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ARAB REPUBLIC OF EGYPT
ATOMIC ENERGY ESTABLISHMENT
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CONTENT

ABSTRACT

MODIF-Code is a computer program for calculating the reflector saving, material buckling, and effective multiplication constant of completely reflected cylindrical reactors. The calculational method is based on a modified iterative algorithm which has been deduced from the general analytical solution of the two group diffusion equations. The code has been written in FORTRAN language suited for the ICL-1906 computer facility at cairo University. The computer time required to solve a problem of actual reactor is less than 1 minute. The problem converges within five iteration steps. The accuracy in determining the effective multiplication constant lies within $\pm 10^{-5}$.

The code has been applied to the case of UA-RR-1 reactor, the results confirm the validity and accuracy of the calculational method.

1. INTRODUCTION

A general analytical solution of completely reflected reactors is presently not available. Instead, one can use iterative procedure depending on the replacement of the original reactor by elementary configuration which incorporate only one feature of the actual reactor geometry. For each of these configurations it is assumed that only one face is reflected while the others are taken to be bare so that analytical solution can be obtained for each face. For the case of completely reflected cylindrical reactors use of two elementary configurations (side and end reflected ones) were discussed[1],[2]. The dependence between material buckling B_m^2 and effective multiplication constant K_{eff} for both elementary configurations were plotted graphically. The reflector saving and effective multiplication constant of the actual reactor was then obtained by using simple iterative technique. Nassar and Gaafar[3] applied this iterative technique to determine the reflector saving of the UARR-1 reactor. In their work, a numerical solution of the two group two region diffusion equation was presented. This solution involves the evaluation of different kinds of Bessel functions for each prescribed trial value of the axial and radial dimensions of the two elementary reactor configurations. A computer code was developed to perform these calculations, and the iteration calculation was carried out by hand.

In the present work (MODIF-code) the iterative procedure is fully computerized. Further developments has been made which comprise speed, simplicity, and accuracy.

The mean features of such developments can be summarized in the following:

1. The whole computation are carried out by computer.
2. More advanced numerical techniques have been employed in order to reduce time of computation and memory size needed for input data.
3. The iteration procedure has been improved so that an intermidiate step in the calculation of the previous work has been canceled.
4. Calculations of the different kinds of Bessel function were made in separate subrontine to any desired degree of accuracy without interfering the main program.

2. PHYSICAL MODEL

The two group two region analytical solution of the diffusion equation was treated in details by Maghreblian[1] and Greenspan[2]. The solution of the criticality determinant was reduced to the following form:

$$\frac{Z'}{Z} = \frac{\omega\psi(\alpha_3 D_1 D_4 + \alpha_2 D_2 D_3) - D_1 D_4 \omega\beta(\alpha_1 + \alpha_3) + D_3 D_4 \psi\beta(\alpha_1 - \alpha_2)}{D_1 D_2 \omega(a_2 - a_1) - D_1 D_4 \beta(a_2 + a_3) + \psi(a_1 D_2 D_3 + a_3 D_1 D_4)} \qquad (1)$$

Where the constants a_1 , a_2 , and a_3 are defined as follows

$$a_1 = \frac{P_c \Sigma_{R1}}{D_2 \mu^2 + \Sigma_{a2}} = \frac{D_1 \mu^2 + \Sigma_{R1}}{\nu \Sigma_{f2}} \qquad (2)$$

$$a_2 = \frac{P_R \Sigma_{R1}}{-D_2 \lambda^2 + \Sigma_{a2}} = \frac{-D_1 \lambda^2 + \Sigma_{R1}}{\nu \Sigma_{f2}} \qquad (3)$$

$$a_3 = \frac{P_R \Sigma_{R1}}{D_4(K_3^2 - K_4^2)} \quad , \quad K_3^2 = \frac{R3}{D_3} \quad , \text{and} \quad K_4^2 = \frac{a4}{D_4} \qquad (4)$$

Here D_i, Σ_{Ri}, Σ_{ai} , and $\nu\Sigma_{fi}$ are the diffusion coefficients, removal, absorption, and fission macroscopic cross-sections, $i = 1, 2, 3, 4$
($i=1,2$ stands for fast and thermal groups in the core region while $i = 3, 4$ stands dor fast and thermal groups in the reflector region respectively).

P_c and P_R are the resonance escap probability in core and reflector respectively. μ^2 , λ^2 , K_3^2 and K_4^2 are the eigen values of the following eigen functions:

$$\nabla^2 Z(r) + \mu^2 Z(r) = 0 \qquad (5)$$

$$\nabla^2 W(r) - \lambda^2 W(r) = 0 \qquad (6)$$

$$\nabla^2 U(r) - K_3^2 U(r) = 0 \qquad (7)$$

$$\nabla^2 V(r) - K_3^2 V(r) = 0 \qquad (8)$$

The functions Z, W, U, V and their derivatives were defined in reference (1) so that:

$$\frac{Z'}{Z} = \xi \ , \quad \frac{W'}{W} = \omega \ , \quad \frac{U'}{U} = \Psi \quad , \text{and} \quad \frac{V'}{V} = \beta$$

Let the left hand side(LHS) of equation (1) is set equal to ξ and the(RHS)is set equal to η . The criticality condition given by equation (1) can be written in a more compact form which satisfy both geometrical and material characteristics of the system then,

$$Y(x) = \eta - \xi \tag{10}$$

Where $x = B_m^2$, consequently one can define the value x_o at which $Y(x) = 0$ and both sides of equation (1) are equals. At this specific value one get $B_m^2 = B_g^2 = (B_r^2 + B_h^2)$. From the analytical solution it can be shown that the RHS of equation (1), η is very slowly varying function of x, while the LHS of equation (1), ξ is a periodicaly and rapidly varying function of x. It follows that the two functions ξ and Y are nearly complementary functions and x_o must exist in the interval x_i and x_f (initial and final values of x) at which $Y(x) = 0$. In this way the problem is reduced to find the value of x_o by simple iteration method in which a complete iteration cycle takes the form

$$B_h^2(t) \longrightarrow B_m^2 \longrightarrow B_r^2(t+1) \tag{11}$$

$$B_r^2(t) \longrightarrow B_m^2 \longrightarrow B_h^2(t+1) \tag{12}$$

We suggest the following procedure for the numerical solation. Calculate a mean value of $_m$ where x_m is the midpoint between x_i and x_f defined as follows:

$$x_m = (x_i + x_f)/2 \tag{13}$$

Three possibilities may arises for the corresponding Y_m values:

First: Y_m equal zero which corresponds to x_o required.

Second: Y_m is negative then x_o falles between x_m and x_f.

Third: Y_m is positive then x_o falles between x_i and x_m.

- (note that both η and ξ are negatives).

The first possibility represnt the solution required. For second and third possibilities, an iteration procedure is continued by replacing the value of x_i by x_m or x_f by x_m for the second or third possibilities respectively.

The complete solution of the problem requires the investigation of both side and end reflected elementary configurations.

For the case of side reflected reactors, the analytical solution gives:

$$\xi = \frac{Z'}{Z} = - l_i \; J_1(l_i R)/J_o\,(l_i R) \qquad (14)$$

Where l_i equal $\sqrt{B_m^2 - (\pi/2h_i)^2}$, h_i being the halfheight of the core of several elementary configurations, and R is the radius of the side reflected cores being fixed through these calculations.

J_o and J_1 are Bessel functions of the first kind of zero and first order respectively.

For each of these configurations we have

$$X_i = \left(\frac{\pi}{2h_i}\right)^2 \; B_{hi}^2 \quad \text{and} \quad X_f = B_{hi}^2 + \left(\frac{2.405}{R}\right)^2 \qquad (15)$$

For the case of end reflected reactore, the analytical solution gives:

$$\xi = \frac{Z'}{Z} = -l_i \; \tan\,(l_i H) \qquad (16)$$

Where l_i equal $\sqrt{B_m^2 - \left(\frac{2.405}{R_i}\right)^2}$, R_i being the radius of the core of several elementary configurations, and H is the half height of the end reflected cores being fixed through these calculations.

For each of these configurations we have

$$x_i = \left(\frac{2.405}{R_i}\right)^2 \; B_{r_i}^2 \quad \text{and} \quad x_f = B_{r_i}^2 + \left(\frac{\pi}{2H}\right)^2 \qquad (17)$$

3. INPUT-OUTPUT DESCRIPTION

The MODIF-code is divided into four segments, the master program, two subroutines, and one function. A complete list of the code is given in appendix I. A flowchart showing the flow of instructions in the code is given in Fig.(1).

1) The master program:

The required input data of the master program are the nuclear constants and the dimensions of the reactor under consideration. The fortran symbols used for the input data are given in Table (1). The fortran symbols for the output data are given in Table(2).

2) The subroutine SZRL:

This subrouthine is responsible for calculating the functions ξ , η and γ which are defined in equations (1) and (10). The fortran symbols of the important parameters and functions in this subroutine and their mathematical identifications are given in Table (3).

3) The subroutine BSIK (x,BIO, BIL, BKO,BK1):

This subroutine is responsible for calculating the modefied Bessel functions of the first and second kinds for both zero and first order.
The fortran symbols of the mathematical arguments and their identifications are given in Table (4).

4) The function BSI (N,X):

This function is responsible for calculating the Bessel function of the first kind for any desired order required $\lceil J_n(x) \rfloor$, where n is the order of the Bessel function required and x is the value at which the function is calculated.

4. RESULTS OF SAMPLE PROBLEM

The MODIF-code has been used in the study of several UO_2 critical lattices[4]. In the present work, the UARR-1 reactor at Inshas is studied. It is a completely reflected cylindrical reactor having light water as moderator and reflector. A recent analysis by Hammad et al[5] showed that the fuel rods have a small graphite cone at the upper top of each fuel rod. Taking this into account an effective height of the fuel rod must be equal 47.25 cm instead of 50 cm taken before in previous work.

The following are the general properties of fuel cell.

Fuel rod radius	0.35 cm
Al clad thickness	0.15 cm
Effective fuel height	47.25 cm
Fuel enrichment	10 %
Lattice pitch	1.75 cm
Moderator to fuel volume ratio	5.92

The following are fast and thermal macroscopic cross-sections in the core region.

	Fast	Thermal
D	1.43390	0.21809
Σ_R	0.03411	--
Σ_a	0.00352	0.08897
$\nu\Sigma_f$	0.00308	0.15052

The folowing are fast and thermal macroscopic cross-sections in the reflector region

	Fast	Thermal
D	1.35080	0.13394
Σ_R	0.04918	---
Σ_a	0.00042	0.01935
$\nu\Sigma_f$	--	--

The diffusion coefficients and macroscopic cross-section in both core and reflector region were obtained by the help of CROSS-Code[6].

The results obtained by MODIF-code for the UARR-1 reactor can be summarized as follows:

Axial reflector saving $\lambda_H \simeq 7.549$ cm
Radial reflector saving $\lambda_R \simeq 7.261$ cm
Material Buckling $B_m^2 \simeq 0.0104\ cm^{-2}$
Effective multiplication constant $\simeq 1.0433$

The values of reflector saving in both axial and radial directions agree very well with the experimental results and the calculations in previous work. Also the material bucking agree with the experimental value for the UARR-1 reactor. While higher value of the effective multiplication constant was deduced. This could be due to uncertainity in the evaluation of the macroscopic cross-sections.

Table (1)

Identifications of input data for master program

Fortran	Mathematical symbol	Identification
R	R	Core radius of the original reactor
RP	$\tilde{R}$	Extropolated radius of the reflector
HH	H	Core half height of the reflector
DP	$\tilde{D}$	Extropolated half height of the reflector
D1	D_1	Fast diffusion coefficient in the core
D2	D_2	Thermal diffusion coefficient in the core
SGR1	Σ_{R1}	Fast removal macroscopic cross-section in the core
SGA1	Σ_{a1}	Fast absorption macroscopic cross-section in the core
SGA2	Σ_{a2}	Thermal absorption macroscopic cross-section in the core
SGFN1	$\nu\Sigma_{f1}$	Fast fission macroscopic cross-section in the core
SGFN2	$\nu\Sigma_{f2}$	Thermal fission macroscopic cross-section in the core
D3	D_3	Fast diffusion coefficient in the reflector
D4	D_4	Thermal diffusion coefficient in the reflector
SGR3	Σ_{R3}	Fast removal macroscopic cross-section in the reflector
SGA4	Σ_{a4}	Thermal absorption macroscopic cross-section in the reflector
AC	-	The required accuracy in K_{eff}
FR	-	A factor for determining the first guess of h_i

Table (2)

Identification of output data for master program

Fortran symbol	Mathematical symbol	Identification
BS(1)	B^2_{hi}	The axial geometrical buckling
BS(2)	B^2_{ri}	The radial geomwtrical buckling
USS	B^2_g	The total geo;etrical buckling
HVC	h_i	The half height of equivalent bore reactors
RVC	R_i	The radius of equivalent bore reactors
GFI	K_{eff}	The effective multiplication constant
DELZ	λ_h	The axial reflector saving
DELR	λ_r	The radial reflector saving

Table (3)

Identifications of important parameters in SZRL subroutine

Fortran symbol	Mathematical symbol	Identification
LD	-	It is an indicator which shows whether the original reactor is replaced by aside reflected or end reflected configyrations LD 1 stands for side reflected reactor LD 2 stands for end reflected reactor
SP_2	-	Stands for the asial (B^2_{hi}) or radial (B^2_{ri}) geometrical buckling
US	$B^2_g(B^2_m=B^2_g)$	The material buckling at which the calculations are carried out.
ZETAR	η	The R.H.S. of equation (1)
ZETAL	ξ	The L.H.S. of equation (1)
RL	Y	The L.H.S. of equation (10)

Table (4)

Identification of the arguments of the Subroutine BSIK (x,BIO, BTI, BKO, BK1)

Fortran symbol	Mathematical symbol	Identification
X		The value at which the modified Bessel functions are calculated.
BIO	I_0	Modified Bessel function of the first kind of the zero order.
BI1	I_1	Modified Bessel function of the first kind of the first order.
BKO	K_0	Modified Bessel function of the second kind of the zero order.
BK1	K_1	Modified Bessel function of the second kind of the first order.

APPENDIX I
MODIF CODE FORTRAN STATEMENTS

```
      MASTER ITERATION ADVANTAG
      DIMENSION CNN(2),BS(2),USS(2)
      COMMON LD,US,SP2,ZETAL,ZETAR,RL,E1,D1,SGR1,D2
      COMMON SGFN2,D3,A3,SVL3,D4,SVL4,R,RP,HH,DP
7     FORMAT(6E12.5)
8     FORMAT(4E12.5)
110   FORMAT(//10x,6E12.5)
100   FORMAT(//'.OX,'THERE IS SOME THING WRONG!)
      READ(2,8) D3,D4,SGA3,SGA4
      READ(2,8) SGR3,SGR4,SGFN3, SGFN4
      READ(2,8) HH,DP
      DO 10 I = 1,8
      READ(2,8) D1, SGA1, SGR1,SGFN1
      READ(2,8) D2,SGA2,SGFN2
      READ(2,8)R,RP
      SGFN2 = SGFM2*2.4
      AC=0.00001
      PI = 3.1415926
      PII = PI/2.0
      TC = DI/SGR1
      SL2 = D2/SGA2
      SMA = TC*SL2
      SVL3 = SGR3/D3
      SVL4 = SGA4/D4
      A3 = SGR3/(D4*(Sv13-SVL4)
      E1 = SMA/(2.*TC*SL2)
      E2 = 2./(E1*SMA)
      GFI = (SGFN1*SGFN2*SGR1)/(SGA2+SGR1)
50    DELLA = 3.097+0.11949*SMA
      WRITE (3,110)TC,SL2,GFI,DELLA
      CNN(1) = (2.405/R)**2
      CNN(2) = (PII/HH)**2
      GF = 0.0
      HV = HH
      WRITE(3,110)R,RP,HH,DP
      SP2 = (PII/HV)**2
      LD = 1
      DO 60 L = 1,30
      BS(LD) = SP2
      USI = SP2
      US = USI
      CALL SZRL
```

```
      IF(ZETAR)55,25,26
55    S1 = -1.0
      USF = SP2+CNN(LD)
      S2 =1.0
27    USM = (USI+USF)/2.0
      US = USM
      CALL SZRL
      IF(RL.EQ.0.0)GO TO 25
      S3 = RL/ABS(RL)
      IF(S1-S3)28,29,28
29    USI = USM
      GO TO 31
28    USF = USM
31    ER = (USF-USI)/USI
      IF(ER-AC)32,32,27
32    US = (USF+USI)/2.0
25    USS(LD) = US
      IF(LD-2)17,18,18
17    LD = 2
      GO TO 19
18    LD = 1
19    IF(L-1)15,15,16
16    WRITE(3,110)BS(1),BS(2),USS(1),USS(2)
      ERR = ABS(USS(1)-USS(2)
      ERR = ERR/ABS (USS(1)
      IF(ERR.LE.AC)GO TO45
15    SP2 = US-SP2
60    CONTINUE
      GO TO26
45    HVC = PII/SQRT(BS(1)
      RVC = 2.405/SQRT(BS(2)
      GFI = (USS(1)/E1+1.0)**2
      GFI =(GFI+E2-1.0)/E2
      DELR =RVC-R
      DELZ = HVC-HH
      WRITE(3,110)BS(1),BS(2),USS(1),HVC,RVC,GFI
      WRITE(3,110)DELR,DELZ
      GO TO30
26    WRITE(3,100)
30    CONTINUE
L0    CONTINUE
97    STOP
      END
      FUNCTION BSI(N,X)
      A =0.0000001
```

```
      XH2 = XH**2
      IFN = 1
      IF(N-0)1,3,1
1     DO 10 I = 1,N
10    IFN = IFN*I
3     B = XH**N/IFN
      SUM3 = B
      DO20 I = 1,30
      IN = I+N
      B = -B*XH2/(I*IN)
      SUM = SUM+B
      ERR = ABS(B/SUM)
      IF(ERR-A)5,5,20
20    CONTINUE
5     BSI = SUM
      RETURN
      END


      SUBROUTINE SZRL
      DIMENSION X(5),BMFO(5),BMFI(5),BMSO(5),BMSI(5)
      COMMON LD,US,SP2,ZETAL,ZETAR,RL,EI,D1,SGR1,D2
      COMMON SGFN2,D3,A3,SVL3,D4,SVL4,R,RP,HH,DP
      YS = US+2.*EI
      A1 = (D1*US*SGR1)/DHGN2
      A2 = (-D1*YS*SGR1)/SGFN2
      SP3 = YS*SP2
      SP4 = SVL3+SP2
      SP5 = SVL4+SP2
      P3 = SQRT(SP3)
      P4 = SQRT(SP4)
      P5 = SQRT(SP5)
      If(LD-2)10,11,11
10    X(1) = P4*R
      X(2) = P4*RP
      X(3) = P5*R
      X(4) = P5*RP
      X(5) = P3*R
      DO40 I = 1,3
      XX = X(J)
      CALL BSIK (XX,BMFO(J),BMFI(J),BMSO(J),BMSI(J))
40    CONTINUE
      W = BMFO(5)
      WP = P3*BMFI(5)
```

```
      UU = BMFO(1)*BMSO(2)-BMFO(2)*BMSO(1)
      UUP = P4*(BMFI(1)*BMSO(2)+BMFO(2)*BMSI(1))
      V = BMFO(3)*BMSO(4)-BMFO(4)*BMSO(3)
      VP = P5*(BMFI(3)*BMSO(4)+BMFO(4)*BMSI(3))
      GO TO 57
11    T5 = P3*HH
      W = (EXP(T2)-EXP(-T2))/2.
      UUP = -P4*(EXP(T2)+EXP(-T2))/2.
      T3 = P5*(DP-HH)
      V = (EXP(T3)-EXP(-T3))/2.
      VP = -P5*(EXP(T3)+EXP(-T3))/2.
57    WPW = WP/W
      PSI = UUP/UU
      BETA = VP/V
      UMER = (WPW*PSI)*(A3*DI*D4+A2*D2*D3)-D1*D4*WPW*
     **BETA*(A1+A3)+D3*D4*PSI*BETA*(A1-A2)
      DNOM = D1*D2*WPW*(A2-A1)-D1*D4*BETA*(A2+A3)+PSI*
     **(A1*D2*D3+A3*DI*D4)
      ZETAR = UMER/DNOM
      SPI = US-SP2
      IF(SPI)21,22,21
21    P1 = SQRT(SPI)
      IF(LD-2)30,31,31
30    XX = P1*R
      Z = BSI(0,XX)
      ZP = -P1*BSI(1,XX)
      GO TO32
31    T4 = PI*HH
      Z = COS(T4)
      ZP = -PI*SIN(T4)
32    ZETAL = ZP/Z
      RL = ZETAR-ZETAL
22    RETURN
      END


      SUBROUTINE BSIK(X,BIO,BII,BKO,BKI)
      DIMENSION BI(2),BK(2)
      PI = 3.1415926
      A = 0.0001
      GAM = 0.577215665
      IF(X-5.0)1,1,2
1     XH = X/2
      XH2 = XH**2
      XL = GAM*ALOG(XH)
```

```
      RX = 1.0/X
      DO 10 N=1,2
      N1 = N-1
      B = XH**N1
      SUM = B
      DO 20 I = 1,30
      II = I+N1
      B = B*XH2/(I*II)
      SUM = SUM+B
      ERR = ABS(B/SUM)
      IF(ERR-A)3,3,20
20    CONTINUE
3     BI(1) = SUM
      N2 = 2-N1
      B = XH**N2/N
      SU = B
      RH = 1.
      DO 30 I = 2,30
      II = I-N1
      IM = I-1
      R = RH+1.0/I
      QRM = 0.5*N1/IM
      QR = 0.5*N1/I
      B = B*XH2*(R-QR)/(I*II*(RM*QRM))
      SU = SU+B
      ERR = ABS(B/SU)
      IF(ERR-A)11,11,31
31    RM = R
30    CONTINUE
11    BK(N) = (-1)**N1*(SU-XL*SUM)+RX*N1
10    CONTINUE
      GO TO 5
2     XD = 8.0*X
      U = 2.*PI*X
      U = SQRT(U)
      E = EXP(X)
      UI = E/U
      UK = PI/(E*U)
      DO 40  N = 1,2
      N1 = N-1
      BKK = 1.0
      BII = 1.0
      SUMI = BII
      SUMK = BKK
      DO 50  I = 1,5
      I1 = 2*(I+N1)-1
```

```
      I2 = 2*(I-N1)-1
      FM = I1*I2/(I*XD)
      BII = FM*BII
      SUMI = SUMI+BII
      SUMK = SUMK+BKK
50    CONTINUE
      BI(N) = UI*SUMI
      BK(N) = UK*SUMK
40    CONTINUE
5     BI0 = BI(1)
      BI1 = BI(2)
      BK0 = BK(1)
      BK1 = BK(2)
      RETURN
      END
```

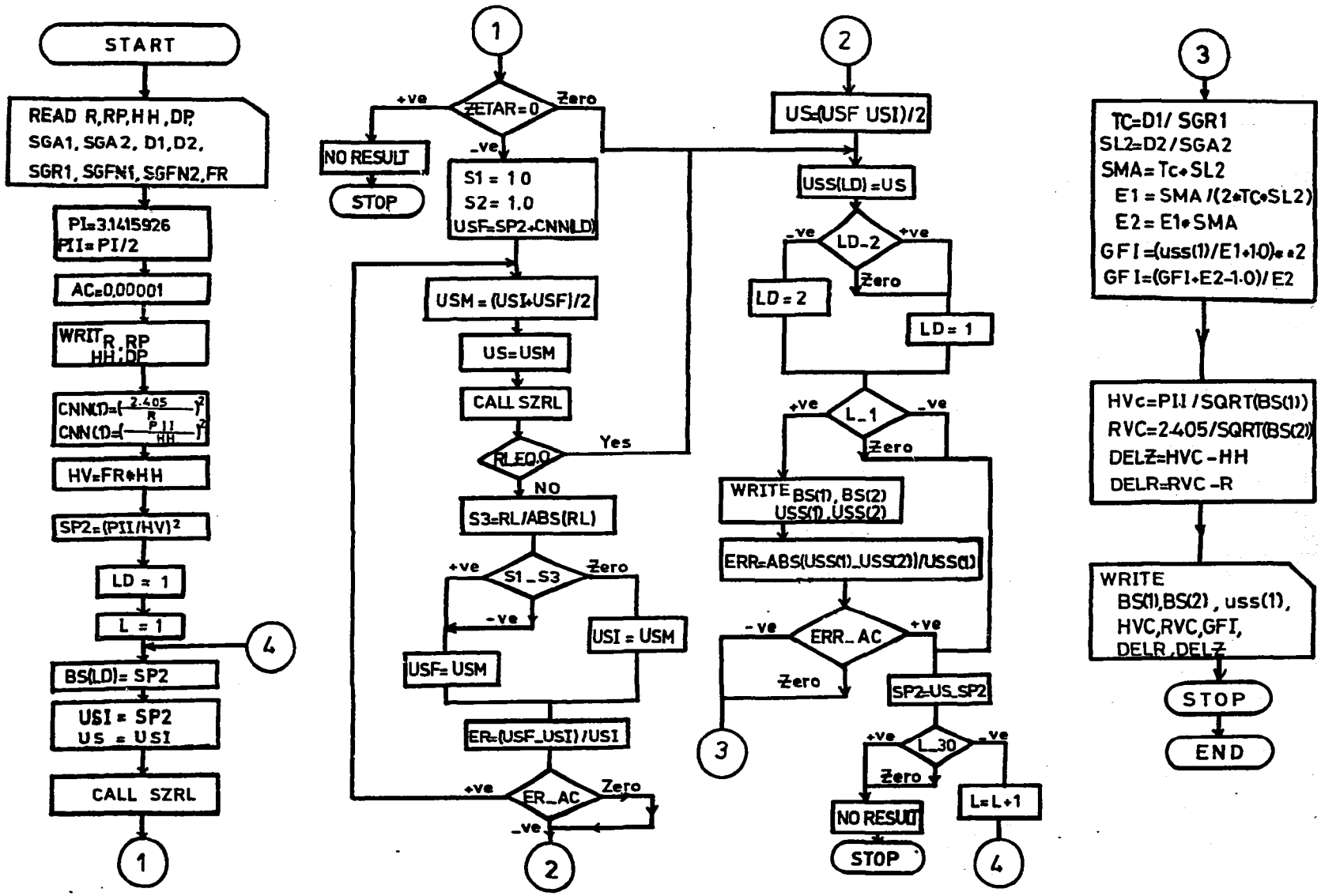

Fig:(1): MODIF _CODE FLOWCHART

TEST CASE FOR MODRIB-CODE PWR-2097MW (FROM ICTP-NOTES) 000000 CASE N°: 2

TEMPO 152, GIORNI

DENSITA ATOMICHE IN JMU,AT./CMBARN E PESI IN KG DEGLI ELEMENTI NEL FUEL

U235	U236	U238	PU239	PU240	PU241	PU242	O
4.6127E-04	1.9150E-05	1.9929E-02	4.4537E-05	4.6511E-06	1.1042E-06	4.4611E-08	4.1116E-02
1.5864E 03	6.6062E 01	6.9406E 04	1.5548E 02	1.6317E 01	3.8898E 00	1.5781E-01	9.6273E 03

SEZIONI MICROSCOPICHE VELOCI IN BANS

UNIV	U235A	U235F	U236A	U238A	PU239A	PU239F	PU240A	PU241A	PU241F	PU242A
0.02957	4.06783	7.96322	9.43259	0.87178	6.62934	8.57106	203.06863	5.38837	17.02249	58.56738

SEZIONI MICROSCOPICHE TERMICHE IN BARNS

UNIT	U235A	U235F	PU239A	PU239F	PU240A	PU241F	H TR	H SC
5.47734E-01	3.45294E 02	2.92073E 02	1.17913E 03	7.52767E 02	1.88919E 02	7.70419E 02	2.18111E 01	3.37492E 01

COSTANTI DEI TRE GRUPPI VELOCI

GRUPPO	D	SIGMA-A	SIGMA-R	SIGMA-F	NU-SIGMA-F	SIGMA-P	SIGMA A-P
1	2.12511E 00	1.98095E-03	4.61672E-02	1.47671E-03	3.92915E-03	0.00000E 00	1.98095E-03
2	1.04275E 00	0.00000E 00	1.19076E-01	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00
3	9.16395E-01	3.22867E-02	6.01750E-02	4.98159E-03	1.24280E-02	0.00000E 00	3.22867E-02

COSTANTI A DUE GRUPPI

GRUPPO	D	SIGMA-A	SIGMA-R	SIGMA-F	NU-SIGMA-F	SIGMA-P
1	1.57305E 00	9.70988E-03	1.61695E-02	2.10952E-03	5.39077E-03	0.00000E 00	9.70988E-03
2	5.86525E-01	8.42848E-02	0.00000E 00	5.13570E-02	1.30544E-01	0.00000E 00	8.42848E-02

K-EFF	K-INF	EPSILON	ETA-F	P	P-TOT	B**2	TAU	L**2	M**2
1.15500	1.17602	1.05408	1.54884	0.75544	0.62480	2.82	60.81	4.59	65.40

(FI1/FI2)FUEL	SEZ.ASS.VELENI	MWD/TON	C-INIZ.	C-INTEGR.	FATT.OMOG.
5.6470E 00	1.6121E-02	4.4535E 03	5.1358E-01	3.6790E-01	1.0819E 00

DELTA-25	DELTA-28	RO-28
1.4230E-01	5.3276E-02	3.0654E 00

FATTORI DI SVANTAGGIO

CLAD	REFRIG.	BOX	MOD.EST.	INT.BOX	F.PICCO
1.08210	1.13942	0.98029	0.88214	1.08387	1.06110

TEST CASE FOR MODRIB-CODE PWR-2097MW (FROM ICTP-NOTES) 000000 case No: 2

TEMPO 704, GIORNI

DENSITA ATOMICHE IN JMU.AT./CMBARN E PESI IN KG DEGLI ELENENTI NEL FUEL

U235	U236	U238	PU239	PU240	PU241	PU242	O
2.0802E-04	6.1485E-05	1.9681E-02	9.8805E-05	3.5335E-05	1.9314E-05	4.5103E-06	4.1116E-02
7.1541E 02	2.1211E 02	6.8543E 04	3.4492E 02	1.2397E 02	6.8039E 01	1.5955E 01	9.6273E 03

SEZIONI MICROSCOPICHE VELOCI IN BANS

UNIV	U235A	U235F	U236A	U238A	PU239A	PU239F	PU240A	PU241A	PU241F	PU242A
0.02849	4.02228	7.79429	8.00832	0.84060	6.27363	8.14963	111.86971	5.19188	16.39048	54.45075

SEZIONI MICROSCOPICHE TERMICHE IN BARNS

UNIT	U235A	U235F	PU239A	PU239F	PU240A	PU241F	H TR	H SC
5.53643E-01	3.48995E 02	2.95355E 02	1.15145E 03	7.37579E 02	1.89971E 02	7.65232E 02	2.20522E 01	3.39533E 01

COSTANTI DEI TRE GRUPPI VELOCI

GRUPPO	D	SIGMA-A	SIGMA-R	SIGMA-F	NU-SIGMA-F	SIGMA-P	SIGMA A-P
1	2.12511E 00	1.95632E-03	4.61672E-02	1.45835E-03	3.88030E-03	0.00000E 00	1.95632E-03
2	1.04275E 00	0.00000E 00	1.19076E-01	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00
3	9.16393E-01	3.70833E-02	6.01750E-02	3.48144E-03	9.23243E-03	0.00000E 00	3.70833E-02

COSTANTI A DUE GRUPPI

GRUPPO	D	SIGMA-A	SIGMA-R	SIGMA-F	NU-SIGMA-F	SIGMA-P	
1	1.58207E 00	1.06362E-02	1.55709E-02	1.67293E-03	4.44327E-03	0.00000E 00	1.06362E-02
2	3.83052E-01	8.61650E-02	0.00000E 00	4.52039E-02	1.23382E-01	0.00000E 00	8.61650E-02

K-EFF	K-INF	EPSILON	ETA-F	P	P-TOT	B**2	TAU	L**2	M**2
1.00234	1.02046	1.05337	1.43192	0.75808	0.59429	2.82	60.97	4.45	64.82

(FI1/FI2) FUEL	SEZ.ASS.VELENI	MWD/TON	C-INIZ.	C-INTEGR.	FATT.OMOG.
0.0015E 00	2.3264E-02	2.0627E 04	6.5749E-01	4.6054E-01	1.0838E 00

DELTA-25	DELTA-28	RO-28
1.4613E-01	1.2820E-01	3.1024E 00

FATTORI DI SVANTAGGIO

CLAD	REFRIG.	BOX	MOD.EST.	INT.BOX	F.PICCO
1.08370	1.14241	0.98661	0.88782	1.08565	1.06740

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