{V}_2$: Focus
R : Width of the line of apsides

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} ,
(KBDY=8) 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

5. Conclusions

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

(1) The Monte Carlo results agree well with the other methods.

(2) The present method can be used for view factor calculation.

Acknowledgements

The author is indebted Mr. H. Yoshida in Century Research Center, Ltd., Co. for help of making the computer program. The author would like to thank Dr. A. B. Shaphiro for supplying me the computer program FACET(a computer program for view factor calculation using area integration, line integration, Mitalas and Stephenson and cross string methods).

References

(1) Sparrow, E. M. and Cess, R. D.,:"Radiation Heat Transfer", McGraw Hill (1978).

(2) ibid.

(3) Mitalas, G. P. and Stephenson, D. G.,:"FORTRAN IV Program Calculate Radiant Interchange Factors", DRD-25 (1966).

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(2) ibid.

(3) Mitalas, G. P. and Stephenson, D. G.,:"FORTRAN IV Program Calculate Radiant Interchange Factors", DRD-25 (1966).

(4) Hottel, H. C. and Sarofim, A. F.,:"Radiative Transfer", McGraw

Hill (1967).

(5) ibid.

(6) Wong, R. L.,:"User's Manual for COVUFAC, The General Dynamics Heat Transfer Radiation View Factor Program", UCID-17275 (1976).

(7) Singer G. L.:"VIEWPIN A FORTRAN Program to Calculate View Factor for Cylindrical Pins", ANCR-1054 (1972).

(8) Shapiro, A. B.,:"FACET - A Radiation View Factor Computer Code for Axisymmetric, 2D Planar and 3D Geometries with Shadowing" UCID-19887 (1983).

(9) Burns, P. J.,:"MONTE - A Two Dimensional Radiative Exchange Factor Code", Colorado State University (1983).

(10) Edwards, A. L.,:"TRUMP - A Computer Program for Transient and Steady State Temperature Distributions in Multidimensional System", UCRL-14754 (1972).

(11) Turner, W. D., Elrod, D. C. and Siman-Toy, I. I.,:"HEATING 5 - An IBM 360 Heat Conduction Program", ORNL/CSD/TM-15 (1977).

(12) Elrod, D. C., Giles, G. E. and Turner, W. D.,:"HEATING6: A Multidimensional Heat Conduction Analysis with the Finite-Diference Formulation", ORNL/NUREG/CSD-2/V2 (1981).

(13) Emmett, M. B.,:"The Monte Carlo Radiation Transport Code System", ORNL-4972 (1975).

APPENDICES

APPENDIX A Sample Problem Input

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

 MCVIEW EXAMPLE NO.  ONE SPH SOURCE & ONE RCC DETECTOR
  1000 1000 700   3000    4
    1.1 0.001 0.5
 'SPH'   1        0.       0.       3.0       1.        0.        0.
 'RCC'   2        0.       0.      -1.0       0.        0.        1.0
                  2.
 'RPP'   3      -1.E10    1.E10   -1.E10    1.E10    -1.E10     1.E10
 'RPP'   4      -2.E10    2.E10   -2.E10    2.E10    -2.E10     2.E10
 'END'   4      -20.      20.     -20.      20.0     -20.       20.
 'RG1'  1      +1
 'RG2'  1      +2
 'RG3'  3      +3     -1      -2
 'RG4'  2      +4     -3
 'END'  1      +1
    3
    1 1. 2 0. 4 0.
 'SPH' 0 0  4     0.      0.          3.        1.
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
```

APPENDIX B **Sample Problem Output**

```
            VIEW FACTORS    NMGALB=    3

   I MGALB    RALB    CALB    FALB       I MGALB    RALB    CALB    FALB       I MGALB    RALB    CALB    FALB
   1     1 1.00000 0.0     0.0           2     2 0.0     0.12428 0.00387       3     4 0.0     0.87564 0.00065

TOTAL CPU TIME FOR THIS PROBLEM WAS   3.95 MINUTES.

TOTAL CPU TIME FOR THIS PROBLEM WAS     237.00 SECONDS.

TOTAL CPU TIME FOR THIS PROBLEM WAS       237489 MILI-SECONDS.
```