APR 12 1965

PRATT & WHITNEY AIRCRAFT

CANEL

TECHNICAL INFORMATION MEMORANDUM

MASTER

SUBJECT: SCARF - A Neutron Scattering Code
for SNAP Type Radiators

TIM NO. 799

DATE OF REPORT: Jan. 23, 1964

COPIES TO: W. G. Kennedy, C. C. Bigelow,
J. R. Smolen, H. J. Richings, W. J. Fader,
R. Spring, R. S. Check, A. Larson, P. I. Perry,
A. I. Chalfant, H. Johnson
Circ: R. I. Strough, H. R. Dytko

WRITTEN BY: W. Granter *WJG*

APPROVED BY: H. J. Richings
HJR

Unclassified
Classification

C. C. Bigelow
Authorized Classifier

1/21/64
Date

I. General Description

The SCARF radiator scattering code was written by Atomics International and recently received by CANEL. It was written primarily to determine a first order approximation to the fast neutron current at a target point due to neutrons that scatter off a radiator fin. The data printed out by SCARF enables one to locate the reactor sources that are the major contributors to the fluxes at various mesh points on the scattering surface i.e. fin, and also those areas of the scattering surface that contribute significantly to the neutron flux at the target. Fig. 1 describes the general system geometry.

A brief description of the analytical methods used will be given here, while most of the details will be found in the section on theory.

The code assumes an isotropic neutron source for each volume element in the core and side reflector. Each of these sources is attenuated exponentially through the various regions between it and each scattering mesh point on the fin. From the resultant fluxes on the fin surface, the differential scattering cross sections, and the atomic density of the fin surface, the flux at a target point can be calculated.

As mentioned previously, the purpose of SCARF is to give a first order approximation to the neutron current. It is a relatively cheap method of "scoping in" on a shield radiator-design. In the final analysis, Monte Carlo methods will have to be used. Some of the "short comings" of SCARF that would be treated properly using Monte Carlo are as follows:

PATENT CLEARANCE OBTAINED: REFERENCE TO
THE PUBLIC IS APPROVED. ~~REDACTED~~
ARE ON FILE IN THE ~~REDACTED~~ SECTION.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

January 23, 1964

1. Use of an energy independent isotropic source
2. Neglect of attenuation in the radiator
3. Only single scattering is accounted for
4. Side reflector sources can only be approximated,
i. e. first scattering collisions
5. The use of an exponential point kernel method in
a finite geometry

The time involved to run a case varies with the number of straight line trajectories used, which in turn are approximately equal to the product of the number of sources, fin mesh points, and target points. A checkout case with a $6 \times 6 \times 4$ source region mesh, a 10×10 fin mesh, and a 6×6 target mesh took about 6 minutes or 7×10^{-4} sec/mesh point.

II. Theory

A. Geometry

Fig 2 describes the system geometry along with all the geometrical input parameters. Fig 3 describes the mesh structure of the reactor, fin, and target. The source region which can include both the core and side reflector is divided up into volume elements. The core Δr and reflector Δr need not be the same. However, the total number of Δr 's in the core plus reflector must not exceed 10. Core and side reflector Δz 's are the same, and cannot exceed a total of 10. The maximum number of $\Delta \theta$'s is 10 for purposes of integration only. In the case of a symmetrically positioned radiator, one could have as many as 20 actual $\Delta \theta$'s but only integrate over 10 of them. The code does not double the answers in this case, the user must double the printout result.

The fin is rectangular and divided up into a maximum mesh of 10 by 10. The center of each mesh area is considered the scattering point. If more than one radiator fin is to be considered, SCARF will assume they are symmetrically positioned and simply multiply the result by the number of fins. In any event the number of target angular divisions divided by the number of fins must be an integer. Another restriction on radiator placement is that the distance from the reactor axis to the fin must be equal to or greater than the reactor radius.

SYSTEM GEOMETRY

TIM-799

FIG. 1

SYSTEM DESCRIPTION

TIM-799

FIG. 2

MESH DESCRIPTION

TARGET

$$\left. \begin{aligned} X_{os} &= R_0 \cos \theta_s \\ Y_{os} &= R_0 \sin \theta_s \end{aligned} \right\} 1 \leq o \leq RT, 1 \leq s \leq S$$

$$\text{AND } R_0 = (o - \frac{1}{2}) \frac{R_3}{RT} = (o - \frac{1}{2}) \Delta r$$

$$\theta_s = (s - \frac{1}{2}) \frac{2\pi}{S} = (s - \frac{1}{2}) \Delta \theta$$

FIN

$$\Delta W = W/V$$

$$\Delta CL = CL/U$$

$$\left. \begin{aligned} X_u &= X_1 + (u - \frac{1}{2}) \Delta CL \\ Z_v &= Z_1 + (v - \frac{1}{2}) \Delta W \end{aligned} \right\} 1 \leq v \leq V, 1 \leq u \leq U$$

REACTOR

a) CORE

$$\left. \begin{aligned} X_{ij} &= R_i \cos \theta_j \\ Y_{ij} &= R_i \sin \theta_j \end{aligned} \right\} 1 \leq i \leq AI, 1 \leq j \leq AJ$$

$$Z_k = Z_c + (k - \frac{1}{2}) \Delta H = Z_c + (k - \frac{1}{2}) \frac{H}{AK}$$

$$1 \leq k \leq AK$$

$$R_i = (i - \frac{1}{2}) \Delta R_1, \theta_j = (j - \frac{1}{2}) \frac{2\pi}{AAJ}$$

b) REFLECTOR

$$R_i = R_1 + \frac{R_2 - R_1}{AIP - AI} (i - \frac{1}{2} + AI)$$

$$AI \leq i \leq (AIP - AI)$$

$$\Delta H = \frac{H}{AK}$$

January 23, 1964

Although the fin must be rectangular in shape, there is a provision to disregard as many scattering mesh points as desired, thus enabling the user to approximate any radiator shape. Two input quantities are needed to do this, namely, BL the total number of mesh points that are to be deleted, and T_n the specific mesh points to be deleted. The specific mesh points are numbered as in the following sketch.

T_n for any mesh point can be calculated as follows:

$$T_n = V_n + (U_n - 1) V \text{ and } 1 \leq n \leq BL$$

where V_n = number of divisions along z axis in which the nth deleted mesh point lies

U_n = number of divisions along the x axis in which the nth deleted mesh point lies

V = total number of fin divisions along z axis

It should be pointed out that the T_n 's should be ordered such that $T_{n+1} > T_n$ when preparing code input. (See sample case)

The target is considered a disc of zero thickness and radius $R3$. Again the maximum mesh is a 10 by 10 and the Δr 's and $\Delta \theta$'s are constant. There is no restriction on the radius of the target as there was in the complementary direct shielding code PARSE. Unfortunately in the case of target symmetry with respect to the radiators, there is no option in the code to delete that area of the target which gives repetitious flux values.

The rear parabolic shield does not necessarily have to have its vertex on the system axis. The input parameters $Z0$ and SRO will describe the vertex of any parabola with its axis parallel to the system axis. The code then assumes

January 23, 1964

that the parabolic curve between Z4 and Z5 for positive values of z and r is a surface of revolution about the system axis. The front parabolic shield does have its vertex on the system axis, and is also considered a surface of revolution about this axis.

B. Core Sources

The neutron sources in the core are described by a J_0 Bessel function radially, a sine function axially, and a constant azimuthally. The total core power P (watts), which is an input parameter, is related to these distributions through the following equation.

$$(P)(K) \text{ (neutrons/sec)} = A \int_{\text{core volume}} J_0(Wr) \sin B(C - Z_c + z) dV$$

where K = power to source constant ($3.1 \times 10^{10} \text{ W}$)

A = the number of $\frac{\text{neutrons}}{\text{cc-sec}}$ produced at the center of the core

W = radial extrapolation factor

B and C = axial extrapolation factors

Z_c = the origin to core distance

The radial extrapolation factor can be found by plotting the power density and extrapolating to zero. Then $J_0(WR_0) = J_0(2.405) = 0$, and $W = 2.405/R_0$. B and C of the axial distribution term can be found as follows:

L = value of Z where sine term = 0

Z_c = origin to core distance

H = core height

At $Z = L$, $\sin B (C - Z_c + L) = 0$ or $C = Z_c - L$

Also at $Z = Z_c + H/2$, $\sin B (C - Z_c + Z_c + H/2) = 1$ or $B(C + H/2) = \pi/2$

Substituting the value of C in the above equation we get

$$B = \pi / [2(Z_c - L + H/2)]$$

It then follows that for the ijk volume element in the core, the source is given by

$$S_{ijk} = (A) (\Delta V_{ijk}) J_0 (W r_i) \sin B (C - Z_c + z_k)$$

where V_{ijk} = volume of the ijk source element

r_i = radius of center of i th Δr

z_k = height of k th Δz

and j denotes the j th angular segment.

C. Side Reflector Sources

The side reflector sources are described in essentially the same manner as the core sources. Both radial and axial distribution functions are the same as those in the core, but the coefficient A now becomes $(A) (FR)$ where FR is the ratio of the reflector to core source strength at the core-reflector interface. FR will usually vary from 0 to 1.0, but can be made greater than 1.0 if desired. In many instances the radial distribution in the side reflector will be exponential. In this case a judicious selection of FR will have to be made in order to fit the J_0 Bessel function to the actual radial source distribution. The side reflector source equation is then $S_{ijk} = (A) (FR) (\Delta V_{ijk}) J_0 (W r_i) \sin B (C - Z_c + z_k)$. It should be noted that there is no provision to include sources in the end reflectors or plug shields. However, an approximation to the number of neutrons that scatter from these regions can be made by assigning them to the core and adjusting the core length and power accordingly.

D. Flux at Fin Surface

The flux at the point uv on the fin mesh due to sources from the source volume element ijk is given by

$$\Phi_{ijkuv} = \frac{S_{ijk} e^{-\sum_n \Sigma_n x_n}}{4\pi \rho_{ijkuv}^2}$$

where Σ_n = attenuation cross section of region n (cm^{-1})

x_n = distance ray travels in region n on way from source point to scatter point (cm)

ρ_{ijkuv} = distance from source point to scatter point (cm)

E. Neutron Flux at Target

The neutron flux at the target point os due to all scattering events on the radiator is given by the following expression:

$$\Phi_{os} = \sum \Phi_{ijkuv} N_{uv} A_{uv} \left(\frac{d\sigma}{d\Omega} \right)_{ijkuvos} e^{-\sum_n \Sigma_n x_n} d\Omega_{uvos}$$

where Φ_{ijkuv} = neutron flux at uv on the fin surface due to the source at ijk ($\text{n/cm}^2\text{-sec}$)

N_{uv} = atomic density per unit area at scatter point ($\frac{\text{atoms}}{\text{cm}^2}$)

A_{uv} = area of scatter mesh

$\left(\frac{d\sigma}{d\Omega} \right)_{ijkuvos}$ = differential scattering cross section for neutrons which leave source ijk and scatter from fin mesh uv toward target point os ($\text{cm}^2/\text{atom-steradian}$)

$e^{-\sum_n \Sigma_n x_n}$ = attenuation by reactor-shield assembly of neutrons traveling from scatter point uv to target point os

$d\Omega_{uvos}$ = solid angle at scatter point uv subtended by unit area at target point os (steradians)

The differential scattering cross section $\frac{d\sigma}{d\Omega}$ is described as a function of $\cos \theta$ where θ is the angle between the "neutron ray" from the source ijk , and the "ray" from the scatter point uv to the target point os as shown in Fig (2). There is provision in the input to describe the scattering cross section with a polynomial equation as follows:

$$\frac{d\sigma}{d\Omega} = D + E \cos^{\text{AM}} \theta + \text{EPR} \cos^{\text{AMP}} \theta$$

where D , E and EPR are the coefficients, and AM and AMP can be any integer powers of $\cos \theta$. $\cos \theta$ as calculated by the code is given by:

$$\cos \theta_{ijkuvos} = \frac{d_{ijkos}^2 + l_{uvos}^2 - \rho_{ijkuv}^2}{2 l_{uvos} \rho_{ijkuv}}$$

where d_{ijkos} = distance between source point ijk and target point os

l_{uvos} = distance between scattering point uv and target point os

ρ_{ijkuv} = distance between source point ijk and scattering point uv

From this it can be seen that $d\Omega$, the solid angle at the scatter point can be expressed as $1/r_{uvos}^2$. At the present, these input constants can be calculated by the univariate polynomial fit program available at UAC Research, or a CANEL Bendix program if AM and AMP are set equal to one and two respectively. Up to the present time, it has been found that a fairly good fit can be had by assuming the polynomial to be a quadratic equation.

III. Input

There are a minimum of 54 pieces of information required to run one case. The first card describes the case number which is placed in column 3 if less than 10, or columns 2 and 3 if 10 or greater. Columns 2 and 3 of the following cards indicate the relative location of the first piece of information on that card, and columns 11 and 12 indicate the relative location of the last piece of data on the card. Columns 13, 25, 37, 49,

TIM 799
To: W. G. Alwang

- 11 -

January 23, 1964

and 61 are used to start the 5 values of the input parameters, however, if an exponential parameter is to be used it must terminate at the far right of the field i.e. in column 12, 24, 36, 48 or 60. For case 1 the card which has the 54th piece of data on it must have a one in column one. This card is followed by the T_n 's if desired, which are inputted as shown in the sample problem.

Cases may be run back to back, and only the case number and those parameters which are being changed need be inputted. In this case the card containing the last change must have a 1 in column 1.

An input listing follows, which along with the sample problem will enable one to run a SCARF case. The only input parameter that warrants further discussion is the tolerance EPSL. After the neutron ray has scattered, one of the possible neutron paths to the target is through both of the surfaces of the parabolic shields. In calculating this distance the code resorts to an iterative technique. When the difference between two successive calculations is less than EPSL, the last calculated distance is used.

INPUT LISTING

<u>Relative Location</u>	<u>Symbol</u>	<u>Description</u>
card 1		case number ending in column 3
1	AN	number of fins
2	X1	X distance axis to fin (cm)
3	Y1	Y distance axis to fin (cm)
4	Z0	Z coordinate of rear parabolic shield vertex (cm)
5	Z1	Z coordinate of fin (cm)
6	Zc	Z coordinate of front of core (cm)
7	Z3	Z coordinate of front parabolic shield vertex (cm)
8	Z4	Z coordinate of intersection of parabolic shields (cm)
9	H	core height (cm)
10	T1	front end reflector thickness (cm)
11	T2	front plug shield thickness (cm)
12	T3	rear plug shield thickness (cm)
13	T4	rear end reflector thickness
14	CL	fin width along X axis (cm)
15	W	fin length along Z axis (cm)
16	R1	core radius (cm)
17	R2	reactor radius (cm)
18	R3	target radius (cm)
19	R4	front plug shield radius (cm)
20	R5	rear plug shield radius (cm)

<u>Relative Location</u>	<u>Symbol</u>	<u>Description</u>
21	R6	radius of intersection of parabolic shields (cm)
22	SRO	rear parabolic shield radial displacement
23	FR	reflector source coefficient $FR A J_0(Wr) \sin B(c-Zc+Z)$
24	P	power (watts)
25	W	radial coefficient $J_0(Wr)$
26	B	axial coefficient $\sin B(C-Zc+z)$
27	C	axial coefficient $\sin B(C-Zc+z)$
28	D	cross section coefficient $D + E \cos \theta + EPR \theta$ AM AMP
29	E	cross section coefficient $D + E \cos \theta + EPR \theta$ AM AMP
30	AM	cross section exponent $D + E \cos \theta + EPR \theta$ AM AMP
31	CN	radiator atomic density (atoms/cm ² x 10 ⁻²⁴)
32	RT	number of target Δr 's (max 10)
33	S	number of target $\Delta \theta$'s (max 10)
34	U	number of fin width intervals (max 10)
35	V	number of fin length intervals (max 10)
36	AI	number of Δr 's in core (max 10)
37	AJ	number of $\Delta \theta$'s in core for integration (max 10)
38	AK	number of Δz 's in core (max 10)
39	AIP	number of Δr 's in reactor (core + side reflector) (maximum 10)
40	Σ_c	core effective removal cross section(cm ⁻¹)
41	Σ_r	reflector effective removal cross section (cm ⁻¹)

TIM 799
To: W. G. Alwang

- 14 -

January 23, 1964

<u>Relative Location</u>	<u>Symbol</u>	<u>Description</u>
42	Σs	front plug shield effective removal cross section (cm ⁻¹)
43	Σsp	rear plug shield effective removal cross section (cm ⁻¹)
44	Σssp	parabolic shields effective removal cross section (cm ⁻¹)
45	EPSL	tolerance (see description at beginning of input section)
46	BL	total number of fin mesh points to be omitted
47	CON	conversion factor $(3.1 \times 10^{10} \frac{\text{fissions}}{\text{watt-sec}}) (\frac{\text{neutrons}}{\text{fission}})$ 4π
48	AAJ	actual number of 40's in the core
49	AXT	printout format AXT = 0 for short form, AXT = 1 for long form
50	PS	density of front plug shield (grams/cc)
51	PSP	density of rear plug shield (grams/cc)
52	PSPP	density of parabolic shields (grams/cc)
53	EPR	cross section coefficient $D + E \cos \theta + \frac{AM}{EPR \cos \theta}$
54	AMP	cross section exponent $D + E \cos \theta + \frac{AM}{EPR \cos \theta}$

INPUT DECK ORDER

To: W. G. Alwang

OUTPUT

The long form output consists of a printout of most of the input parameters, shield weights, relative contribution at each fin point from each source point, the total neutron current to each target point due to scattering from each fin point, and the total current to all target points. The box omission term that is printed out is BI_i , the number of fin mesh points that are being omitted. The relative contributions are simply normalized fluxes at the scattering surface due to reactor sources. In terms of the program these relative fluxes denoted by $SIJKUV$ are as follows for the core:

$$SIJKUV = \frac{(2BI_i - 1) J_0(Wr_i) \sin B(C - Z_c + Z_k) (e^{-\sum_n \epsilon_n X_n})}{\rho_{ijkuv}^2}$$

where all terms have been previously defined except $(2BI_i - 1)$ which is a normalized source volume, and BI_i is the index for the Δr where the source point is being considered. The actual volume of a source region is given by:

$$V = \Delta\theta \Delta Z \pi (BI_i^2 \Delta r^2 - (BI_i - 1)^2 \Delta r^2)$$

For the reflector, $SIJKUV$ is given by the following expression:

$$SIJKUV = \left[2R1 + \left(\frac{R2 - R1}{AIP - AI} \right) (2(BI_i - AI) - 1) \right] \left[\frac{\frac{R2 - R1}{AIP - AI}}{\left(\frac{R1}{AI} \right)^2} \right] \frac{FR J_0(Wr_i) \sin B(C - Z_c + Z_k) (e^{-\sum_n \epsilon_n X_n})}{\rho_{ijkuv}^2} (e^{-\sum_n \epsilon_n X_n})$$

where the first two expressions in parenthesis are a normalized source volume, and the actual volume is given by

$$V_{ijk} = \left[2R1 + \left(\frac{R2 - R1}{AIP - AI} \right) (2(BI_i - AI) - 1) \right] \left(\frac{R2 - R1}{AIP - AI} \right) \pi \Delta\theta_j \Delta Z_k$$

$R1$ = core radius

$R2$ = side reflector radius

BI_i = core Δr index

TIM 799
To: W. G. Alwang

- 17 -

January 23, 1964

AI = number of Δr 's in the core
AIP = number of Δr 's in the reactor
PR = side reflector source coefficient

All other terms are similar to those used in the core relative contributions and have been defined there.

If the short form is desired i.e. $AXT = 0$, the code will not printout the relative contributions. In many instances this data will not be of use and AXT should be set to zero. When $AXT = 1$ the printout becomes extremely large.

The following sketch will describe the ordering of the fin mesh points on the printout which is different (for some unknown reason) from the order used in calculating the T_n 's.

RADIATOR

3	6	9
2	5	8
1	4	7

V →

Walter H. Granter
Walter Granter

SAMPLE PROBLEM

MESH POINTS WITH CHECKS
HAVE BEEN OMITTED

3 [✓]	6	9	12	15	18	21	24
2 [✓]	5	8	11	14	17	20	23 [✓]
1 [✓]	4	7 [✓]	10	13 [✓]	16	19 [✓]	22 [✓]

SCATTERING FROM RADIATOR FINS

CASE 2

NUMBER OF FINS 1

VERTEX OF REAR PARABOLIC SHIELD 16.57
 FIN DISTANCE FROM TARGET 9.00
 DISTANCE FROM TARGET TO CORE 16.00
 VERTEX OF FRONT PARABOLIC SHIELD 12.00
 INTERSECTION OF PARABOLIC SHIELDS 13.00

FRONT REFLECTOR THICKNESS 0.
 FRONT DISC SHIELD THICKNESS 0.
 REAR DISC SHIELD THICKNESS 0.
 REAR REFLECTOR THICKNESS 0.

POWER OF REACTOR 0.100000E 01
 HEIGHT OF CORE 4.000
 WIDTH OF FIN 8.000
 LENGTH OF FIN 3.000
 RADIUS OF CORE 2.000
 RADIUS OF REACTOR 2.000
 RADIUS OF TARGET 1.000
 FRONT DISC SHIELD RADIUS 0.
 REAR DISC SHIELD RADIUS 0.

COMMON RADIUS OF PARABOLIC SHIELDS 5.000

FIN DISTANCE FROM X-AXIS 6.000
 FIN DISTANCE FROM Y-AXIS 0.
 AXIS DISPLACEMENT 0.
 REFLECTOR SOURCE COEFF. 1.000
 CONVERGENCE CRITERION 0.100
 BOX COMMISSION 8.000

RADIAL SOURCE COEFF. 0.0010
 AXIAL SOURCE COEFF. -0.0195
 AXIAL SOURCE COEFF. -84.0000
 CROSS-SECTION COEFF. 1.0000
 CROSS-SECTION COEFF. 1.0000
 CROSS-SECTION COEFF. 1.0000

TARGET RADIAL DIVISIONS 1.00
 TARGET ANGULAR DIVISIONS 4.00
 FIN LENGTH DIVISIONS 3.00
 FIN WIDTH DIVISIONS 8.00

ATOMIC DENSITY OF FIN 0.1000
 CORE RADIAL DIVISIONS 1.0000
 CORE ANGULAR DIVISIONS 2.00
 (IN J LOOP)
 CORE HEIGHT DIVISIONS 2.00

SIGMA C 0.
 SIGMA R 0.
 SIGMA S 0.
 SIGMA S PRIME 0.
 SIGMA S 2 PRIME 2.000

CORE ANGULAR DIVISIONS 4.00
 (ACTUAL)
 REACTOR RADIAL DIVISIONS 1.00

CONSTANT FOR CALCULATION OF SD 6.170E 09

SHIELD WEIGHTS

FRONT DISC =0.
 REAR DISC =0.
 FRONT PARABOLIC =8.657578E-02
 REAR PARABOLIC =3.012575E-01
 TOTAL WEIGHT =3.878333E-01

FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	REACTOR RADIAL INTERVAL	REACTOR ANGULAR INTERVAL	REACTOR AXIAL INTERVAL	RELATIVE CONTRIBUTION
2.0	1.0	1.0	1.0	1.0	2.381773E-06
2.0	1.0	1.0	1.0	2.0	1.694281E-04
2.0	1.0	1.0	2.0	1.0	4.961726E-07
2.0	1.0	1.0	2.0	2.0	1.898763E-06

FIN WIDTH FIN LENGTH TARGET TARGET FAST NEUTRON CURRENT FROM

INTERVAL	INTERVAL	RADIUS	ANGLE	SINGLE FIN ELEMENT
2.0	1.0	1.0	1.0	9.085661E 01
2.0	1.0	1.0	2.0	8.071037E 01
2.0	1.0	1.0	3.0	8.071037E 01
2.0	1.0	1.0	4.0	9.085661E 01

FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	REACTOR RADIAL INTERVAL	REACTOR ANGULAR INTERVAL	REACTOR AXIAL INTERVAL	RELATIVE CONTRIBUTION
2.0	2.0	1.0	1.0	1.0	1.713068E-06
2.0	2.0	1.0	1.0	2.0	8.410768E-03
2.0	2.0	1.0	2.0	1.0	3.283069E-07
2.0	2.0	1.0	2.0	2.0	1.649514E-05

FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	TARGET RADIUS	TARGET ANGLE	FAST NEUTRON CURRENT FROM SINGLE FIN ELEMENT
2.0	2.0	1.0	1.0	3.373335E 03
2.0	2.0	1.0	2.0	2.962708E 03
2.0	2.0	1.0	3.0	2.962708E 03
2.0	2.0	1.0	4.0	3.373335E 03

FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	REACTOR RADIAL INTERVAL	REACTOR ANGULAR INTERVAL	REACTOR AXIAL INTERVAL	RELATIVE CONTRIBUTION
2.0	3.0	1.0	1.0	1.0	2.962196E-05
2.0	3.0	1.0	1.0	2.0	7.491691E-03
2.0	3.0	1.0	2.0	1.0	2.259215E-07
2.0	3.0	1.0	2.0	2.0	6.348271E-03

FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	TARGET RADIUS	TARGET ANGLE	FAST NEUTRON CURRENT FROM SINGLE FIN ELEMENT
2.0	3.0	1.0	1.0	4.157928E 03
2.0	3.0	1.0	2.0	3.612196E 03
2.0	3.0	1.0	3.0	3.612196E 03
2.0	3.0	1.0	4.0	4.157928E 03

FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	REACTOR RADIAL INTERVAL	REACTOR ANGULAR INTERVAL	REACTOR AXIAL INTERVAL	RELATIVE CONTRIBUTION
3.0	2.0	1.0	1.0	1.0	1.546663E-04
3.0	2.0	1.0	1.0	2.0	9.718649E-03
3.0	2.0	1.0	2.0	1.0	5.399041E-07
3.0	2.0	1.0	2.0	2.0	8.057467E-03

FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	TARGET RADIUS	TARGET ANGLE	FAST NEUTRON CURRENT FROM SINGLE FIN ELEMENT
3.0	2.0	1.0	1.0	6.046107E 03
3.0	2.0	1.0	2.0	5.344192E 03
3.0	2.0	1.0	3.0	5.344192E 03
3.0	2.0	1.0	4.0	6.046107E 03

FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	REACTOR RADIAL INTERVAL	REACTOR ANGULAR INTERVAL	REACTOR AXIAL INTERVAL	RELATIVE CONTRIBUTION
3.0	3.0	1.0	1.0	1.0	1.092068E-02
3.0	3.0	1.0	1.0	2.0	8.512017E-03
3.0	3.0	1.0	2.0	1.0	5.595325E-06
3.0	3.0	1.0	2.0	2.0	7.065991E-03

FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	TARGET RADIUS	TARGET ANGLE	FAST NEUTRON CURRENT FROM SINGLE FIN ELEMENT
3.0	3.0	1.0	1.0	6.732443E 03
3.0	3.0	1.0	2.0	5.978124E 03
3.0	3.0	1.0	3.0	5.878124E 03

3.0	3.0	1.0	4.0	6.732443E 03	
FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	REACTOR RADIAL INTERVAL	REACTOR ANGULAR INTERVAL	REACTOR AXIAL INTERVAL	RELATIVE CONTRIBUTION
4.0	1.0	1.0	1.0	1.0	1.048832E-03
4.0	1.0	1.0	1.0	2.0	1.310465E-02
4.0	1.0	1.0	2.0	1.0	3.806584E-06
4.0	1.0	1.0	2.0	2.0	1.056035E-02
FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	TARGET RADIUS	TARGET ANGLE	FAST NEUTRON CURRENT FROM SINGLE FIN ELEMENT	
4.0	1.0	1.0	1.0	8.897485E 03	
4.0	1.0	1.0	2.0	7.998820E 03	
4.0	1.0	1.0	3.0	7.998821E 03	
4.0	1.0	1.0	4.0	8.897485E 03	
FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	REACTOR RADIAL INTERVAL	REACTOR ANGULAR INTERVAL	REACTOR AXIAL INTERVAL	RELATIVE CONTRIBUTION
4.0	2.0	1.0	1.0	1.0	1.493443E-02
4.0	2.0	1.0	1.0	2.0	1.124926E-02
4.0	2.0	1.0	2.0	1.0	3.357198E-05
4.0	2.0	1.0	2.0	2.0	9.081970E-03
FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	TARGET RADIUS	TARGET ANGLE	FAST NEUTRON CURRENT FROM SINGLE FIN ELEMENT	
4.0	2.0	1.0	1.0	9.816855E 03	
4.0	2.0	1.0	2.0	8.708701E 03	
4.0	2.0	1.0	3.0	8.708701E 03	
4.0	2.0	1.0	4.0	9.816855E 03	
FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	REACTOR RADIAL INTERVAL	REACTOR ANGULAR INTERVAL	REACTOR AXIAL INTERVAL	RELATIVE CONTRIBUTION
4.0	3.0	1.0	1.0	1.0	1.226098E-02
4.0	3.0	1.0	1.0	2.0	9.663632E-03
4.0	3.0	1.0	2.0	1.0	1.244966E-04
4.0	3.0	1.0	2.0	2.0	7.841738E-03
FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	TARGET RADIUS	TARGET ANGLE	FAST NEUTRON CURRENT FROM SINGLE FIN ELEMENT	
4.0	3.0	1.0	1.0	6.272387E 03	
4.0	3.0	1.0	2.0	5.488015E 03	
4.0	3.0	1.0	3.0	5.488015E 03	
4.0	3.0	1.0	4.0	6.272387E 03	
FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	REACTOR RADIAL INTERVAL	REACTOR ANGULAR INTERVAL	REACTOR AXIAL INTERVAL	RELATIVE CONTRIBUTION
5.0	2.0	1.0	1.0	1.0	1.696311E-02
5.0	2.0	1.0	1.0	2.0	1.300482E-02
5.0	2.0	1.0	2.0	1.0	1.264815E-03
5.0	2.0	1.0	2.0	2.0	1.019284E-02
FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	TARGET RADIUS	TARGET ANGLE	FAST NEUTRON CURRENT FROM SINGLE FIN ELEMENT	
5.0	2.0	1.0	1.0	9.242438E 03	
5.0	2.0	1.0	2.0	8.202064E 03	
5.0	2.0	1.0	3.0	8.202064E 03	
5.0	2.0	1.0	4.0	9.242438E 03	
FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	REACTOR RADIAL INTERVAL	REACTOR ANGULAR INTERVAL	REACTOR AXIAL INTERVAL	RELATIVE CONTRIBUTION

5.0	3.0	1.0	1.0	1.0	1.359589E-02
5.0	3.0	1.0	1.0	2.0	1.093128E-02
5.0	3.0	1.0	2.0	1.0	6.788341E-03
5.0	3.0	1.0	2.0	2.0	8.656317E-03

FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	TARGET RADIUS	TARGET ANGLE	FAST NEUTRON CURRENT FROM SINGLE FIN ELEMENT
5.0	3.0	1.0	1.0	6.713748E 03
5.0	3.0	1.0	2.0	5.864876E 03
5.0	3.0	1.0	3.0	5.864876E 03
5.0	3.0	1.0	4.0	6.713748E 03

FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	REACTOR RADIAL INTERVAL	REACTOR ANGULAR INTERVAL	REACTOR AXIAL INTERVAL	RELATIVE CONTRIBUTION
6.0	1.0	1.0	1.0	1.0	2.478477E-02
6.0	1.0	1.0	1.0	2.0	1.841335E-02
6.0	1.0	1.0	2.0	1.0	1.702120E-02
6.0	1.0	1.0	2.0	2.0	1.375639E-02

FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	TARGET RADIUS	TARGET ANGLE	FAST NEUTRON CURRENT FROM SINGLE FIN ELEMENT
6.0	1.0	1.0	1.0	1.662990E 04
6.0	1.0	1.0	2.0	1.494087E 04
6.0	1.0	1.0	3.0	1.494087E 04
6.0	1.0	1.0	4.0	1.662990E 04

FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	REACTOR RADIAL INTERVAL	REACTOR ANGULAR INTERVAL	REACTOR AXIAL INTERVAL	RELATIVE CONTRIBUTION
6.0	2.0	1.0	1.0	1.0	1.888733E-02
6.0	2.0	1.0	1.0	2.0	1.494893E-02
6.0	2.0	1.0	2.0	1.0	1.348078E-02
6.0	2.0	1.0	2.0	2.0	1.134971E-02

FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	TARGET RADIUS	TARGET ANGLE	FAST NEUTRON CURRENT FROM SINGLE FIN ELEMENT
6.0	2.0	1.0	1.0	1.010793E 04
6.0	2.0	1.0	2.0	8.934063E 03
6.0	2.0	1.0	3.0	8.934063E 03
6.0	2.0	1.0	4.0	1.010793E 04

FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	REACTOR RADIAL INTERVAL	REACTOR ANGULAR INTERVAL	REACTOR AXIAL INTERVAL	RELATIVE CONTRIBUTION
6.0	3.0	1.0	1.0	1.0	1.480479E-02
6.0	3.0	1.0	1.0	2.0	1.227289E-02
6.0	3.0	1.0	2.0	1.0	1.091571E-02
6.0	3.0	1.0	2.0	2.0	9.476659E-03

FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	TARGET RADIUS	TARGET ANGLE	FAST NEUTRON CURRENT FROM SINGLE FIN ELEMENT
6.0	3.0	1.0	1.0	6.118248E 03
6.0	3.0	1.0	2.0	5.307704E 03
6.0	3.0	1.0	3.0	5.307704E 03
6.0	3.0	1.0	4.0	6.118248E 03

FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	REACTOR RADIAL INTERVAL	REACTOR ANGULAR INTERVAL	REACTOR AXIAL INTERVAL	RELATIVE CONTRIBUTION
7.0	2.0	1.0	1.0	1.0	2.043251E-02
7.0	2.0	1.0	1.0	2.0	1.697957E-02
7.0	2.0	1.0	2.0	1.0	1.424994E-02
7.0	2.0	1.0	2.0	2.0	1.248318E-02

FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	TARGET RADIUS	TARGET ANGLE	FAST NEUTRON CURRENT FROM SINGLE FIN ELEMENT	
7.0	2.0	1.0	1.0	8.076566E 03	
7.0	2.0	1.0	2.0	7.060606E 03	
7.0	2.0	1.0	3.0	7.060606E 03	
7.0	2.0	1.0	4.0	8.076566E 03	
FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	REACTOR RADIAL INTERVAL	REACTOR ANGULAR INTERVAL	REACTOR AXIAL INTERVAL	RELATIVE CONTRIBUTION
7.0	3.0	1.0	1.0	1.0	1.573768E-02
7.0	3.0	1.0	1.0	2.0	1.360909E-02
7.0	3.0	1.0	2.0	1.0	1.141460E-02
7.0	3.0	1.0	2.0	2.0	1.025407E-02
FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	TARGET RADIUS	TARGET ANGLE	FAST NEUTRON CURRENT FROM SINGLE FIN ELEMENT	
7.0	3.0	1.0	1.0	4.749392E 03	
7.0	3.0	1.0	2.0	4.054424E 03	
7.0	3.0	1.0	3.0	4.054424E 03	
7.0	3.0	1.0	4.0	4.749392E 03	
FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	REACTOR RADIAL INTERVAL	REACTOR ANGULAR INTERVAL	REACTOR AXIAL INTERVAL	RELATIVE CONTRIBUTION
8.0	3.0	1.0	1.0	1.0	1.624965E-02
8.0	3.0	1.0	1.0	2.0	1.481916E-02
8.0	3.0	1.0	2.0	1.0	1.168154E-02
8.0	3.0	1.0	2.0	2.0	1.092631E-02
FIN WIDTH INTERVAL	FIN LENGTH INTERVAL	TARGET RADIUS	TARGET ANGLE	FAST NEUTRON CURRENT FROM SINGLE FIN ELEMENT	
8.0	3.0	1.0	1.0	3.278986E 03	
8.0	3.0	1.0	2.0	2.700934E 03	
8.0	3.0	1.0	3.0	2.700934E 03	
8.0	3.0	1.0	4.0	3.278986E 03	
		TARGET RADIUS	TARGET ANGLE	FAST NEUTRON CURRENT FROM ALL FINS	
		1	1	1.103046E 05	
		1	2	9.713900E 04	
		1	3	9.713900E 04	
		1	4	1.103046E 05	