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VIEWPIN
A FORTRAN PROGRAM TO CALCULATE
VIEW FACTORS FOR CYLINDRICAL PINS

G. L. SINGER

Aerojet Nuclear Company

NATIONAL REACTOR TESTING STATION

Idaho Falls, Idaho — 83401

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A FORTRAN Program to Calculate
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by

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ABSTRACT

VIEWPIN is a computer code which calculates view factors (the fraction of the total radiation emitted from a source surface that strikes a target surface) for circular pins. View factors are necessary input to such radiation heat transfer codes as RADHT and MOXY.

VIEWPIN is a two-dimensional code and assumes that the length of the circular pins is large compared to their diameters. The code can calculate a view factor within an array of pins to 0.01% accuracy in less than 0.25 second. The code provides for renormalizing the view factors to ensure that the sum of the view factors from one pin to all other pins in an enclosing array is unity.

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I. INTRODUCTION

One of the major tasks preliminary to running a radiation heat transfer code, such as RADHT(1) or MOXY(2), is the calculation of view factors. A view factor can be defined as the fraction of the total radiation emitted from a source surface that strikes a target surface. The VIEWPIN code was written to provide a fast, accurate, and easy way to calculate view factors for cylindrical pins.

The accuracy of most of the view factors calculated is better than 0.01%. Most view factors can be calculated using no more than five simple input cards which describe the size and location of the source, target, and, possibly, shadowing pins. However, there are certain pin configurations which can be accurately calculated only by repeating the above type of input two or more times, but in these cases the true view factor to the distant pin is usually small compared to the view factors to nearer pins and could have been ignored anyway for most uses. If a high degree of accuracy is desired, it may be obtained for these cases by calculating the view factor in pieces using several runs. Appendix A, *Complicated Shadowing Cases*, indicates the method to be used in such a case.

VIEWPIN assumes that the length of the pins is very large compared to the diameter, so that only two dimensions need be considered in calculating the view factors.

Since the sum of the view factors to target pins completely surrounding a source pin must be 1.0, the code allows the user the option of renormalizing the original view factors to ensure radiation balance.

II. DISCUSSION OF EQUATIONS

Since VIEWPIN assumes the problem to be solved may be represented two dimensionally, we shall define view factors and configuration factors two dimensionally, using the notation indicated in Figure 1.

A view factor, v_{12} , can be defined as the fraction of the total radiation emitted from a source segment, L_1 , that strikes a target segment, L_2 . A configuration factor, c_{12} , can be defined as the fraction of the total radiation emitted from a source point (infinitesimal segment), dL_1 , that strikes the target segment, L_2 .

Fig. 1 Projection of a Segment of the Target onto the x-axis

We shall assume the following equations for the view factor and the configuration factor and show that the innermost integration (which is the configuration factor) can be replaced by a simple trigonometric function. See Appendix E for a derivation of Equation (1).

$$v_{12} = \frac{1}{L_1} \int_{L_1} \int_{L_2} \frac{\cos\theta_1 \cos\theta_2}{2S} d\ell_2 d\ell_1 \quad (1)$$

$$c_{12} = \int_{L_2} \frac{\cos\theta_1 \cos\theta_2}{2S} d\ell_2 \quad (2)$$

We shall project an infinitesimal length, $d\ell_2$, on the target circle onto a unit circle about the source point and further project this onto the x-axis. The x-axis is assumed here to be tangent to the source circle at the point considered.

Using the following elementary relationships

$$d\omega_1 = \frac{\cos\theta_2 d\ell_2}{S}$$

$$d\omega_1 = d\ell_2'$$

$$d\ell_2' = \frac{d\ell_2''}{\cos\theta_1}$$

and then

$$d\omega_1 = \frac{d\ell_2''}{\cos\theta_1}$$

we have

$$\frac{\cos\theta_2 d\ell_2}{S} = \frac{d\ell_2''}{\cos\theta_1}$$

thus

$$c_{12} = \int_{L_2} \frac{\cos\theta_1 \cos\theta_2}{2S} d\ell_2 = \int_{L_2} \frac{d\ell_2''}{2} = \frac{L_2''}{2} = \frac{\cos\phi_2 - \cos\phi_1}{2}$$

Therefore, the configuration factor for circular pins from a point on the source pin to the target pin is merely a function of the angle formed by the tangent lines to the target circle, or, where shadowing is involved, by the angles formed by the lines from the point to the source which delimit the segments of the target that are "seen" by the source point.

Since VIEWPIN uses N equally spaced points around the source pin, the view factor from source to target is simply

$$v_{12} = \frac{1}{N} \sum_{i=1}^N \frac{\cos\phi_{2i} - \cos\phi_{1i}}{2} \quad (3)$$

where the "i" subscript indicates the angles for the i'th point on the source pin.

The above equation is used for all types of problems, which implies that for complicated shadowing patterns in which the target is shadowed in such a way that more than one segment on the target is "seen" by the source pin, the problem must be input in pieces. This is discussed in more detail in Appendix A, *Complicated Shadowing Cases*.

The problem of finding view factors thus reduces to finding the angles ϕ_{1i} and ϕ_{2i} . If it were not for shadowing, the calculation ϕ_{1i} and ϕ_{2i} would mainly be a matter of calculating the angles of the tangent lines to the target pin. Fortunately, for the bulk of cases, the matter is only slightly more complicated. For unless the pins vary greatly in size, the shadowing effects can be represented by a lower and upper shadowing pin as shown in Figure 2. The view factor from pin S to pin T can be calculated using pin L as the lower shadowing pin and pin U as the upper shadowing pin.

If the array of pins is rectangular and the pins are of equal diameter, then the method could yield answers arbitrarily close to the true view factor. With the position of the array of pins shown in Figure 2 fixed, the method used would fail to be theoretically exact only if pin U or pin L were considerably smaller or pins I_2 or I_3 were considerably larger.

While it would be rare that a view factor which could not be calculated to a useful accuracy in a single run would be of significant

Fig. 2 Choice of Lower and Upper Shadowing Pins

size compared to the view factors to nearer pins, the user must understand the method used and exercise some judgment in using the code. If the problem is such that it cannot be reasonably represented by a single run using a source pin, a target pin, and optionally, a lower and/or upper shadowing pin, the view factor should be calculated in parts, using two or more runs.

The calculation of ϕ_1 and ϕ_2 for calculating the configuration factor from a point, P , on the source pin involves calculating the tangents to the target circle, to the lower shadowing circle, and to the upper shadowing circle from the point P . Then the tangent lines representing the limits of the portion of the target that the point can "see" must be chosen.

Fig. 3 The Calculation of the Tangent Lines and Angles Delimiting the Visibility of the Target from a Point

In Figure 3 these lines are represented by the lines L_ℓ and L_μ . The line L_ℓ is the line with the maximum angle to the x-axis, considered counterclockwise, of the two lines, the lower tangent to the target circle and the upper tangent to the lower shadowing circle. Similarly, the line L_μ is the line with the minimum angle of the two lines, the upper tangent to the target circle and the lower tangent to the upper shadowing circle.

An additional consideration can be seen by observing that the configuration factor for point Q must be zero. Thus before calculating the various tangents mentioned above, we must calculate to see whether it is even possible that the target can be seen from the point, say P, on the source circle. If the tangent to the source circle at P intersects the target or if the centers of the source and target circles are on opposite sides of this tangent, then the target is not completely shielded from the point P by the source circle itself. For similar reasons of self shielding (the point being shielded from the target by the source pin itself), later in the calculations the angles ϕ_1 and ϕ_2 must be readjusted to a maximum of π radians and a minimum of 0 radians

For the equations below we shall give only the final equations used and the method used to derive them. Details of the derivations will be omitted since they involve only elementary algebra.

To check for self shielding at a point, $P = (x_p, y_p)$, the program first checks to see whether the tangent line to the source circle intersects the target circle.

Let $x^2 + y^2 = r_1^2$ be the equation of the source circle, and let $(x - x_2)^2 + (y - y_2)^2 = r_2^2$ be the equation of the target circle, then the equation of the tangent line at P is $x_p x + y_p y = r_1^2$. For $y_p \neq 0$, the tangent to the source at P intersects the target circle if and only if

$$\left(-2x_2 - \frac{2r_1^2 x_p}{y_p^2} + \frac{2y_2 x_p}{y_p} \right)^2 - 4 \left(1 + \frac{x_p^2}{y_p^2} \right) \left(x_2^2 + \frac{r_1^4}{y_p^2} - \frac{2y_2 r_1^2}{y_p} + y_2^2 - r_2^2 \right) > 0.$$

If $y_p = 0$, the tangent intersects the target if and only if

$$r_2 > \left| \frac{r_1^2}{x_p} - x_2 \right|.$$

If the tangent line intersects the circle, then the program proceeds with the calculation of the configuration factor. Otherwise, it checks to see whether the centers of the source or target are on the same side of the tangent line.

The centers will be on the same side of the tangent line if and only if $(0 \cdot x_p + 0 \cdot y_p - r_1^2) (x_2 x_p + y_2 y_p - r_1^2) \geq 0$, which reduces to $x_2 x_p + y_2 y_p \leq r_1^2$. If the centers are on the same side then the point must be self shielded, so the configuration factor is set equal to zero and the code proceeds to the next point. Otherwise, the code proceeds to calculate the configuration factor.

The procedure most used by the program is the calculation of the tangent lines to a circle, C, with center at (x_1, y_1) and radius r_1 , from a point, P, on the source circle, S, and outside the circle C. Refer to Figure 4.

Fig. 4 Calculation of the Tangent Lines from a Point to a Circle

First the points Q' and Q'' at which the tangent lines from P touch the circle C are found. These points are the intersection of the circle C and another circle, C', with center at (x_2, y_2) half way between the point P and the center of the circle C and of radius, r_2 , equal to half the distance from P to the center of C.

When $y_1 \neq y_2$, the points are found from the roots of the equation:

$$x^2 \left[1 + \left(\frac{D_2 - D_1}{E_1 - E_2} \right)^2 \right] + x \left[\frac{2(D_2 - D_1)(F_2 - F_1)}{(E_1 - E_2)^2} + D_1 + E_1 \left(\frac{D_2 - D_1}{E_1 - E_2} \right) \right] + \left(\frac{F_2 - F_1}{E_1 - E_2} \right)^2 + E_1 \left(\frac{F_2 - F_1}{E_1 - E_2} \right) + F_1 = 0$$

and from the equation:

$$y = \frac{D_2 - D_1}{E_1 - E_2} x + \frac{F_2 - F_1}{E_1 - E_2}$$

where

$$D_i = -2x_i$$

$$E_i = -2y_i$$

$$F_i = x_i^2 + y_i^2 - r_i^2$$

$$i = 1, 2$$

When $y_1 = y_2$, the points are found from the equations:

$$x = \frac{F_1 - F_2}{D_2 - D_1} \text{ and } y = y_1 \pm \sqrt{r_1^2 - (x - x_1)^2}$$

Once Q' and Q'' are found, the tangent lines are determined and the calculation of the angles, ϕ_{1i} and ϕ_{2i} , that these lines make with the tangent to the source circle is easy. As these angles are calculated for the points around the source circle, Equation (3) is used to find the view factor.

III. USE OF THE CODE

This section deals with making efficient use of the capabilities of the code. The following section will deal with details and formats.

The normal use of VIEWPIN would be to calculate many view factors for an array of pins. The input is designed to allow ease of input and input checking for such arrays.

Each type of input card is identified by a key word in columns 1 to 8 of the card. The data indicated by the key word follow the key word on the same card, except for titles and subtitles, for which the data are on the card following the TITLE or SUBTITLE card.

The input and output of VIEWPIN is divided into series of runs and subdivided into runs within each series. For clarity of input, we suggest that each series begin with a TITLE card and each run within the series begin with a SUBTITLE card; however, the only requirements on the order of the input cards are that an EXECUTE card be present at the end of each run, an END card be present at the end of each series of runs, and a STOP card be present at the end of all the input data.

Normally, a series would correspond to the set of calculations for all the unique view factors from a given source pin. A run within a series would correspond to the calculation of a view factor to one of the possible target pins in the array of pins surrounding the given source pin.

The essential information the code needs is the radius of the source pin and the coordinates and radii of the target and, possibly, those of shadowing pins. Either or both shadowing pins may be omitted by giving them a radius of 0.0. The number of points used for the integration around the source pin may be input to override the default value of 100. However, for most problems for the portion of the source pin which contributes the most to the view factor, the configuration factors vary sufficiently slowly that little is gained by increasing the number of integration points.

These radii and coordinates are contained on the cards with the key words: SOURCE, TARGET, LOWER, and UPPER. It is very important to note that the line from the center of the source pin to the center of the lower shadowing pin must form a smaller angle with the x-axis, viewed

counterclockwise, than the corresponding angle formed by the line from the center of the source pin to the center of the upper shadowing pin and the x-axis. This is, in effect, the code's definition of the words LOWER and UPPER.

To simplify the input, the input variables are initialized at the start of each series, but within a series values from the previous run are saved. Thus, if the procedure of calculating the different view factors to all the pins around a fixed pin in one series is used, the source pin radius need be read in only for the first run of the series. The center of the source pin is assumed to be at (0,0) by the code. The TARGET card will normally be input for each run, but the shadowing pin data needs to be read in for a given series only when the pins doing the shadowing change. The radii, coordinates, and multiplying factors are initialized to zero. The number of points for the integration is initialized to 100.

An error message will be printed and the code will skip to the next series of runs if any of the following input errors occur: the source or target pin has a nonpositive radius, a shadowing pin has a negative radius (a zero radius here implies the absence of the shadowing pin), any two of the pins intersect, or there is not a proper key word in columns 1 to 8 when one is expected.

Since, for a completely enclosed pin, the sum of the view factors around a given pin must be 1.0, we have an easy check on the user's input. If we calculate all the different view factors for the given source pin in one series, multiplying each different view factor by the number of pins symmetrically placed about the source as compared to the pin for which the view factor was calculated, and sum the results, we have a number which should be approximately 1.0. If it is not, we should expect either an input error or that we have an unusual array of pins which VIEWPIN cannot handle as simply as expected.

When given multiplying factors on the END card, the code will perform the above multiplication and summing for the runs in the series. The user should check that this sum in the output listing is reasonably close to 1.0. VIEWPIN will then use this sum to renormalize the view factors for the series so that the products will sum to 1.0.

Fig. 5 Sample Array of Pins

Fig. 6 Extended Array of Pins

As a specific example, assume that the square array of pins in Figure 5 has equally sized pins with equal diameters. Assuming that pins H, I, and J are completely shielded from A, due to symmetry all possible view factors will have been calculated with the calculation of the view factors from A to B, A to E, A to F, and A to G. We check these four different view factors as follows. We imagine the array of pins extended to almost completely enclose pin A, as shown in Figure 6. It is then apparent that the configuration from A to B, A to E, A to F, and A to G occur 4, 4, 8, and 8 times, respectively, and that if we use these numbers as multiplying factors for the corresponding view factors and sum the products, the result should be close to 1.0. The code will perform these operations when the multiplying factors are placed on the END card in the order of the runs for which the corresponding view factor was calculated.

Without further explanation the reader should be able to see the use of adding an imaginary pin X, as shown in Figure 6, to the array and to the calculations.

Whether the original view factors, the renormalized view factors, or some compromise between them should be used depends on the nature of the problem and on the user's judgment. For example, if a source pin is not completely surrounded, then the difference between 1.0 and the above sum represents the radiation leakage outside the entire array of pins. In this case it is reasonable to use the unrenormalized view factors. If the source pin is completely surrounded, it is reasonable to use the renormalized view factors. However, since the view factors to the nearer pins are theoretically exact while the view factors to distant pins may be only an approximation, due to the assumption by the code that the use of at most two shadowing pins is sufficient, some compromise which emphasizes the accuracy of the nearer pins may be in order.

IV. INPUT DESCRIPTION

All input cards except title and subtitle cards contain a key word code in columns 1 to 8. The key words must be left justified in these columns. Only columns 1 to 4 are actually checked by the code, but for

clarity the entire key word should normally be used. The format for title and subtitle data cards is (20A4); all other cards use the format (A4,7X,3E11.0,9I4). After the TITLE card (a card with the key word TITLE in columns 1 to 5), a title data card must follow. Similarly, the card following a SUBTITLE card must be a subtitle data card. The title and subtitle data cards will be printed at the top of each page of output to which they apply.

For cards with any key word other than TITLE or SUBTITLE, any data applicable to that key word will follow on the same card rather than on the following card. For floating point data (for pin coordinates and radii) columns 12-22, 23-33, 34-44 are used. For integer data (for view factor multiplying factors and the number of points for the integration), columns 45-48, 49-52, 53-56, ..., 77-80 are used.

In the input description in Table I, an X, Y, or R marks the last column of the field for a given type of card for which floating point data is applicable. The X, Y, or R represent the x-coordinate and y-coordinate of the center of a pin and the radius of the pin, respectively.

0000000001111111112222222223333333334444444445555555556666666667777777778									
1234567890123456789012345678901234567890123456789012345678901234567890									
TITLE									
Signals that the next card will be a title data card of format (20A4).									
SUBTITLE									
Signals that the next card will be a subtitle data card of format (20A4).									
NPT									
I									
Gives the number of equally spaced points around the source pin to be used for the integration. This number goes in columns 45 to 48. The default value is 100. NPT is not reset from series to series, but will retain the value used in the previous series.									
SOURCE									
R									
Since the source is assumed to be centered at the origin, only the radius is given here.									
LOWER									
X Y R									
This card gives data for the lower shadowing pin.									
UPPER									
X Y R									
This card gives data for the upper shadowing pin.									
0000000001111111112222222223333333334444444445555555556666666667777777778									
1234567890123456789012345678901234567890123456789012345678901234567890									

DESCRIPTION OF INPUT

TABLE I

TABLE I (Contd)

DESCRIPTION OF INPUT

00000000011111111122222222233333333344444444455555555566666666677777777778
1234567890123456789012345678901234567890123456789012345678901234567890

CONCISE

If this card is present, the details of the calculations will not be given. CONCISE is the default value.

STOP

The last card of the input data must be a STOP card. If it is not present, the program will end with a systems error message indicating an end of file condition after listing the input data.

00000000011111111122222222233333333344444444455555555566666666677777777778
1234567890123456789012345678901234567890123456789012345678901234567890

TABLE I (Contd)

DESCRIPTION OF INPUT

V. REFERENCES

1. D. R. Evans, "RADHT, A Routine for Computing Radiation Heat Transfer in the BWR-FLECHT Rod Bundle", Quarterly Technical Report Nuclear Safety Program Division, (October-December 1969), pp. 1-6, IN-1320 (August 1970).
2. D. R. Evans, MOXY: A Digital Computer Code for Core Heat Transfer Analysis, IN-1392 (August 1970).
3. K. A. Toups, A General Computer Program for the Determination of Radiant-Interchange Configuration and Form Factors--CONFAC II, SID 65-1043-2 (October 1965).

APPENDIX A
COMPLICATED SHADOWING CASES

When the diameters of the pins in an array vary greatly, the use of VIEWPIN becomes slightly more difficult. This appendix will outline considerations to be made when the above situation occurs.

If the situation pictured in Figure A-1 should occur, the view factor from pin S to pin T would have to be calculated as the sum of the view factors obtained in two runs, one using pin L as the lower shadower and pin UL as the upper shadower and the other using pin UL as the lower shadower and pin U as the upper shadower.

Fig. A-1 Target Shadowing Segmented

If the situation pictured in Figure A-2 occurs, the view factor from pin S to pin T can be accurately calculated as the sum of the view factors obtained from using pin L once as the lower shadower and once (in a separate run) as the upper shadower.

Fig. A-2 Single Pin as Both Lower and Upper Shadower

VIEWPIN cannot calculate the view factor from pin S to pin T for the situation shown in Figure A-3 in a single run with complete accuracy, since, for example, the point P on pin S is shadowed from part of pin T by pin A, while the point Q on pin S is shadowed from part of pin T by pin B. The best approximation for this view factor obtained then can be in a single run by ignoring pin B, in which case the problem reduces to that pictured in Figure A-2.

However, VIEWPIN can calculate this view factor exactly in four runs by the following formula, where the $X \xrightarrow{L} Y$ notation indicates the view factor from pin X to pin Y with pin L as the shadower.

$$S \xrightarrow{A,B} T = (S \xrightarrow{A} T) - (S \xrightarrow{B} T)$$

Fig. A-3 Shadowing of Different Points by Different Pins

APPENDIX B
OPERATION INFORMATION

VIEWPIN is written in standard FORTRAN and is presently operating on an IBM 360/75. Conversion to other computers should be extremely easy. The program requires 12.5K single precision (4 byte) words of core storage (50K bytes). One subroutine contains some double precision variables.

Three input/output devices are required as follows.

<u>Description of Use of Device</u>	<u>FORTRAN Logical Number</u>
Input Unit	5
Printed Output Unit	6
Scratch	4

The scratch unit can easily be eliminated if a listing of the card input is not desired. This unit must have a logical record length of 80 bytes. We suggest 800 bytes as the blocking factor.

Table B-I gives the Job Control Language used to execute the program on the IBM 360/75 plus the card input data for the first series of runs in the sample problem of Appendix C.

TABLE B-I

JOB CONTROL LANGUAGE PLUS SAMPLE INPUT DATA

```
//Your job card here
// COR=050,CPU=001,WT=000
//JOB LIB DD DSN=PROLIB,DISP=SHR,UNIT=DKPRV2,VOL=SER=PERM02
//VIEWPN EXEC PGM=PO214001,REGION=50K,TIME=1
//FT06F001 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=1596),
//          SPACE=(TRK,(50),RLSE)
//FT04F001 DD UNIT=DKSCRA,SPACE=(TRK,(11)),          SCRATCH
//          DCB=(RECFM=FBS,LRECL=80,BLKSIZE=800)
//FT05F001 DD *
TITLE      SAMPLE PROBLEM,  EQUALLY SIZED PINS.
SUBTITLE   DIAGONAL PIN
SOURCE
LOWER      4.25      0.0      2.
UPPER      0.0      4.25      2.
TARGET     4.25      4.25      2.
EXEC
SUBTITLE   UNSHADOWED PIN
LOWER
UPPER
TARGET     4.25      0.      2.
EXEC
NPT
SUBTITLE   DIAGONAL PIN DOWN ONE
LOWER      4.25      0.      2.
UPPER      4.25      4.25      2.
TARGET     8.5      4.25      2.
EXEC
NPT
SUBTITLE   IMAGINARY LEAKAGE PIN
UPPER      8.5      4.25      2.
TARGET     12.75     2.125     2.
EXECUTE
END
STOP
/*
```

4 4 8 8

APPENDIX C
SAMPLE PROBLEM LISTING

The first two sample problem series in the sample problem output below are typical practical problems. The second sample problem consists of six test runs which calculate view factors which can easily be calculated by hand. The final two runs show what happens when the user makes an input error. This problem took three seconds of CPU time and six seconds of WAIT time on the IBM 360/75.

Figure C-1 shows the pin configurations for the view factors calculated in the first sample problem. The number by the arrow is the run number for the run by which the view factor was calculated.

Fig. C-1 Pin Configurations for the First Sample Problem Series

ALL INPUT CARDS AS READ IN:

C-3

```
TITLE
SAMPLE PROBLEM, EQUALLY SIZED PINS.
SUBTITLE
DIAGONAL PIN
SOURCE
LOWER 4.25 0.0 2.
UPPER 0.0 4.25 2.
TARGET 4.25 4.25 2.
EXEC
SUBTITLE
UNSHADOWED PIN
LOWER
UPPER
TARGET 4.25 0. 2.
EXEC
NPT 200
SUBTITLE
DIAGONAL PIN DOWN ONE
LOWER 4.25 0. 2.
UPPER 4.25 4.25 2.
TARGET 8.5 4.25 2.
EXEC
NPT 100
SUBTITLE
IMAGINARY LEAKAGE PIN
UPPER 8.5 4.25 2.
TARGET 12.75 2.125 2.
EXECUTE
END 4 4 8 8
TITLE
SAMPLE PROBLEM, 2X4 ARRAY OF PINS WITH DIAGONAL PIN, DOWN ONE, LARGER THAN REST
SUBTITLE
VIEW FROM PIN (1,1) TO PIN (2,1) -- ADJACENT UNSHADOWED PIN
DETAILS
SOURCE .211
TARGET .563 .211
EXEC
SUBTITLE
VIEW FROM PIN (1,1) TO PIN (2,2) -- DIAGONAL PIN
CONCISE
LOWER .563 0. .211
UPPER 0. .563 .211
TARGET .563 .563 .211
EXEC
SUBTITLE
VIEW FROM PIN (1,1) TO PIN (2,3) -- DIAGONAL PIN, DOWN ONE
UPPER .563 .563 .211
TARGET 1.126 .563 .2725
EXEC
SUBTITLE
VIEW FROM PIN (1,1) TO PIN (2,4) -- DIAGONAL PIN, DOWN TWO
```

UPPER 1.126 .563 .2725
TARGET 1.689 .563 .211
EXEC
SUBTITLE
VIEW FROM PIN (1,1) TO PIN (1.5,5) -- IMAGINARY LEAKAGE PIN
TARGET 2.252 .2815 .211
EXECUTE
END 4 4 8 8 8
TITLE

POINT SOURCE OR TARGET TESTS

SUBTITLE
NORMAL SOURCE TO POINT TARGET

SOURCE 1.

LOWER

UPPER

TARGET 5. 0. 0.05

EXEC

SUBTITLE

POINT SOURCE TO NORMAL TARGET

SOURCE .01

TARGET 50. .5

EXEC

SUBTITLE

NORMAL SOURCE TO POINT TARGET, VERTICAL

SOURCE 1.

TARGET 5. .05

EXEC

SUBTITLE

POINT SOURCE TO NORMAL TARGET, VERTICAL

SOURCE .01

TARGET 50. .5

EXEC

SUBTITLE

NORMAL SOURCE TO POINT TARGET, 45 DEGREES

SOURCE 1.

TARGET 3.53553 3.53553 .05

EXEC

SUBTITLE

POINT SOURCE TO NORMAL TARGET, 45 DEGREES

SOURCE .01

TARGET 35.3553 35.3553 .5

EXEC

END

TITLE

TEST ZERO RADIUS FOR TARGET

SOURCE

EXEC

END

TITLE

TEST INTERSECTING PINS ERROR MESSAGE

SOURCE 1.

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 3

TARGET 0. 2. 1.1
EXEC
END
STOP

SERIES NO. 1 TITLED: SAMPLE PROBLEM, EQUALLY SIZED PINS.

RUN NO. 1 SUBTITLED: DIAGONAL PIN

NUMBER OF POINTS USED FOR
THE SOURCE PIN INTEGRATION

100

*** SOURCE PIN ***

CENTER POINT

RADIUS

0.0

0.0

2.00000E 00

*** LOWER SHADOWING PIN ***

CENTER POINT

RADIUS

4.25000E 00 0.0

2.00000E 00

*** UPPER SHADOWING PIN ***

CENTER POINT

RADIUS

0.0 4.25000E 00

2.00000E 00

*** TARGET PIN ***

CENTER POINT

RADIUS

4.25000E 00 4.25000E 00

2.00000E 00

*** VIEW FACTOR ***

0.079668

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 5

SERIES NO. 1 TITLED: SAMPLE PROBLEM, EQUALLY SIZED PINS.

RUN NO. 2 SUBTITLED: UNSHADOWED PIN

NUMBER OF POINTS USED FOR
THE SOURCE PIN INTEGRATION

100

*** SOURCE PIN ***

CENTER POINT

0.0 0.0

RADIUS

2.00000E 00

*** TARGET PIN ***

CENTER POINT

4.25000E 00 0.0

RADIUS

2.00000E 00

*** VIEW FACTOR ***

0.166358

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 6

SERIES NO. 1 TITLED: SAMPLE PROBLEM, EQUALLY SIZED PINS.

RUN NO. 3 SUBTITLED: DIAGONAL PIN DOWN ONE

NUMBER OF POINTS USED FOR
THE SOURCE PIN INTEGRATION

200

*** SOURCE PIN ***

CENTER POINT		RADIUS
0.0	0.0	2.00000E 00

*** LOWER SHADOWING PIN ***

CENTER POINT		RADIUS
4.25000E 00	0.0	2.00000E 00

*** UPPER SHADOWING PIN ***

CENTER POINT		RADIUS
4.25000E 00	4.25000E 00	2.00000E 00

*** TARGET PIN ***

CENTER POINT		RADIUS
8.50000E 00	4.25000E 00	2.00000E 00

*** VIEW FACTOR ***

0.001852

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 7

SERIES NO. 1 TITLED: SAMPLE PROBLEM, EQUALLY SIZED PINS.

RUN NO. 4 SUBTITLED: IMAGINARY LEAKAGE PIN

NUMBER OF POINTS USED FOR
THE SOURCE PIN INTEGRATION

100

*** SOURCE PIN ***

CENTER POINT		RADIUS
0.0	0.0	2.00000E 00

*** LOWER SHADOWING PIN ***

CENTER POINT		RADIUS
4.25000E 00	0.0	2.00000E 00

*** UPPER SHADOWING PIN ***

CENTER POINT		RADIUS
8.50000E 00	4.25000E 00	2.00000E 00

*** TARGET PIN ***

CENTER POINT		RADIUS
1.27500E 01	2.12500E 00	2.00000E 00

*** VIEW FACTOR ***

0.000140

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 8

SERIES NO. 1 TITLED: SAMPLE PROBLEM, EQUALLY SIZED PINS.

SUMMARY OF RESULTS FOR SERIES NO. 1

RUN NO.	VIEW FACTOR	INPUT FACTOR	PRODUCT	SUM
1	0.079668	4.000000	0.318673	
2	0.166358	4.000000	0.665430	
3	0.001852	8.000000	0.014813	
4	0.000140	8.000000	0.001117	
				1.00003

RENORMALIZED VIEW FACTORS

RUN NO.	VIEW FACTOR	RUN NO.	VIEW FACTOR	RUN NO.	VIEW FACTOR	RUN NO.	VIEW FACTOR
1	0.079666	2	0.166352	3	0.001852	4	0.000140

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 9

SERIES NO. 2 TITLED: SAMPLE PROBLEM, 2X4 ARRAY OF PINS WITH DIAGONAL PIN, DOWN ONE, LARGER THAN REST

RUN NO. 1 SUBTITLED: VIEW FROM PIN (1,1) TO PIN (2,1) -- ADJACENT UNSHADOWED PIN

NUMBER OF POINTS USED FOR
THE SOURCE PIN INTEGRATION

100

*** SOURCE PIN ***

CENTER POINT

RADIUS

0.0

0.0

2.11000E-01

*** TARGET PIN ***

CENTER POINT

RADIUS

0.0

5.63000E-01

2.11000E-01

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 10

SERIES NO. 2 TITLED: SAMPLE PROBLEM, 2X4 ARRAY OF PINS WITH DIAGONAL PIN, DOWN ONE, LARGER THAN REST

RUN NO. 1 SUBTITLED: VIEW FROM PIN (1,1) TO PIN (2,1) -- ADJACENT UNSHADOWED PIN

DETAILED OUTPUT

PT. NO.	X	Y	SOURCE ANGLE	LOWER ANGLE	UPPER ANGLE	PHI LOWER	PHI UPPER	CONFIGURATION FACTOR
1	2.1100E-01	0.0	-1.5708E 00	1.5708E 00	2.2879E 00	3.1416E 00	3.1416E 00	0.0
2	2.1058E-01	1.3249E-02	-1.5080E 00	1.5700E 00	2.3032E 00	3.0780E 00	3.1416E 00	1.0106E-03
3	2.0934E-01	2.6445E-02	-1.4451E 00	1.5677E 00	2.3179E 00	3.0128E 00	3.1416E 00	4.1395E-03
4	2.0726E-01	3.9537E-02	-1.3823E 00	1.5636E 00	2.3320E 00	2.9459E 00	3.1416E 00	9.5388E-03
5	2.0437E-01	5.2474E-02	-1.3195E 00	1.5578E 00	2.3454E 00	2.8772E 00	3.1416E 00	1.7368E-02
6	2.0067E-01	6.5202E-02	-1.2566E 00	1.5500E 00	2.3580E 00	2.8066E 00	3.1416E 00	2.7794E-02
7	1.9618E-01	7.7674E-02	-1.1938E 00	1.5401E 00	2.3698E 00	2.7339E 00	3.1416E 00	4.0986E-02
8	1.9092E-01	8.9839E-02	-1.1310E 00	1.5280E 00	2.3807E 00	2.6589E 00	3.1416E 00	5.7116E-02
9	1.8490E-01	1.0165E-01	-1.0681E 00	1.5135E 00	2.3904E 00	2.5817E 00	3.1416E 00	7.6350E-02
10	1.7815E-01	1.1306E-01	-1.0053E 00	1.4966E 00	2.3990E 00	2.5019E 00	3.1416E 00	9.8846E-02
11	1.7070E-01	1.2402E-01	-9.4248E-01	1.4772E 00	2.4062E 00	2.4196E 00	3.1416E 00	1.2474E-01
12	1.6258E-01	1.3450E-01	-8.7965E-01	1.4550E 00	2.4119E 00	2.3346E 00	3.1416E 00	1.5415E-01
13	1.5381E-01	1.4444E-01	-8.1681E-01	1.4301E 00	2.4158E 00	2.2469E 00	3.1416E 00	1.8713E-01
14	1.4444E-01	1.5381E-01	-7.5398E-01	1.4023E 00	2.4179E 00	2.1563E 00	3.1416E 00	2.2368E-01
15	1.3450E-01	1.6258E-01	-6.9115E-01	1.3718E 00	2.4179E 00	2.0630E 00	3.1090E 00	2.6347E-01
16	1.2402E-01	1.7070E-01	-6.2832E-01	1.3385E 00	2.4155E 00	1.9668E 00	3.0438E 00	3.0473E-01
17	1.1306E-01	1.7815E-01	-5.6549E-01	1.3026E 00	2.4105E 00	1.8681E 00	2.9760E 00	3.4669E-01
18	1.0165E-01	1.8490E-01	-5.0266E-01	1.2643E 00	2.4026E 00	1.7669E 00	2.9052E 00	3.8866E-01
19	8.9840E-02	1.9092E-01	-4.3982E-01	1.2239E 00	2.3916E 00	1.6637E 00	2.8314E 00	4.2976E-01
20	7.7675E-02	1.9618E-01	-3.7699E-01	1.1818E 00	2.3772E 00	1.5588E 00	2.7542E 00	4.6896E-01
21	6.5203E-02	2.0067E-01	-3.1416E-01	1.1385E 00	2.3592E 00	1.4527E 00	2.6733E 00	5.0510E-01
22	5.2474E-02	2.0437E-01	-2.5133E-01	1.0947E 00	2.3375E 00	1.3460E 00	2.5888E 00	5.3696E-01
23	3.9538E-02	2.0726E-01	-1.8850E-01	1.0510E 00	2.3119E 00	1.2395E 00	2.5004E 00	5.6332E-01
24	2.6446E-02	2.0934E-01	-1.2566E-01	1.0082E 00	2.2826E 00	1.1339E 00	2.4083E 00	5.8306E-01
25	1.3249E-02	2.1058E-01	-6.2833E-02	9.6699E-01	2.2498E 00	1.0298E 00	2.3126E 00	5.9529E-01
26	2.6747E-07	2.1100E-01	-1.2676E-06	9.2801E-01	2.2136E 00	9.2801E-01	2.2136E 00	5.9943E-01
27	-1.3249E-02	2.1058E-01	6.2830E-02	8.9184E-01	2.1746E 00	8.2901E-01	2.1118E 00	5.9529E-01
28	-2.6445E-02	2.0934E-01	1.2566E-01	8.5896E-01	2.1334E 00	7.3329E-01	2.0077E 00	5.8306E-01
29	-3.9537E-02	2.0726E-01	1.8849E-01	8.2966E-01	2.0906E 00	6.4117E-01	1.9021E 00	5.6332E-01
30	-5.2473E-02	2.0437E-01	2.5133E-01	8.0414E-01	2.0469E 00	5.5281E-01	1.7956E 00	5.3696E-01
31	-6.5202E-02	2.0067E-01	3.1416E-01	7.8241E-01	2.0031E 00	4.6826E-01	1.6889E 00	5.0510E-01
32	-7.7674E-02	1.9618E-01	3.7699E-01	7.6443E-01	1.9598E 00	3.8744E-01	1.5828E 00	4.6896E-01
33	-8.9839E-02	1.9092E-01	4.3982E-01	7.5003E-01	1.9177E 00	3.1021E-01	1.4779E 00	4.2976E-01
34	-1.0165E-01	1.8490E-01	5.0265E-01	7.3901E-01	1.8773E 00	2.3636E-01	1.3747E 00	3.8866E-01
35	-1.1306E-01	1.7815E-01	5.6548E-01	7.3112E-01	1.8390E 00	1.6564E-01	1.2735E 00	3.4669E-01
36	-1.2402E-01	1.7070E-01	6.2832E-01	7.2611E-01	1.8031E 00	9.7790E-02	1.1748E 00	3.0473E-01
37	-1.3450E-01	1.6258E-01	6.9115E-01	7.2371E-01	1.7698E 00	3.2557E-02	1.0786E 00	2.6347E-01

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 11

SERIES NO. 2 TITLED: SAMPLE PROBLEM, 2X4 ARRAY OF PINS WITH DIAGONAL PIN, DOWN ONE, LARGER THAN REST

RUN NO. 1 SUBTITLED: VIEW FROM PIN (1,1) TO PIN (2,1) -- ADJACENT UNSHADOWED PIN

DETAILED OUTPUT

PT. NO.	X	Y	SOURCE ANGLE	LOWER ANGLE	UPPER ANGLE	PHI LOWER	PHI UPPER	CONFIGURATION FACTOR
38	-1.4444E-01	1.5381E-01	7.5398E-01	7.2367E-01	1.7393E 00	0.0	9.8527E-01	2.2368E-01
39	-1.5381E-01	1.4444E-01	8.1681E-01	7.2575E-01	1.7115E 00	0.0	8.9471E-01	1.8713E-01
40	-1.6258E-01	1.3450E-01	8.7964E-01	7.2973E-01	1.6866E 00	0.0	8.0695E-01	1.5415E-01
41	-1.7070E-01	1.2402E-01	9.4248E-01	7.3542E-01	1.6644E 00	0.0	7.2196E-01	1.2474E-01
42	-1.7815E-01	1.1306E-01	1.0053E 00	7.4262E-01	1.6450E 00	0.0	6.3965E-01	9.8847E-02
43	-1.8490E-01	1.0165E-01	1.0681E 00	7.5118E-01	1.6281E 00	0.0	5.5992E-01	7.6350E-02
44	-1.9092E-01	8.9840E-02	1.1310E 00	7.6094E-01	1.6136E 00	0.0	4.8265E-01	5.7116E-02
45	-1.9618E-01	7.7675E-02	1.1938E 00	7.7178E-01	1.6015E 00	0.0	4.0772E-01	4.0986E-02
46	-2.0067E-01	6.5203E-02	1.2566E 00	7.8357E-01	1.5916E 00	0.0	3.3500E-01	2.7794E-02
47	-2.0437E-01	5.2474E-02	1.3195E 00	7.9622E-01	1.5838E 00	0.0	2.6435E-01	1.7368E-02
48	-2.0726E-01	3.9538E-02	1.3823E 00	8.0963E-01	1.5779E 00	0.0	1.9565E-01	9.5389E-03
49	-2.0934E-01	2.6446E-02	1.4451E 00	8.2372E-01	1.5739E 00	0.0	1.2877E-01	4.1395E-03
50	-2.1058E-01	1.3249E-02	1.5080E 00	8.3841E-01	1.5716E 00	0.0	6.3592E-02	1.0106E-03
51	-2.1100E-01	5.3493E-07	1.5708E 00	8.5364E-01	1.5708E 00	0.0	2.8610E-06	0.0

*** VIEW FACTOR ***

0.126171

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 12

SERIES NO. 2 TITLED: SAMPLE PROBLEM, 2X4 ARRAY OF PINS WITH DIAGONAL PIN, DOWN CME, LARGER THAN REST

RUN NO. 2 SUBTITLED: VIEW FROM PIN (1,1) TO PIN (2,2) -- DIAGONAL PIN

NUMBER OF POINTS USED FOR
THE SOURCE PIN INTEGRATION

100

*** SOURCE PIN ***

CENTER POINT		RADIUS
0.0	0.0	2.11000E-01

*** LOWER SHADOWING PIN ***

CENTER POINT		RADIUS
5.63000E-01	0.0	2.11000E-01

*** UPPER SHADOWING PIN ***

CENTER POINT		RADIUS
0.0	5.63000E-01	2.11000E-01

*** TARGET PIN ***

CENTER POINT		RADIUS
5.63000E-01	5.63000E-01	2.11000E-01

*** VIEW FACTOR ***

0.085411

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 13

SERIES NO. 2 TITLED: SAMPLE PROBLEM, 2X4 ARRAY OF PINS WITH DIAGONAL PIN, DOWN ONE, LARGER THAN REST

RUN NO. 3 SUBTITLED: VIEW FROM PIN (1,1) TO PIN (2,3) -- DIAGONAL PIN, DOWN ONE

NUMBER OF POINTS USED FOR
THE SOURCE PIN INTEGRATION

100

*** SOURCE PIN ***

CENTER POINT

RADIUS

0.0

0.0

2.11000E-01

*** LOWER SHADOWING PIN ***

CENTER POINT

RADIUS

5.63000E-01

0.0

2.11000E-01

*** UPPER SHADOWING PIN ***

CENTER POINT

RADIUS

5.63000E-01

5.63000E-01

2.11000E-01

*** TARGET PIN ***

CENTER POINT

RADIUS

1.12600E 00

5.63000E-01

2.72500E-01

*** VIEW FACTOR ***

0.018225

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 14

SERIES NO. 2 TITLED: SAMPLE PROBLEM, 2X4 ARRAY OF PINS WITH DIAGONAL PIN, DOWN ONE, LARGER THAN REST

RUN NO. 4 SUBTITLED: VIEW FROM PIN (1,1) TO PIN (2,4) -- DIAGONAL PIN, DOWN TWO

NUMBER OF POINTS USED FOR
THE SOURCE PIN INTEGRATION

100

*** SOURCE PIN ***

CENTER POINT

RADIUS

0.0 0.0

2.11000E-01

*** LOWER SHADOWING PIN ***

CENTER POINT

RADIUS

5.63000E-01 0.0

2.11000E-01

*** UPPER SHADOWING PIN ***

CENTER POINT

RADIUS

1.12600E 00 5.63000E-01

2.72500E-01

*** TARGET PIN ***

CENTER POINT

RADIUS

1.68900E 00 5.63000E-01

2.11000E-01

*** VIEW FACTOR ***

0.000030

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 15

SERIES NO. 2 TITLED: SAMPLE PROBLEM, 2X4 ARRAY OF PINS WITH DIAGONAL PIN, DOWN ONE, LARGER THAN REST

RUN NO. 5 SUBTITLED: VIEW FROM PIN (1,1) TO PIN (1.5,5) -- IMAGINARY LEAKAGE PIN

NUMBER OF POINTS USED FOR
THE SOURCE PIN INTEGRATION

100

*** SOURCE PIN ***

CENTER POINT		RADIUS
0.0	0.0	2.11000E-01

*** LOWER SHADOWING PIN ***

CENTER POINT		RADIUS
5.63000E-01	0.0	2.11000E-01

*** UPPER SHADOWING PIN ***

CENTER POINT		RADIUS
1.12600E 00	5.63000E-01	2.72500E-01

*** TARGET PIN ***

CENTER POINT		RADIUS
2.25200E 00	2.81500E-01	2.11000E-01

*** VIEW FACTOR ***

0.000984

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 16

SERIES NO. 2 TITLED: SAMPLE PROBLEM, 2X4 ARRAY OF PINS WITH DIAGONAL PIN, DOWN ONE, LARGER THAN REST

SUMMARY OF RESULTS FOR SERIES NO. 2

RUN NO.	VIEW FACTOR	INPUT FACTOR	PRODUCT	SUM
1	0.126171	4.000000	0.504684	
2	0.085411	4.000000	0.341645	
3	0.018225	8.000000	0.145798	
4	0.000030	8.000000	0.000243	
5	0.000984	8.000000	0.007870	
				1.00024

RENORMALIZED VIEW FACTORS

RUN NO.	VIEW FACTOR	RUN NO.	VIEW FACTOR	RUN NO.	VIEW FACTOR	RUN NO.	VIEW FACTOR
1	0.126141	2	0.085391	3	0.018220	4	0.000030
5	0.000984						

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 17

SERIES NO. 3 TITLED: 'POINT' SOURCE OR TARGET TESTS

RUN NO. 1 SUBTITLED: NORMAL SOURCE TO POINT TARGET

NUMBER OF POINTS USED FOR
THE SOURCE PIN INTEGRATION

100

*** SOURCE PIN ***

CENTER POINT

RADIUS

0.0

0.0

1.00000E 00

*** TARGET PIN ***

CENTER POINT

RADIUS

5.00000E 00

0.0

5.00000E-02

*** VIEW FACTOR ***

0.003205

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 18

SERIES NO. 3 TITLED: 'POINT' SOURCE OR TARGET TESTS

RUN NO. 2 SUBTITLED: POINT SOURCE TO NORMAL TARGET

NUMBER OF POINTS USED FOR
THE SOURCE PIN INTEGRATION

100

*** SOURCE PIN ***

CENTER POINT		RADIUS
0.0	0.0	1.00000E-C2

*** TARGET PIN ***

CENTER POINT		RADIUS
5.00000E 01	0.0	5.00000E-C1

*** VIEW FACTOR ***

0.003183

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 19

SERIES NO. 3 TITLED: 'POINT' SOURCE OR TARGET TESTS
RUN NO. 3 SUBTITLED: NORMAL SOURCE TO POINT TARGET, VERTICAL

NUMBER OF POINTS USED FOR
THE SOURCE PIN INTEGRATION

100

*** SOURCE PIN ***

CENTER POINT

RADIUS

0.0

0.0

1.00000E 00

*** TARGET PIN ***

CENTER POINT

RADIUS

0.0

5.00000E 00

5.00000E-02

*** VIEW FACTOR ***

0.003205

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 20

SERIES NO. 3 TITLED: 'POINT' SOURCE OR TARGET TESTS
RUN NO. 4 SUBTITLED: POINT SOURCE TO NORMAL TARGET, VERTICAL

NUMBER OF POINTS USED FOR
THE SOURCE PIN INTEGRATION

100

*** SOURCE PIN ***

CENTER POINT		RADIUS
0.0	0.0	1.00000E-02

*** TARGET PIN ***

CENTER POINT		RADIUS
0.0	5.00000E 01	5.00000E-01

*** VIEW FACTOR ***

0.003183

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 21

SERIES NO. 3 TITLED: 'POINT' SOURCE OR TARGET TESTS
RUN NO. 5 SUBTITLED: NORMAL SOURCE TO POINT TARGET, 45 DEGREES

NUMBER OF POINTS USED FOR
THE SOURCE PIN INTEGRATION

100

*** SOURCE PIN ***

CENTER POINT

RADIUS

0.0

0.0

1.00000E 00

*** TARGET PIN ***

CENTER POINT

RADIUS

3.53553E 00

3.53553E 00

5.00000E-02

*** VIEW FACTOR ***

0.003205

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/31/72 PAGE 22

SERIES NO. 3 TITLED: 'POINT' SOURCE OR TARGET TESTS
RUN NO. 6 SUBTITLED: POINT SOURCE TO NORMAL TARGET, 45 DEGREES

NUMBER OF POINTS USED FOR
THE SOURCE PIN INTEGRATION

100

*** SOURCE PIN ***

CENTER POINT		RADIALS
0.0	0.0	1.0000CE-02

*** TARGET PIN ***

CENTER POINT		RADIALS
3.53553E 01	3.53553E 01	5.0000CE-01

*** VIEW FACTOR ***

0.003184

C-24

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 23

SERIES NO. 3 TITLED: 'POINT' SOURCE OR TARGET TESTS

SUMMARY OF RESULTS FOR SERIES NO. 3

RUN NO.	VIEW FACTOR	INPUT FACTOR	PRODUCT	SUM
1	0.003205	0.0	0.0	
2	0.003183	0.0	0.0	
3	0.003205	0.0	0.0	
4	0.003183	0.0	0.0	
5	0.003205	0.0	0.0	
6	0.003184	0.0	0.0	
				0.0

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 24

SERIES NO. 4 TITLED: TEST ZERO RADIUS FOR TARGET
RUN NO. 1 SUBTITLED:

NUMBER OF POINTS USED FOR
THE SOURCE PIN INTEGRATION

100

*** SOURCE PIN ***

CENTER POINT		RADIUS
0.0	0.0	0.0

*** TARGET PIN ***

CENTER POINT		RADIUS
0.0	0.0	0.0

*** INPUT ERROR *** SOURCE OR TARGET PIN HAS A NONPOSITIVE RADIUS.

*** DUE TO AN INPUT ERROR THE PROGRAM IS SKIPPING TO THE NEXT SERIES ***

C-26

2

(VIEWPIN/ 1, 1-10-71, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS DATE OF RUN 02/01/72 PAGE 25

SERIES NO. 5 TITLED: TEST INTERSECTING PINS ERROR MESSAGE

RUN NO. 1 SUBTITLED:

NUMBER OF POINTS USED FOR
THE SOURCE PIN INTEGRATION

100

*** SOURCE PIN ***

CENTER POINT

RADIUS

0.0 0.0

1.00000E 00

*** TARGET PIN ***

CENTER POINT

RADIUS

0.0 2.00000E 00

1.10000E 00

*** INPUT ERROR *** PIN NUMBER 1 INTERSECTS PIN NUMBER 4

*** DUE TO AN INPUT ERROR THE PROGRAM IS SKIPPING TO THE NEXT SERIES ***

STOP CARD ENCOUNTERED, NORMAL END OF PROGRAM ; HOWEVER, 2 SERIES HAVE (HAS) BEEN SKIPPED DUE TO ONE OR MORE INPUT ERRORS.

APPENDIX D
SOURCE LISTING

VIEWPIN SOURCE LIST

```

C      MAIN FOR VIEWPIN
C      VIEWPIN CALCULATES VIEW FACTORS FOR CIRCULAR PINS.
COMMON /ARYCOM/ FAC(20),RA(4),XA(4),VIEWFC(20),YA(4)
COMMON /INTCOM/ IEND,IEXEC,INPUTU,IPT,ISEC,ISIDE,
1      ISKPSR,ISTOP,LDETAI,NPT,NSKPSR
COMMON /RLCOM/ CONFIG,HAFPI,PHI1,PHI2,PI,PI2,
1      SFORM,SUMFAC,T1,T2,THETA,TS,XNPT,XV,YV
COMMON /TITCOM/ RDATE,VDATE,TITLE(20),SUBTIT(20),
1      IPAGEF,IRUN,ISERI ,IVERS,LINER,NPAGE
REAL*8 RDATE,VDATE
DIMENSION RUCH(6,4)
DATA RUCH / 96HRUN NO.   VIEW FACTOR   RUN NO.   VIEW FACTOR
1RUN NO.   VIEW FACTOR   RUN NO.   VIEW FACTOR
DATA HEND /4HEND /
IVERS = 1
CALL ZERO(1)
CALL PAGER
CALL PRININ(INPUTU)
100  CONTINUE
CALL ZERO(2)
200  CONTINUE
CALL ZERO(3)
CALL ININ
IF (ISTOP .EQ. 1) GO TO 900
IF (ISKPSR .EQ. 1) GO TO 800
IF (IEND .NE. 1) GO TO 230
IRUNSV = IRUN - 1
IRUN = 0
GO TO 600
230  CONTINUE
CALL CHKIN
IF (ISKPSR .EQ. 1) GO TO 800
IF (LDETAI .EQ.0) GO TO 240
CALL PAGER
WRITE(6,9001)
9001  FORMAT(/ 1H ,53X,15HDETAILED OUTPUT,//1H ,
*      7HPT. NO., 7X, 1HX, 12X, 1HY, 11X, 6HSOURCE, 7X,
1      5HLOWER, 8X, 5HUPPER, 8X, 3HPHI, 10X, 3HPHI, 8X,
2      13HCONFIGURATION, / 40X, 2( 5HANGLE, 8X),
3      5HANGLE, 7X, 5HLOWER, 8X, 5HUPPER, 11X, 6HFACTOR/)
240  CONTINUE
XNPT = NPT
DELTA = PI2 / XNPT
DO 500 IPT = 1,NPT
XIPT = IPT - 1
THETA = DELTA * XIPT
CALL CALC
IF (ISEC .NE. 1 .AND. ISIDE .NE. -1) GO TO 500
IF (LDETAI.EQ. 0) GO TO 250
LINER = LINER + 1
IF (LINER .LT. 45) GO TO 245
CALL PAGER

```

VIEWPIN SOURCE LIST

```

WRITE(6,9001)
245  CONTINUE
WRITE(6,9002) IPT,XV,YV,TS,T1,T2,PHI1,PHI2,CONFIG
9002  FORMAT(1H ,I3,5X,1P8E13.4)
250  CONTINUE
500  CONTINUE
VIEWFC(IRUN) = VIEWFC(IRUN)/ XNPT
WRITE(6,9003) VIEWFC(IRUN)
9003  FORMAT(/1H0,51X,19H*** VIEW FACTOR *** ,//1H ,55X,F9.6)
GO TO 200
600  CONTINUE
CALL PAGER
DO 650 I = 1,IRUNSV
SUMFAC = SUMFAC + VIEWFC(I)*FAC(I)
650  CONTINUE
WRITE(6,9005) ISERI
9005  FORMAT(/ 1H ,43X,33HSUMMARY OF RESULTS FOR SERIES NO., I3)
WRITE(6,9006)
9006  FORMAT(/1H , 7HRUN NO., 13X,11HVIEW FACTOR, 9X,12HINPUT FACTOR,
1      8X ,7HPRODUCT, 13X, 3HSUM )
DO 680 I = 1,IRUNSV
VXF = VIEWFC (I) * FAC(I)
WRITE(6,9007) I,VIEWFC(I),FAC(I),VXF
9007  FORMAT(1H , I4, 18X, F8.6,12X, F8.6, 10X, F8.6 )
680  CONTINUE
WRITE(6,9008) SUMFAC
9008  FORMAT( 1H ,78X, F7.5)
IF (FAC(1) .EQ. 0.0) GO TO 690
C  NORMALIZE TO 1.0
DO 685 I = 1,IRUNSV
VIEWFC(I) = VIEWFC(I) / SUMFAC
685  CONTINUE
WRITE(6,9009)
9009  FORMAT(/1H ,48X, 26H RENORMALIZED VIEW FACTORS //)
M4 = 4
IF (IRUNSV .LT. 4) M4 = IRUNSV
WRITE(6,9010)((RUCH(I,J),I=1,6),J=1,M4)
9010  FORMAT(/ 1H , 4(6A4,6X) )
WRITE(6,9000)
9000  FORMAT(1H )
WRITE(6,9011) (I,VIEWFC(I), I=1,IRUNSV)
9011  FORMAT(1H ,(4(1H ,I3,8X, F8.6,10X)//))
690  CONTINUE
GO TO 100
800  CONTINUE
IF (ISKPSR .NE. 1) GO TO 910
C  SKIP SERIES DUE TO INPUT ERROR
C  READ THROUGH NEXT END CARD
DO 820 I = 1,1000
READ(INPUTU,9016) CODE
9016  FORMAT(A4)
IF (CODE .EQ. HEND ) GO TO 830

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VIEWPIN SOURCE LIST

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820  CONTINUE
830  CONTINUE
      NSKPSR = NSKPSR + 1
      WRITE(6,9013)
9013  FORMAT(41H0*** DUE TO AN INPUT ERROR THE PROGRAM IS,
1      32H SKIPPING TO THE NEXT SERIES *** )
910  CONTINUE
      GO TO 100
900  CONTINUE
      WRITE(6,9012)
9012  FORMAT(//45H STOP CARD ENCOUNTERED, NORMAL END OF PROGRAM )
      IF (NSKPSR .GT. 0) WRITE(6,9014) NSKPSR
9014  FORMAT(1H+,45X,10H; HOWEVER, ,I3,24H SERIES HAVE (HAS) BEEN
1      40H SKIPPED DUE TO ONE OR MORE INPUT ERRORS.)
      STOP
      END
      BLOCK DATA
      COMMON /TITCOM/ RDATE,VDATE,TITLE(20),SUBTIT(20),
1      IPAGEF,IRUN,ISERI ,IVERS,LINER,NPAGE
      REAL*8 RDATE,VDATE
      DATA IPAGEF/ 0/, VDATE/8H 1-10-71/, IVERS/999/
      END
      SUBROUTINE CALC
      COMMON /ARYCOM/ FAC(20),RA(4),XA(4),VIEWFC(20),YA(4)
      COMMON /INTCOM/ IEND,IEXEC,INPUTU,IPT,ISEC,ISIDE,
1      ISKPSR,ISTOP,LDETAI,NPT,NSKPSR
      COMMON /RLCOM/ CONFIG,HAFPI,PHI1,PHI2,PI,PI2,
1      SFORM,SUMFAC,T1,T2,THETA,TS,XNPT,XV,YV
      COMMON /TITCOM/ RDATE,VDATE,TITLE(20),SUBTIT(20),
1      IPAGEF,IRUN,ISERI ,IVERS,LINER,NPAGE
      REAL*8 RDATE,VDATE
      DIMENSION T(2,4)
      XV = RA(1) * COS(THETA)
      YV = RA(1) * SIN(THETA)
      CALL INTSEC(XV,YV,RA(1),XA(4),YA(4),RA(4),ISEC,ISIDE)
      IF (ISEC .NE. 1 .AND. ISIDE .NE. -1) GO TO 900
C      TS IS THE TANGENT TO THE SOURCE PIN AT (XV,YV)
      TS = ATAN2(-XV,YV)
      DO 300 I = 2,4
      IF (RA(I) .EQ. 0.0) GO TO 250
      CALL PTTANG(XV,YV,XA(I),YA(I),RA(I),T1,T2)
      GO TO 280
250  CONTINUE
      T1 = -9999.
      IF (I .EQ. 3) T1 = +9999.
      T2 = T1
280  CONTINUE
      T(1,I) = T1
      T(2,I) = T2
300  CONTINUE
      T1 = AMAX1(T(1,2),T(2,2),AMIN1(T(1,4),T(2,4) ) )
      T2 = AMIN1(T(1,3),T(2,3),AMAX1(T(1,4),T(2,4) ) )

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                                VIEWPIN SOURCE LIST
IF (T1 .GE. T2) GO TO 390
IF (T1 .LT. TS .OR. T1 .GE. TS + PI) GO TO 320
PHI1 = T1 - TS
GO TO 350
320 CONTINUE
PHI1 = 0.0
IF (T1 .GE. TS) PHI1 = PI
350 CONTINUE
IF (T2 .LT. TS .OR. T2 .GE. TS + PI) GO TO 370
PHI2 = T2 - TS
GO TO 380
370 CONTINUE
PHI2 = 0.0
IF (T2 .GE. TS) PHI2 = PI
380 CONTINUE
CONFIG = .5*(COS(PHI1) - COS(PHI2))
GO TO 400
390 CONTINUE
CONFIG = 0.0
400 CONTINUE
VIEWFC(IRUN) = VIEWFC(IRUN) + CONFIG
900 CONTINUE
RETURN
END
SUBROUTINE CHKIN
C CHECKS CARD INPUT
COMMON /ARYCOM/ FAC(20),RA(4),XA(4),VIEWFC(20),YA(4)
COMMON /INTCOM/ IEND,IEXEC,INPUTU,IPT,ISEC,ISIDE,
1 ISKPSR,ISTOP,LDETAI,NPT,NSKPSR
COMMON /RLCOM/ CONFIG,HAFPI,PHI1,PHI2,PI,PI2,
1 SFORM,SUMFAC,T1,T2,THETA,TS,XNPT,XV,YV
COMMON /TITCOM/ DATE,VDATE,TITLE(20),SUBTIT(20),
1 IPAGEF,IRUN,ISERI ,IVERS,LINER,NPAGE
IF (RA(1) .GT. 0.0 .AND. RA(4) .GT. 0.0) GO TO 200
WRITE(6,9000)
WRITE(6,9001)
9000 FORMAT(/,1H ,19H*** INPUT ERROR *** )
9001 FORMAT( 1H+,25X,
1 46HSOURCE OR TARGET PIN HAS A NONPOSITIVE RADIUS.)
ISKPSR = 1
200 CONTINUE
IF (RA(2) .GE. 0.0 .AND. RA(3) .GE. 0.0) GO TO 300
WRITE(6,9000)
WRITE(6,9002)
9002 FORMAT( 1H+,25X,37HA SHADOWING PIN HAS A NEGATIVE RADIUS )
ISKPSR = 1
300 CONTINUE
DO 350 I = 1,3
IP1 = I + 1
DO 330 II = IP1,4
IF (RA(II).EQ. 0.0 .OR. RA(II) .EQ. 0.0) GO TO 320
IF ((XA(II) - XA(I))**2 + (YA(II) - YA(I))**2 .GT.

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                                VIEWPIN SOURCE LIST
1      (RA(II) + RA(I))*2 ) GO TO 330
      WRITE(6,9000)
      WRITE(6,9003) I, II
9003  FORMAT(1H+,25X,
1      10HPIN NUMBER, I2,22H INTERSECTS PIN NUMBER, I2)
      ISKPSR = 1
320  CONTINUE
330  CONTINUE
350  CONTINUE
      RETURN
      END
      SUBROUTINE ININ
      DIMENSION HAR(12),IA(9)
      COMMON /ARYCOM/ FAC(20),RA(4),XA(4),VIEWFC(20),YA(4)
      COMMON /INTCOM/ IEND,IEXEC,INPUTU,IPT,ISEC,ISIDE,
1      ISKPSR,ISTOP,LDETAI,NPT,NSKPSR
      COMMON /RLCOM/ CONFIG,HAFPI,PHI1,PHI2,PI,P12,
1      SFORM,SUMFAC,T1,T2,THETA,TS,XNPT,XV,YV
      COMMON /TITCOM/ RDATE,VDATE,TITLE(20),SUBTIT(20),
1      IPAGEF,IRUN,ISERI ,IVERS,LINER,NPAGE
      REAL*8 RDATE,VDATE
      DATA HAR / 4HEXEC,      4HEND ,  4HTITL,  4HSUBT,  4HDETA,
1      4HCONC,      4HSOUR,  4HLOWE,  4HUPPE,  4HTARG,
2      4HNPT ,      4HSTOP
100  CONTINUE
      READ (INPUTU,9001) CODE,C58,X,Y,R,(IA(I),I=1,9)
      DO 200 I = 1,12
      IH = I
      IF (CODE .EQ. HAR(I) ) GO TO 300
200  CONTINUE
      WRITE(6,9003) CODE,C58
9003  FORMAT(50H0*** INPUT ERROR *** COLUMNS 1 TO 8 DO NOT CONTAIN,
1      34H A PROPER CODE. CODE IN ERROR = ', 2A4,2H'. )
      GO TO 800
300  CONTINUE
      GO TO (490,410,420,430,440,450,460,470,470,480,880),IH
410  CONTINUE
C  END CARD
      DO 413 I = 1,9
      FAC(I) = IA(I)
413  CONTINUE
      IEND = 1
      GO TO 900
420  CONTINUE
C  TITLE CARD
      READ(INPUTU,9002) TITLE
9002  FORMAT(20A4)
      GO TO 100
430  CONTINUE
C  SUBTITLE CARD
      READ(INPUTU,9002) SUBTIT
      GO TO 100

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VIEWPIN SOURCE LIST

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440 CONTINUE
C DETAIL CARD
    LDETAI = 1
    GO TO 100
450 CONTINUE
C CONCISE CARD
    LDETAI = 0
    GO TO 100
460 CONTINUE
C SOURCE PIN CARD
    RA(1) = R
    GO TO 100
470 CONTINUE
C LOWER, UPPER AND TARGET PIN CARDS
    IHM6 = IH-6
    XA(IHM6) = X
    YA(IHM6) = Y
    RA(IHM6) = R
    GO TO 100
480 CONTINUE
C NPT CARD
    NPT = IA(1)
    GO TO 100
490 CONTINUE
    IEXEC = 1
500 CONTINUE
    CALL PAGER
    WRITE(6,9010) NPT
9010 FORMAT( /1H ,48X,25HNUMBER OF POINTS USED FOR /
1      1H ,48X,26HTHE SOURCE PIN INTEGRATION //,59X,14//)
    DO 600 I = 1,4
    IF ((I.EQ.2 .AND. RA(2).EQ.0.0).OR.(I.EQ.3.AND.RA(3).EQ.0.0))
1 GO TO 600
    GO TO (510,520,530,540),I
510 WRITE(6,9021)
9021 FORMAT(//1H ,51X,18H*** SOURCE PIN *** )
    GO TO 550
520 WRITE(6,9022)
9022 FORMAT(//1H ,47X,27H*** LOWER SHADOWING PIN *** )
    GO TO 550
530 WRITE(6,9023)
9023 FORMAT(//1H ,47X,27H*** UPPER SHADOWING PIN *** )
    GO TO 550
540 WRITE(6,9024)
9024 FORMAT(//1H ,51X,18H*** TARGET PIN *** )
550 CONTINUE
    WRITE(6,9006) XA(I),YA(I),RA(I)
9006 FORMAT(/ 1H ,34X,12HCENTER POINT,31X, 6HRADIUS,/
1      1H0,25X,1PE13.5,4X,1PE13.5,18X,1PE14.5 )
600 CONTINUE
    GO TO 900
800 CONTINUE

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                                VIEWPIN SOURCE LIST
C  SKIP SERIES DUE TO INPUT ERROR
    ISKPSR = 1
    GO TO 900
880  CONTINUE
C  STOP CARD
    ISTOP = 1
900  CONTINUE
9001  FORMAT(2A4,3X,3E11.0, 914)
    RETURN
    END
    SUBROUTINE INTSEC(XV,YV,R1,X4,Y4,R4,ISEC,ISIDE)
C      FINDS WHETHER TANGENT TO CIRCLE  $X^{**2} + Y^{**2} = R1^{**2}$  AT POINT
C      ON CIRCLE (XV,YV) INTERSECTS THE CIRCLE
C       $(X-X4)^{**2} + (Y-Y4)^{**2} = R4^{**2}$ 
C      TANGENT LINE IS  $XV*X + YV*Y = R1^{**2}$ 
C      ISEC = -1;      FOR NO INTERSECTION
    ISEC = -1
    R1SQ = R1**2
    IF (ABS(YV) .LE. .00001 * ABS(XV) )      GO TO 200
    YVSQ = YV**2
    A = 1. +XV**2/YVSQ
    B = -2.*X4 -2. * R1SQ * XV / YVSQ      + 2.*Y4 *XV/YV
    C = X4**2 + (R1SQ/YV)**2 - 2.*Y4 * R1SQ /YV +Y4**2 - R4**2
    IF (B**2 - 4. * A * C .GT. 0.0 ) ISEC = 1
    GO TO 300
200  CONTINUE
C      YV IS ESSENTIALLY ZERO
    IF (R4**2 - (R1SQ /XV - X4) **2 .GT. 0.0) ISEC = 1
    IF (ISEC .EQ. 1) GO TO 900
300  CONTINUE
C      FINDS WHETHER (0,0) AND (X4,Y4) ARE ON SAME SIDE OF TANGENT
C      ISIDE = -1;      FOR DIFFERENT SIDES
    ISIDE = -1
    IF (XV*X4 + YV*Y4.LT.0.99999 * R1**2)      ISIDE = 1
900  CONTINUE
    RETURN
    END
    SUBROUTINE PAGER
    COMMON /TITCOM/ RDATE,VDATE,TITLE(20),SUBTIT(20),
1      IPAGEF,IRUN,ISERI ,IVERS,LINER,NPAGE
    REAL*8 RDATE,VDATE
    IF (IPAGEF .NE. 0) GO TO 400
    LINER = 0
    NPAGE = 0
    CALL DATE(RDATE)
    IPAGEF = 1
    GO TO 900
400  CONTINUE
    NPAGE = NPAGE + 1
    LINER = 7
    WRITE(6,9001) IVERS,VDATE,RDATE,NPAGE
9001  FORMAT(10H1VIEWPIN/,I2,2H, , A8,

```

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                                VIEWPIN SOURCE LIST
1 60H, G. L. SINGER) CALCULATES VIEW FACTORS FOR CIRCULAR PINS
2      12HDATE OF RUN ,A8,6H PAGE,I4,/)
      IF (IPAGEF.EQ. 2) GO TO 900
      WRITE(6,9002) ISERI , TITLE
9002  FORMAT( 11H SERIES NO., I3,4X , 9HTITLED: ,20A4/)
      IF (IRUN .NE. 0) WRITE(6,9003) IRUN, SUBTIT
9003  FORMAT( 8H RUN NO. I3,4X, 12HSUBTITLED: ,20A4/)
      800  CONTINUE
      WRITE(6,9005)
9005  FORMAT(1H0)
      900  CONTINUE
      RETURN
      END
      SUBROUTINE PRININ(INPUTU)
      REAL*8 A(10),STP
C      READS CARD INPUT, PLACES IT ON SCRATCH UNIT,
C      PRINTS IT, THEN CHANGES INPUT UNIT NUMBER
      COMMON /TITCOM/ RDATE,VDATE,TITLE(20),SUBTIT(20),
1      IPAGEF,IRUN,ISERI ,IVERS,LINER,NPAGE
      REAL*8 RDATE,VDATE
      IPAGEF = 2
      CALL PAGER
      DATA STP/8HSTOP /
      WRITE(6,9000)
      LINE = 0
      DO 300 I = 1,10000
      READ(INPUTU,9001) A
      WRITE(4,9001) A
      WRITE(6,9002) A
      IF ( A(1) .EQ. STP) GO TO 400
      LINE = LINE + 1
      IF (LINE .GT. 50) CALL PAGER
      IF (LINE .GT. 50) LINE = 0
300  CONTINUE
400  CONTINUE
      INPUTU = 4
      REWIND 4
      IPAGEF = 1
9000  FORMAT(1H0,28H ALL INPUT CARDS AS READ IN: / )
9001  FORMAT (10A8)
9002  FORMAT (1H ,10A8)
      RETURN
      END
      SUBROUTINE PTTANG(XPQ,YPQ,X1Q,Y1Q,R1Q,TAQ,TBQ)
C      PTTANG CALCS. THE POINTS (XTA,YTA) AND (XTB,YTB) AT WHICH THE
C      TANGENT TO THE CIRCLE CENTERED AT (X1,Y1) WITH RADIUS R1
C      FROM A POINT (XP,YP) OUTSIDE THE CIRCLE, TOUCHES THE CIRCLE.
C      THIS IS DONE BY FINDING THE MIDPOINT BETWEEN (XP,YP) AND
C      (X1,Y1) ,CALL IT (X2,Y2), AND FINDING THE INTERSECTION OF
C      THE TWO CIRCLES  $(X-X1)**2 + (Y-Y1)**2 = R1**2$ 
C      AND  $(X-X2)**2 + (Y-Y2)**2 = R2**2$ 
C      TA AND TB ARE ANGLES OF TANGENT LINES

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                                VIEWPIN SOURCE LIST
REAL*8      A,AA,B,BB,C,D1,D2,DISC,DISCSQ,DQ,DZ,E1,E2,
1           SQRG,SQRXX,
2           EQ,EZ,F1,F2,FQ,FZ,PI,R1,R2SQ,TA,TB,
3           X1,X2,XP,XTA,XTB,Y1,Y2,YP,YTA,YTB
      XP = XPQ
      YP = YPQ
      X1 = X1Q
      Y1 = Y1Q
      R1 = R1Q

      PI = 3.14159265
C      FIND MID-POINT
      X2 = (XP+X1) * .5
      Y2 = (YP+Y1) * .5
      R2SQ = (X1-X2)**2 + (Y1-Y2)**2
      D1 = -2. * X1
      D2 = -2. * X2
      E1 = -2. * Y1
      E2 = -2. * Y2
      F1 = X1**2 + Y1**2 - R1**2
      F2 = X2**2 + Y2**2 - R2SQ
      DZ = D2 - D1
      EZ = E1-E2
      FZ = F2 - F1
      DQ = DZ**2
      EQ = EZ**2
      FQ = FZ**2
      IF (EZ .EQ. 0.0) GO TO 600
C      FIRST SOLVE FOR Y WHEN Y1 .NE. Y2
      A = 1. + DQ / EQ
      B = 2.0 * DZ * FZ / EQ + D1 + E1 * DZ/EZ
      C = FQ / EQ + E1 * FZ / EZ + F1
      IF (B .NE. 0.0) GO TO 100
      XTA = DSQRT(C/A)
      XTB = -XTA
      GO TO 250
100     CONTINUE
      DISCSQ = B**2 - 4.*A*C
      IF (DISCSQ .GE. 0.0) GO TO 200
      DISC =DSQRT(DABS(DISCSQ))
      IF (DABS(B).GT. 10000. * DISC) GO TO 150
      WRITE(6,9001)
9001    FORMAT(//1H ,18H*** ERROR STOP ***,
1       // 1H ,47HTHE DISCRIMINANT IN S. R. PTTANG IS LESS THAN 0 )
      STOP
150     CONTINUE
C      THE DISCRIMINANT IS ESSENTIALLY ZERO
      XTB = -B / (2.* A )
      XTA = XTB
      GO TO 300
200     CONTINUE
      DISC =DSQRT(DISCSQ)
      XTA = (- B + DISC) / (2.*A)

```

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 $XTB = (-B - DISC) / (2 * A)$

```

250  CONTINUE
    AA = DZ/EZ
        BB = FZ/EZ
    YTA = AA * XTA + BB
    YTB = AA * XTB + BB
300  CONTINUE
    GO TO 800
600  CONTINUE
C      SOLVE FOR X FIRST WHEN Y1 = Y2
        XTB = -FZ / DZ
    XTA = XTB
    SQRG = R1**2 - (XTA - X1)**2
    IF (SQRG .GE. 0.0 ) GO TO 620
    WRITE(6,9002) SQRG,R1,XTA
9002  FORMAT(1H0, 35HIN PTTANG, SQRT ARG .LT. 0, SET = 0,1P3E15.6)
    SQRXX = 0.0
    GO TO 640
620  CONTINUE
    SQRXX = DSQRT(SQRG)
640  CONTINUE
    YTA = Y1 + SQRXX
    YTB = Y1 - SQRXX
800  CONTINUE
    TA = DATAN2(YTA-YP, XTA-XP)
    TB = DATAN2(YTB-YP, XTB-XP)
    TAQ = TA
    TBQ = TB
    RETURN
    END
    SUBROUTINE ZERO(IZ)
    COMMON /ARYCOM/ FAC(20),RA(4),XA(4),VIEWFC(20),YA(4)
    COMMON /INTCOM/ IEND,IEXEC,INPUTU,IPT,ISEC,ISIDE,
1      ISKPSR,ISTOP,LDETAI,NPT,NSKPSR
    COMMON /RLCOM/ CONFIG,HAFPI,PHI1,PHI2,PI,PI2,
1      SFORM,SUMFAC,T1,T2,THETA,TS,XNPT,XV,YV
    COMMON /TITCOM/ RDATE,VDATE,TITLE(20),SUBTIT(20),
1      IPAGEF,IRUN,ISERI ,IVERS,LINER,NPAGE
    REAL*8 RDATE,VDATE
    DATA BLANK/4H /
    GO TO (100,200,300,400      ),IZ
100  CONTINUE
    NSKPSR = 0
    IPAGEF = 0
    ISERI = 0
    ISTOP = 0
    PI = 3.1415926
    NPT = 100
    PI2 = 2.0 * PI
    HAFPI = .5 * PI
    LDETAI = 0
    INPUTU = 5

```

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```
GO TO 900
200 CONTINUE
   IRUN = 0
   ISERI = ISERI + 1
   SUMFAC = 0.0
   ISKPSR = 0
   DO 220 I = 1,20
   TITLE(I) = BLANK
   FAC(I) = 0.0
220 CONTINUE
   SFORM = 0.0
   DO 250 I = 1,4
   XA(I) = 0.0
   YA(I) = 0.0
   RA(I) = 0.0
250 CONTINUE
   IEND = 0
   GO TO 900
300 CONTINUE
   IRUN = IRUN + 1
   DO 320 I = 1,20
   SUBTIT(I) = BLANK
320 CONTINUE
   VIEWFC(IRUN) = 0.0
   IPT = 0
   IEXEC = 0
400 CONTINUE
900 CONTINUE
   RETURN
   END
```


APPENDIX E

DERIVATION OF THE VIEW FACTOR EQUATION

In order to derive the two-dimensional view factor equation,

$$v_{12} = \frac{1}{L_1} \int_{L_1} \int_{L_2} \frac{\cos\theta_1 \cos\theta_2}{2S} d\ell_2 d\ell_1$$

we shall consider the radiation, dR , emitted from an infinitesimal segment, $d\ell_1$, on a curve L_1 . Refer to Figure E-1 for notation.

This radiation emitted must be proportional to the segment length times the normal component to this segment, $\cos\theta_1 d\ell_1$, integrated over the possible angles of emission. Thus for some constant, K , which we shall determine, we have

$$\begin{aligned} dR &= K \int_{-\pi/2}^{\pi/2} d\ell_1 \cos\theta_1 d\theta_1 \\ &= 2Kd\ell_1 \end{aligned}$$

Integration over L_1 yields the total radiation emitted by the curve L_1 , which must equal 1.0.

$$\int_{L_1} dR = \int_{L_1} 2Kd\ell_1$$

$$1 = 2KL_1$$

$$K = \frac{1}{2L_1}$$

so that

$$dR = \frac{1}{2L_1} \int_{L_1} d\ell_1 \cos\theta_1 d\theta_1$$

From Figure E-1, we see that

$$d\theta_1 = \frac{d\ell_2 \cos\theta_2}{S}$$

so that

$$dR = \frac{1}{2L_1} \int_{L_1} \frac{d\ell_1 \cos\theta_1 \cos\theta_2 d\ell_2}{S}$$

Integrating dR over the target curve, L_2 , we have the total radiation, R , which is the view factor.

$$v_{12} = R = \frac{1}{L_1} \int_{L_1} \int_{L_2} \frac{\cos \theta_1 \cos \theta_2 d\lambda_2 d\lambda_1}{2S}$$

Fig. E-1 View Factor Equation Notation